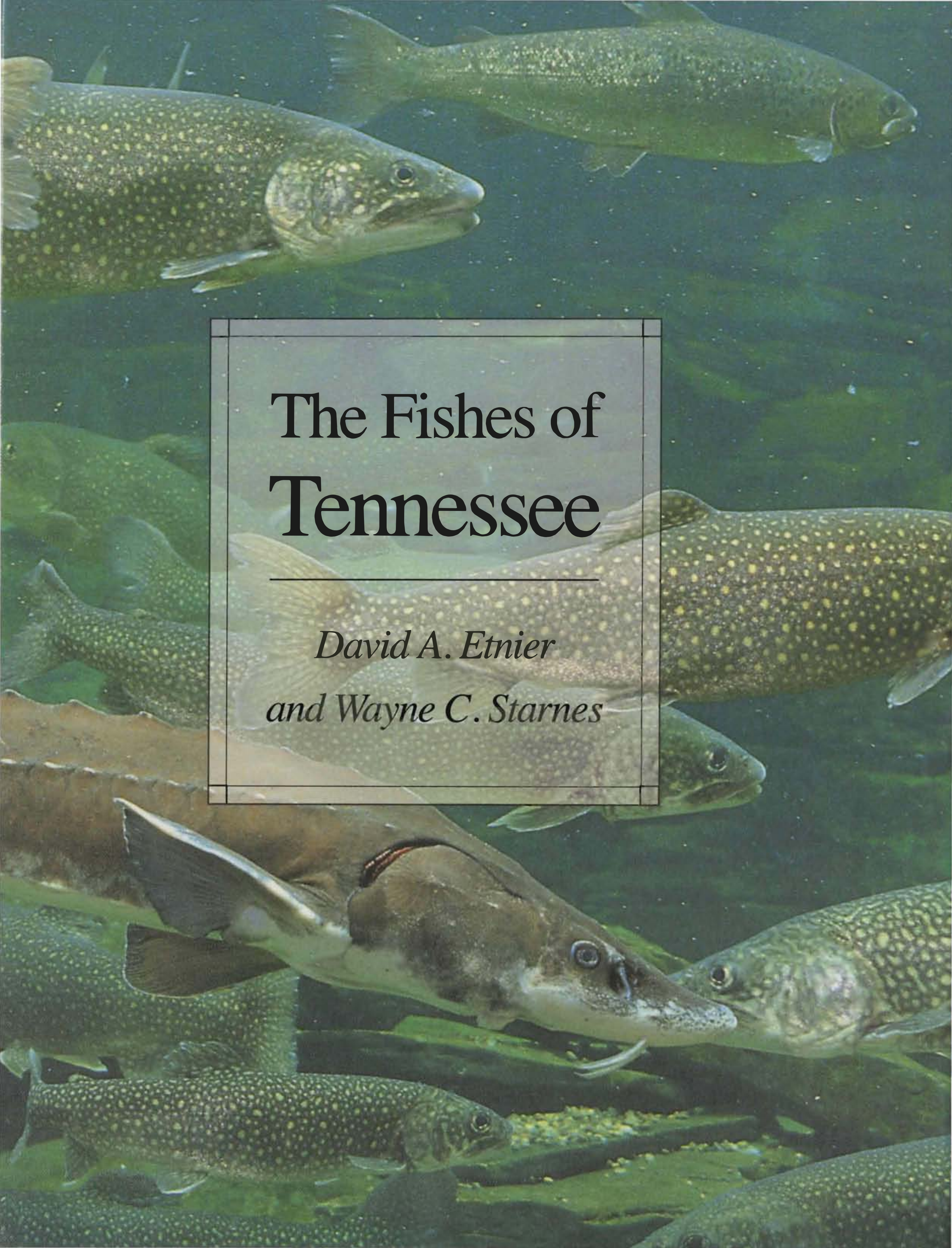

The Fishes of Tennessee

David A. Etnier
and Wayne C. Starnes

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Photographs by Richard T. Bryant
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Frontispiece: Salvelinus fontinalis, brook trout, Tennessee Aquarium, Chattanooga. Photo by Richard T. Bryant.

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To my wife, Liz, and children, Jennifer, Shelley, and Michael, for their patience with me during the fifteen or so years of work on this book; and to the late Samuel F. Eddy, who guided me into the fascinating study of fishes
— DAE

To my family for all their support throughout my ichthyological struggles; to Kenneth Ward, Farragut High School, for providing early "inertia"; and to Cheryl J. Lynn for her tireless efforts in typing and retyping the manuscript for this book and who may now know more about the fishes than we do — WCS

To my mother — RTB

Contents

Preface

As this book goes to press, we are ever more amazed and humbled by how little we know about many of the species of fishes that inhabit Tennessee's waters. But even a brief treatment of what is currently known or hypothesized about the systematics, distribution, and biology of Tennessee's fish assemblage is enough to fill a large book. We have done that, and in a manner that we hope is reasonably clear to a broad audience. The style of the text may have suffered in places from the piecemeal additions of new information that became available during the protracted period of the book's preparation. But these additions were made in the interest of providing complete and up-to-date information, and we hope that readers will forgive us for an occasional bumpy ride.

Even after well over a century of study by various students of fishes, knowledge of certain aspects of these fishes' existence is woefully lacking. This has been made abundantly clear, for instance, as we took for granted our ability to predict the occurrence and collect most of Tennessee's fish species to photograph for the book. Three years hence, we are baffled by the failure of some species to co-occur with our targeted collecting efforts in areas where we have blithely tossed to freedom from our nets scores to hundreds of their kind in years past; we are occasionally pleasantly surprised by their unexpected occurrences elsewhere. Some of those failures, unfortunately, may represent true and tragic declines in abundance of rare species; many, though, simply underscore our imperfect knowledge of their life-styles and the tremendous amount of research that remains to be done.

The waters of Tennessee have served as home to over three hundred species of fishes, the most diverse freshwater fauna of any state in the country. This diversity, in turn, correlates with Tennessee's geologic complexity and the several discrete drainage basins superimposed upon its varied physiographic provinces. A multiplicity of habitat types has resulted from the dynamic erosive forces of water acting on the complex geology of Tennessee. An abundance of aquatic organisms, including many endemic to Tennessee, has evolved with these habitats. In addition to fishes, Tennessee has the richest faunas in aquatic invertebrates, including crayfishes (e.g., Bouchard, 1972), mollusks (e.g., Starnes and Bogan, 1988), and probably several aquatic insect groups.

Tennesseans should revere this rich aquatic heritage that has whetted the interests of biologists for nearly 150 years. We hope that the following sections will inform many persons, including nature enthusiasts, anglers, and biologists, about this heritage and instill an appreciation for it and a will to protect it. Many elements of Tennessee's fish fauna are already jeopardized and a few apparently are extinct (Etnier and Starnes, 1991). We have attempted to write this book for a broad audience and hope that readers of varied backgrounds can gain the information on fishes they desire with equal facility and be encouraged to seek additional knowledge at other levels. In addition to those persons with general interests mentioned above, we have included much information pertinent to the interests of beginning and advanced students of ichthyology and for those biologists who must manage Tennessee's rich aquatic resources.

In the following introductory sections, we describe the drainage systems and geology of Tennessee, generally discuss the composition and occurrence of fishes in Tennessee, including fossils, and relate the history of ichthyological investigations in the region. General information follows on what fishes are, how they are constructed, and how they live. These sections are followed by explanations of the science of ichthyology and how systematic and biological studies of fishes are conducted. Techniques for the collection and preservation of fishes are presented, and we bring to the reader's attention the enjoyment of collecting native fishes and keeping them in aquaria. Before the presentation of Tennessee's fish fauna, methods are related for the identification of fishes as well as for taking counts and measurements for identification purposes or comparative studies. The state's fishes are then accounted in detail, with information on classification, identification, biology, distribution, taxonomic problems, and other aspects.

Beyond the compilation of published works on systematics, distribution, and biology of fishes occurring in Tennessee, a tremendous amount of original research had to be accomplished before this book could be written with as comprehensive a coverage as it has; this book was thus well over a decade in the making. It was necessary to resolve taxonomic problems in several groups which had not yet received sufficient attention from ichthyologists or had eluded previous workers. Many of the results of these efforts are now published elsewhere in the primary scientific literature, as are the results of several studies on the life histories and ecology of Tennessee fishes conducted by ourselves or graduate students at the University of Tennessee. The species accounted herein are in accordance with our concepts of the state's faunal constituents, and most of these concepts have been adopted by our colleagues; these are largely reflected in the most recent compilation of accepted names for fishes (Robins et al., 1991).

We have noted that a tremendous amount of research remains to be done on Tennessee's fishes. Some complex taxonomic problems remain, and the evolutionary relationships among fishes in most groups have yet to be hypothesized. New methods being developed (e.g., molecular), employed prudently along with established techniques, may provide some of these hypotheses. Such hypotheses would help us to understand the distributional history of our fishes and their relationship to geologic history (biogeography). Perhaps the greatest need is for detailed studies on the life histories of many species which are still poorly known and on the ecology of the aquatic communities where they live. Knowledge of both the taxonomy and the biology of the early life-history stages of the majority of fish species is woefully inadequate. This knowledge is essential if we are to develop conservation programs for these fishes and the rich aquatic heritage that exists along with them. We hope this book, by revealing the amazing diversity of our fishes, will appeal to the interests of readers and encourage them to pursue these goals.

Acknowledgments

We cannot begin to count all those who have helped us throughout the protracted preparation of this book. We mention those who come to mind as being especially helpful and apologize to several we have probably forgotten. Those mentioned and not have our deepest gratitude.

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Many former and present U.T. students, as well as colleagues at other institutions, have contributed to the body of ichthyological information upon which this book is based or otherwise assisted in the collection of specimens used in its preparation. Over the past twenty years or so U.T. students, graduate and undergraduate, too numerous to recount, have eagerly participated in collecting expeditions to locales throughout the state, whether in the course of classwork, their own research, or assisting in someone else's research. It is they who have helped build much of the research collection and fish distributional data which have facilitated preparation of this book. Some especially helpful ones who come to mind are: Fred Alsop, Bruce Bauer, Bo Baxter, Jim Beets, Rick Bivens, Art Bogan, Ray Bogardus, George Boronow, Ray and Judy Bouchard, Bryan Brazil, Noel Burkhead, Ty Burnette, Tom Carson, Byron Clark, Charles Comiskey, Bill Dickinson, Gerald Dinkins, the late Joel Dewees, David Eisenhour, Liz and Michael Etnier, T. A. Farmer, Stan Gregory, Arnold Gnilka, Jim Habera, Andy Haines, Doug Harned, John Harris, Charles Heacock, Robert Henson, Robert Hitch, Steve Holdeman, Mark Hughes, Mike Humphreys, Roberta Hylton, Mary Jane Krotzer, Steve Layman, Gene Lebo, Rick Le Duc, Rob Lindbom, Jerry and Christine Louton, John Lowe, Beth McCullough, Dave McKinney, Glenn Moates, Mike Molitor, Chip Munger, Joe Nagy, Jim Negus, David Nieland, Frank Oakberg,

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The Fishes of Tennessee

Waters and Geology of Tennessee

Tennessee owes its rich aquatic fauna to the region's geologic and hydrographic diversity. Six major physiographic provinces (divisions based on prevailing geology) traverse Tennessee (Fig. 1), and a number of these have distinct subprovincial areas. Moreover, five major drainage basins are represented within the state's borders (Figs. 1, 2), and all but two of these have numerous component systems situated in different physiographic circumstances. The significance of this complexity, and the role it may have played in the history of drainage patterns and fish speciation in the region of Tennessee, were analyzed in detail by Starnes and Etnier (1986), Mayden (1988), and Warren et al. (1991).

We hope this section will make an impression on the readers with regard to the extremely involved geologic history of Tennessee and the correspondingly complex physiographic makeup of the state. These factors have resulted in a theater of evolution for aquatic organisms unmatched elsewhere in North America; and many groups, including fishes, have responded wonderfully, giving us our richest of all faunal heritages.

Readers who desire more complete information on the geology of Tennessee and the state's geologic and drainage histories should consult Hardeman (1966), the analyses of Luther (1977), Starnes and Etnier (1986), Mayden (1988), and the many works cited therein.

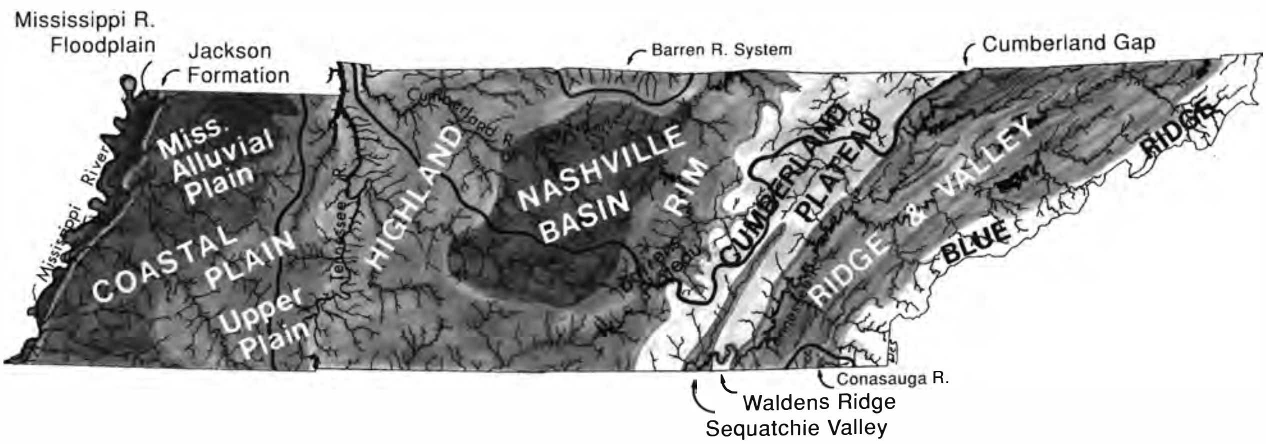


Figure 1. Physiographic provinces, selected geologic features, and major drainage basins (outlined in heavy black) of Tennessee.

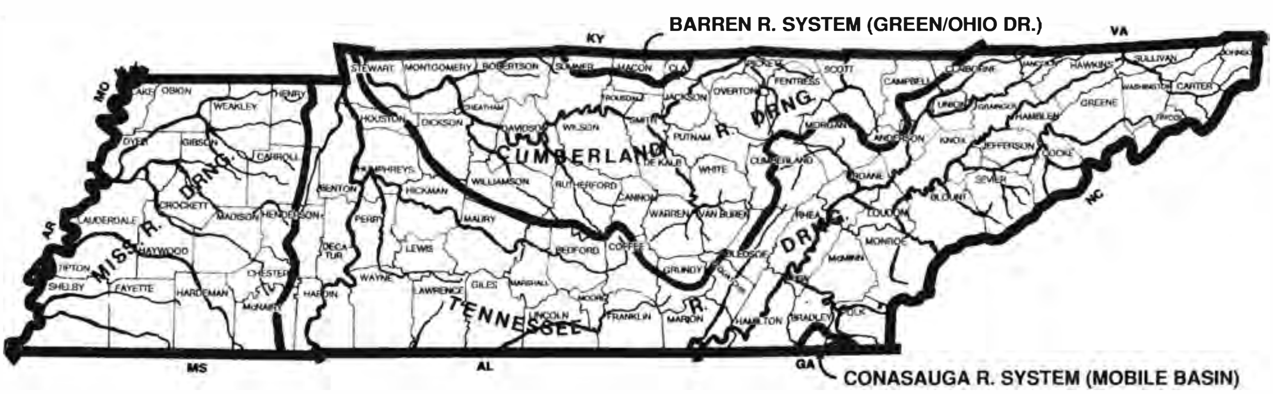


Figure 2. Counties and major drainage basins of Tennessee.

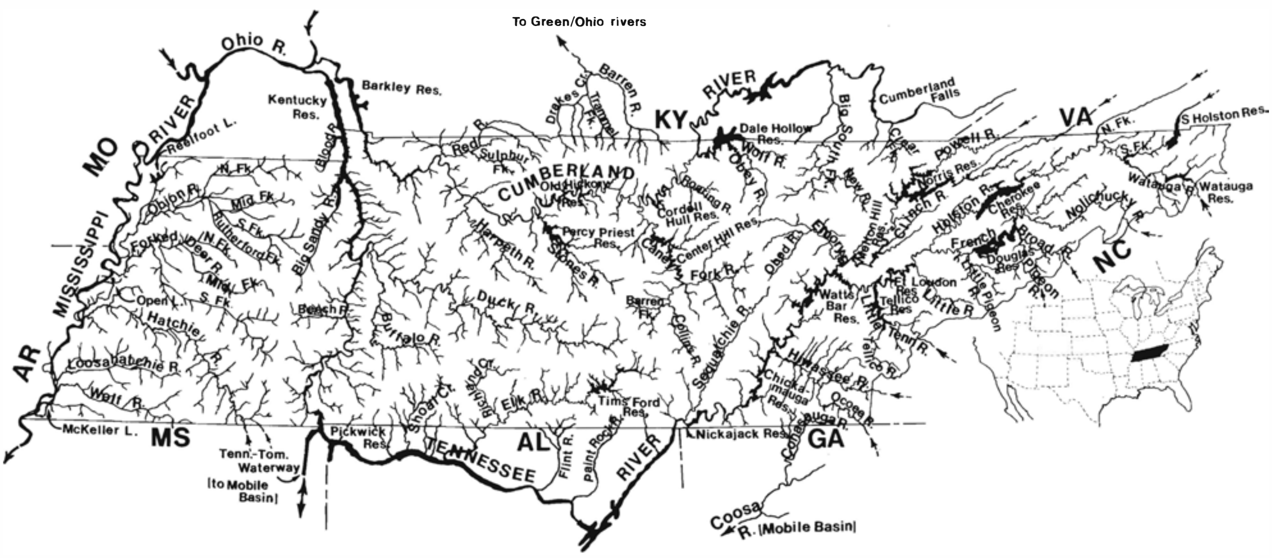


Figure 3. Drainages of Tennessee, denoting major streams, lakes, and reservoirs.

The Mississippi River

At the western border of Tennessee (Fig. 3) we find the Mississippi River, largest in North America, draining about one-half the total area of the United States. The Mississippi averages well over a kilometer in width at average flows in the reach bounding Tennessee. In its natural state, the Mississippi was ever meandering and shifting its channels, thus creating many oxbow lakes and swamps along its course. The river's currents are deceptively strong, averaging 0.3 m/sec or more in some shallower areas. Its waters are constantly turbid, colored by the heavy silt load eroded from the lands of the Midwest. Shallow, current-swept areas around islands and towheads usually consist of sandbars with some gravel deposits; deeper areas and backwaters have substrates of silty sand; numerous sunken tree snags litter the river's bottom. Beginning in the last century, the Mississippi's natural character was altered by levees, wing-dams, and dredging. Only in the highest floods (e.g., 1973) does it, in places, overcome its constraints. It can no longer seasonally flood its natural floodplain on a regular basis, providing access to and rejuvenating marginal swamplands. This doubtless has had a tremendous impact on the ecology of some fish species, as has the destruction of many natural gravel bars in the river's main channel. Still, the river harbors several large river fishes found nowhere else in Tennessee.

Mississippi River south of Memphis, TN, (Wrights Point area) showing evidence of course changes, cutoff channels, and oxbow lake formation (photo courtesy of U.S. Army Corps of Engineers).

The Coastal Plain (Mississippi Embayment)

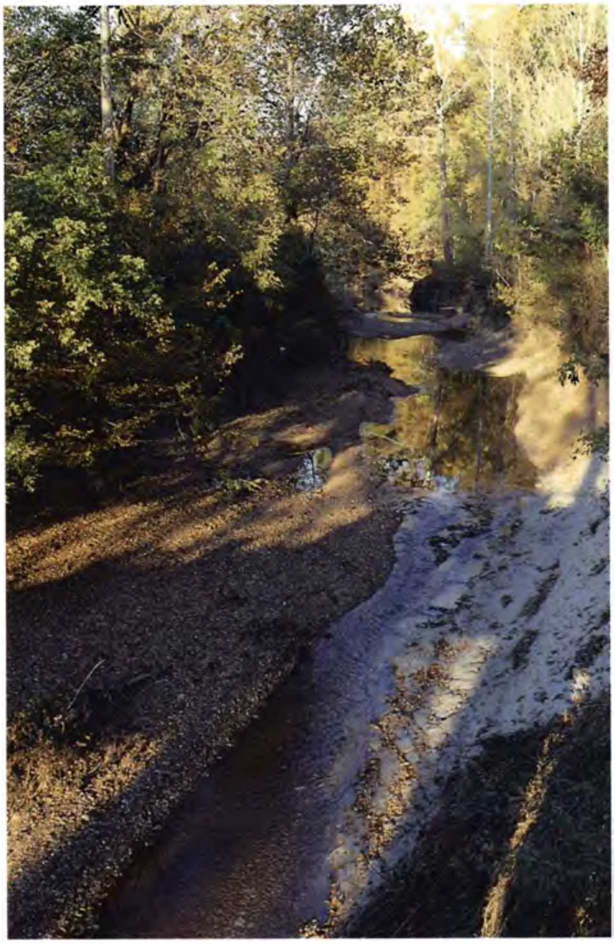
The western quarter of Tennessee, including much of the area between the Mississippi River and the lower Tennessee River, lies in the Mississippi Embayment portion of the Coastal Plain province (Fig. 1), which extends northward to southern Illinois. This province represents a northward intrusion of the Gulf of Mexico during much of the Mezozoic and Tertiary eras which gradually receded during the latter half of the Tertiary. This is a region dominated by Cretaceous to Quaternary geologic formations consisting mainly of sands, hard clays, and silt. The major rivers draining this region (Fig. 3), all of which flow west into the Mississippi River, are the Obion, Forked Deer, Hatchie, Loosahatchie, and Wolf systems. The eastern portion of the embayment is partially drained by lesser tributaries of the Tennessee River. The Coastal Plain is Tennessee's leading agricultural region, and aquatic habitats within the area have generally suffered because of it, particularly from forest clearing and stream channelization, and occasional pesticide runoff.

Within the Coastal Plain, immediately adjacent to the Mississippi River, ranging from 5 to 25 km in width, and only about 60–90 m elevation above sea level, is the Mississippi Floodplain; it consists mainly of deep silt deposited from the Pleistocene to Recent times (past 2 million years). In its natural state, this was an area of bottomland forests with sluggish meandering streams, oxbow lakes, and cypress swamps. A large percentage of the fertile floodplain is now under cultivation for soybeans, cotton, and other crops. Thus, most of the forests are gone, and the characters of many of the local aquatic habitats are much altered from the natural state.

Several of Tennessee's few natural lakes occur in the floodplain belt, including Reelfoot Lake and oxbow lakes such as McKellar, Open, Chisholm, and Isom; these are all characterized by abundant cypress growth and areas of dense aquatic vegetation. Reelfoot Lake (Fig. 3) represents an extraordinary phenomenon, having been formed by tectonic upheaval and subsidence in the Lake County area during the New Madrid Earthquake of 1811–12, which was centered on the great fault by that name lying beneath the Mississippi River's course and was perhaps the most massive quake in recorded North American history. During this period the river rapidly changed course many times within a few weeks, was partially swallowed into opening chasms in its bed, and even experienced reverse flow at times. Devastation was rampant, and there was considerable loss of life in the area. Reelfoot Lake was formed by subsidence and filled by redirected flows from the Mississippi during this tumultuous event. This lake harbors the richest assemblage of swamp-dwelling fishes in Tennessee and once boasted a great sport fishery. It originally occupied perhaps 50,000 acres and had depths of 12 m (40 ft) or so but has been reduced to only about 13,000 acres and average depths of 1–2 m due to filling from erosion of surrounding lands, much hastened by poor agricultural practices (Petit, 1984). In recent years, measures have been taken to preserve what remains of this unique habitat, including building of silt retention dams on tributaries, anti-soil erosion programs, and aquatic vegetation control by both cutting and introduction of plant-eating fishes (grass carp).

A natural Coastal Plain lake, Reelfoot Lake near Walnut Log, Obion Co., TN.

The eastern border of the Mississippi Floodplain is formed by the Chickasaw Bluffs (Jackson Formation) which average perhaps 60–70 m in height. These bluffs are formed of hard clays and lignite of Pliocene age and have some high-level alluvial gravel deposits of early Pleistocene age associated with them. Smaller streams traversing the Chickasaw Bluffs have very localized reaches of increased gradient and patches of gravel substrate, the only such habitats over much of the Coastal Plain. Consequently, remarkably isolated fish assemblages, more typical of upland habitats and not repre-



A typical Chickasaw Bluff stream with localized upland characteristics — increased gradient; clear waters, and gravel substrates, (Pawpaw Creek, Obion Co., TN).

sented elsewhere in the province, uniquely occur in these reaches. Major streams traversing the bluffs (Obion River and others) have cut broad, low gradient valleys through them which are filled with alluvium and extend fingers of Mississippi Floodplain–type habitat far up their courses.

From the top of the bluffs eastward, the Mississippi Alluvial Plain, a tremendous expanse of loess deposits, silt, and sand, extends for 50–75 km across the gently sloping Coastal Plain. The loess plain averages near 150 m in elevation adjacent to the bluffs, dips to about 90 m in its central area, and surpasses 150 m again along its eastern edge. Loess consists of powder-fine dust of glacial origin that was driven by strong prevailing winds following the retreat of the glaciers 10,000 or so years ago. Streams of this region are generally low-gradient, soft-bottomed (predominately silt with some sand), turbid or murky, and, in the natural state, have extensive forested bottomlands associated with them and seasonally flooded swamps with rooted vegetation in more open areas. Over the past 50–70 years, many of these streams were channelized and had their riparian forests removed to "improve" drainage of agricultural lands. The resulting habitats consist of straight ditches with silt bottoms and very little natural cover for aquatic life. The Obion, Forked Deer, and Loosahatchie systems were channelized virtually throughout, while the main channels of the Hatchie and Wolf rivers escaped this devastation, though many of their tributaries did not. The bottomlands along the Hatchie River now harbor some of our best forests and richest wildlife habitat. Recently, there has been some realization by federal and state agencies of the deleterious effects of channelization, including accelerated erosion of farmland, rapid siltation of streams, and increased lowering of the water table during droughts, not to mention the destruction of aquatic and riparian habitat. Attempts may even be

A channelized Coastal Plain stream with most natural habitat destroyed (Cane Creek, Weakley Co., TN).

A typical upper Coastal Plain stream with moderate gradient and sandy bottom (Lane Branch, Hardeman Co., TN).

made to restore some of these streams to a more natural state.

East of the loess plain, the remainder of the Coastal Plain consists of north-south trending bands of sand and hard clay formations, the Claiborne-Wilcox and Midway groups of Tertiary age and, to the east of these, several Cretaceous formations, the most extensive of these being the McNairy Sand and fossil-rich Coon Creek formations. On these "harder" formations, averaging over 150 m elevation, the topography is more rolling, and streams have increased gradient over that of the loess plain and have primarily sandy substrates as opposed to silt. They therefore have distinctive faunal characteristics. Though penetrated by the extreme headwaters of the Wolf and Loosahatchie rivers in the southwestern quarter of Tennessee, most of these formations are drained by the headwaters of the westward flowing Hatchie, Forked Deer, and Obion systems; the easternmost Coastal Plain formations (Coon Creek and others) are drained primarily by numerous tributaries to the Tennessee River. Most of these are moderate gradient streams running more or less directly eastward into the valley of the Tennessee, but a notable exception is the much larger, northward-flowing Big Sandy River situated in a valley formed between the crest of the Coastal Plain on the west and an outlier of the Highland Rim on the east. This 120 km long river, channelized over much of its length, is a very low gradient stream having characteristics much like those of Mississippi Floodplain streams, as does the Blood River, which just barely penetrates the state to the north of it. This intrusion of lower Coastal Plain swamp habitat brings with it to the lower Tennessee drainage several species typical of such habitats. Overall, the Coastal Plain harbors many fish species not found in the Tennessee uplands to the east.

The Highland Rim and Nashville Basin

Lying to the east of the Coastal Plain, partially west of the lower Tennessee River, is the Highland Rim province. The Highland Rim (Fig. 1) is a giant craterlike structure in central Tennessee, extending north into Kentucky and south into Alabama. Higher portions of the Highland Rim average over 300 m in elevation. It surrounds the much lower Nashville Basin of central Tennessee, which averages about 200 m elevation. These provinces represent the remnants of a huge domelike structure (the Nashville Dome), the top of which fractured and eroded away leaving the craterlike center. Pennsylvanian sandstones, if present, were eroded away once they were fractured, and the Mississippian strata, fortified with highly resistant chert formations, constitute much of the crater rim. The core of the crater (Nashville Basin) is composed principally of Ordovician limestones which underwent rapid chemical breakdown after the overlying strata were removed and thus receded more rapidly than the surrounding crater.

The Highland Rim is composed primarily of limestones and chert and some shales. Streams of this region are characterized by coarse chert gravel and sand substrates interspersed with bedrock areas, moderate gradients, clear waters, and moderate to low productivity, and thus little aquatic vegetation except near spring sources. The softer limestones of the Highland Rim are pervaded by dissolution channels, and the region is very rich in cave and spring habitat, particularly in the southern portions. In fact, much of the province may have a network of caves communicating through the interconnected labyrinth of dissolution channels, facilitating the

A typical Highland Rim stream with cool, clear waters, chert gravel substrates, and riffle-pool habitats, (Little Salt Lick Creek, Macon Co., TN).

dispersal of cave organisms. An extremely resistant formation, the Fort Payne Chert, is responsible for numerous shoals and waterfalls in the area, such as Duck River Falls, and the huge Muscle Shoals complex that straddles the Tennessee River in northern Alabama (now inundated by impoundment).

The Tennessee River receives the drainage from the western and southern portions of the Highland Rim, and most of its tributaries in that region—including the lower Duck and Buffalo systems, Shoal and Cypress creeks, much of the Elk system, headwaters of the Flint River in Tennessee, and the numerous minor tributaries interlying these—have very similar characteristics as described above. As stated earlier, there is an outlier of the rim cut off from the main western portion lying west of the lower Tennessee River. This area contains virtually the only extensive exposures of Silurian and Devonian formations in Tennessee. However, streams in the area are similar in character to much of the rest of the rim, having moderate gradient and chert gravel and sand substrates.

The northwestern quarter of the Highland Rim is drained principally by tributaries to the lower Cumberland River, including Yellow Creek and the Red and Harpeth rivers. The dominance of chert gravel, sand, and bedrock habitat types continues in this region as well. During the 1950s–1970s, the main channel of the Cumberland River, which serves a drainage area of 48,000 km^2 in Tennessee and Kentucky, was impounded over much of its length from Barkley Dam in Kentucky virtually to Cumberland Falls in its headwaters (Table 1). Its riverine qualities are largely destroyed, and its preimpoundment fauna is as incompletely known as that of the Tennessee River discussed below. Neither the Red nor the Harpeth River is impounded, but the Red in particular has suffered in some areas from siltation stemming from agricultural practices.

North of the Nashville Basin, in Clay, Macon, and Sumner counties, draining the northward sloping portion of the Highland Rim, is the Barren River system, having its headwaters in Tennessee and flowing into Kentucky to join the Green River, a major tributary to the Ohio River. While it too has typical Highland Rim habitats (chert gravel, etc.), its drainage association is quite remote from the Tennessee and Cumberland systems, resulting in a considerable degree of faunal distinctness and adding several species to Tennessee's fish fauna.

The eastern Highland Rim, except for small portions of the Duck and Elk rivers' headwaters, in Tennessee is drained principally by the Cumberland River via the Caney Fork, Roaring, Wolf, and Obey rivers and several lesser tributaries. Center Hill Reservoir on the Caney Fork has drastically altered much of that drainage's natural characteristics, impounding much of the upper portion and turning most of the lower reach into a very cold river which no longer supports a diverse fauna. The Wolf and Obey rivers have received some impacts from coal surface-mining in their headwaters on the Cumberland Plateau but remain in relatively good condition. Both the upper Duck (Normandy Reservoir) and Elk (Tims Ford and Woods reservoirs) rivers have been impounded in the eastern Highland Rim area, leaving little in the way of undisturbed river habitat in the entire region.

One of the most interesting features of the eastern Highland Rim is a subprovince, the Barrens Plateau (Fig. 1), which straddles the headwaters of the Duck, Elk, and Caney Fork river systems. In this area virtually all of the surface strata is composed of chert rock and its soil derivatives which support limited tree life. Much of the area appears as a natural prairie, a very curious feature in a region that was otherwise originally forested virtually throughout; hence, the name "Barrens." Numerous springs emanate to the surface from the many aquifers in the softer Mississippian limestones below, and the area is characterized by spring-associated fish faunas, including one species endemic to the subprovince.

The Highland Rim, because of its geologic complexity and numerous semi-independent drainage systems, harbors the most diverse fish fauna of any region of comparable size in North America.

The Nashville Basin, as mentioned previously, is dominated by Ordovician limestones. The area has a relatively flat to gently rolling topography and is now largely devoted to grasslands and agriculture. Streams

Table 1. Summary of Impoundment Sites, Completion Dates, and Sizes in the Cumberland and Tennessee River Drainages—Based on TVA and U.S. Army Corps of Engineers Sources. Ownership of dams indicated parenthetically: ALC = Alcoa Aluminum; COE = U.S. Army Corps Engineers; CPL = Carolina Power and Light; TPC = Topoca Power Co.; TVA = Tennessee Valley Authority.

River - Impoundment	Dam Site	(River Mile)	Date	Surface Acres
Cumberland River drainage				
Cumberland River mainstem				
Barkley Res., KY-TN (COE)		31	1964	57,920
Cheatham Res., TN (COE)		144	1952	7,450
Old Hickory Res., TN (COE)		216	1954	22,500
Cordell Hull Res., TN (COE)		314	1973	11,960
Cumberland Res., KY (COE)		461	1950	50,250
Stones River				
Percy Priest Res., TN (COE)		7	1967	14,200
Caney Fork River				
Center Hill Res., TN (COE)		27	1948	18,220
Great Falls Res., TN (TVA)		91	1916	2,110
Obey River				
Dale Hollow Res., TN-KY (COE)		7	1943	27,700
Laurel River				
Laurel River Res., KY (COE)		2	1973	5,600
Martins Fk. River				
Martins Fork Res., KY (COE)		16	mid 1970s	578
Tennessee River drainage				
Tennessee River mainstem				
Kentucky Res., KY-TN (TVA)		22	1944	160,300
Pickwick Res., TN-AL (TVA)		207	1938	43,100
Wilson Res., AL (TVA)		259	1924	15,500
Wheeler Res., AL (TVA)		275	1936	67,100
Guntersville Res., AL (TVA)		349	1939	67,900
Nickajack Res., TN (TVA)		425	1967	10,370
Hales Bar Res., TN (TVA) (dismantled)		431	ca. 1913	NA
Chickamauga Res., TN (TVA)		471	1940	35,400
Watts Bar Res., TN (TVA)		530	1942	39,000
Ft. Loudon Res., TN (TVA)		602	1943	14,600
Duck River				
Normandy Res., TN (TVA)		249	1976	3,160
Beech River system				
Beech Res., TN (TVA)	Beech	35	1963	877
Cedar Res., TN (TVA)	Haley Cr.	4	1963	142
Dogwood Res., TN (TVA)	Big Cr.	7	1965	447
Pine Res., TN (TVA)	Piney Cr.	5	1964	466
Pinoak Res., TN (TVA)	Browns Cr.	5	1964	663
Redbud Res., TN (TVA)	Dry Cr.	1	1965	211
Sycamore Res., TN (TVA)	Dry Br.	1	1965	224
Bear Creek system				
Cedar Creek Res., AL (TVA)	Cedar Cr.	13	1979	4,610
Little Bear Cr. Res., AL (TVA)	L. Bear.	11	1975	1,560
Bear Cr. Res., AL (TVA)	Bear Cr.	75	1969	670
Upper Bear Cr. Res., AL (TVA)	Bear Cr.	115	1978	1,850

Table 1—*Continued*

River - Impoundment	Dam Site	(River Mile)	Date	Surface Acres
Elk River				
Tims Ford Res., TN (TVA)		133	1970	10,600
Woods Res., TN (COE)		170	1952	3,910
Hiwassee River system				
Apalachia Res., NC (TVA)	Hiwassee	66	1943	1,100
Hiwassee Res., NC (TVA)	Hiwassee	76	1940	6,090
Mission Res., NC (ALC)	Hiwassee	106	1924	61
Chatuga Res., NC-GA (TVA)	Hiwassee	121	1942	7,050
Nottely Res., GA (TVA)	Nottely	22	1942	4,180
Parksville (Ocoee #1) Res., TN (TVA)	Ocoee	12	1911	1,890
Ocoee #2 Dam, TN (TVA)	Ocoee	24	1913	NA
Ocoee #3 Res., TN (TVA)	Ocoee	30	1942	480
Blue Ridge Res., GA (TVA)	Ocoee	55	1930	3,290
Clinch River				
Melton Hill Res., TN (TVA)		23	1963	5,960
Norris Res., TN (TVA)		80	1936	34,200
Little Tennessee River system				
Tellico Res., TN (TVA)	Little Tennessee	1	1979	15,860
Chilhowee Res., TN (ALC)	Little Tennessee	34	1957	1,750
Calderwood Res., TN-NC (ALC)	Little Tennessee	44	1930	540
Cheoah Res., NC (ALC)	Little Tennessee	51	1918	590
Fontana Res., NC (TVA)	Little Tennessee	61	1944	10,640
Santeetlah Res., NC (ALC)	Cheoah	9	1927	2,863
Nantahala Res., NC (TPC)	Nantahala	23	1942	1,380
Tuckasegee Res., NC (ALC)	W. Fk. Tuckasegee	3	1950	8
Thorpe Res., NC (TPC)	W. Fk. Tuckasegee	10	1941	1,460
Cedar Cliff Res., NC (ALC)	Tuckasegee	52	1952	121
Bear Creek Res., NC (ALC)	Tuckasegee	55	1953	476
Tennessee Creek Res., NC (ALC)	Tuckasegee	61	1955	40
Wolf Creek Res., NC (ALC)	Wolf Cr.	2	1955	183
French Broad River system				
Douglas Res., TN (TVA)	French Broad	32	1943	30,400
Davy Crockett (Nolichucky) Res., TN (TVA)	Nolichucky	46	1913	383
Walters (Waterville) Res., NC (CPL)	Pigeon	38	1929	360
Holston River system				
Cherokee Res., TN (TVA)	Holston	52	1941	30,300
John Sevier Retent. Dam, TN (TVA)	Holston	106	1955	NA
Ft. Patrick Henry Res., TN (TVA)	S. Fk.	8	1953	872
Boone Res., TN	S. Fk.	19	1952	4,310
South Holston Res., TN-VA (TVA)	S. Fk.	50	1950	7,580
Wilbur Res., TN (TVA)	Watauga	34	1912	72
Watauga Res., TN (TVA)	Watauga	38	1948	6,430

of the Nashville Basin are characterized by low to moderate gradient and are virtually paved in some areas with expanses of limestone bedrock interspersed with rock rubble riffle areas, silty basins, and some sand and gravel reaches. The limestones freely leach nutrients and, consequently, waters are very productive, and algae and rooted vegetation are abundant in streams. Some of these streams sustain tremendous densities of fishes. Some remnants, or "islands," of Mississippian geology (e.g., Fountain Creek area, Maury County) remain in the basin and have physical (e.g., chert gravel, sand) and faunal characteristics typical of the surrounding Highland Rim. The northern half of the basin is drained by tributaries to the Cumberland River, whose course is shunted along the foot of the Highland Rim by the slightly north-dipping basin. In addition to numerous small direct tributaries to the Cumberland, the northern basin is drained by the lower Harpeth, Stones,

Hickman Creek, Smith Co., TN, a typical Nashville Basin stream with limestone bedrock and rubble substrate.

and lower Caney Fork systems. The southern half of the basin is drained by the middle portions of the Duck and Elk rivers. All major rivers draining the province have maintained their outlets from the relatively rapidly descending basin floor by commensurate downcutting of deep valleys through the more resistant Highland Rim to the west. Like other provinces, the Nashville Basin has a distinctive fish fauna which is perhaps as much notable for elements that avoid the region as those that are present.

The Tennessee River

The Tennessee River, in its present configuration, drains a large area of 105,000 km^2 lying in portions of Virginia, North Carolina, Tennessee, Georgia, Alabama, Mississippi, and Kentucky. However, geologic and faunal evidence suggest that such a configuration has not existed throughout the river's history and that this history has been complex. The aforementioned Highland Rim outlier is a manifestation of the unusual drainage pattern of the lower Tennessee River. Not only does the deeply incised (100+ m) confluence area of the Tennessee and Duck rivers have an odd configuration (Fig. 3), the whole course of the lower river, swinging northward away from its waters' eventual goal, the Gulf of Mexico, is enigmatic and indicative of a complex drainage history. The lower Tennessee is very likely several ancestral rivers now interconnected. One hypothesized scenario (Starnes and Etnier, 1986) is that the upper two-thirds of the ancestral Tennessee had its outlet to the Mississippi Embayment portion of the Gulf of Mexico somewhere in northern Mississippi or northwestern Alabama during the Tertiary (Fig. 4a). At some time in the latter half of the Tertiary, as sea level continued to recede and headwater erosion continued, a northern tributary to this river captured the northwest-flowing ancestral Duck River (Fig. 4b), diverting much of it southward to the gulf. The configuration of the present Duck-Tennessee confluence strongly suggests this capture. Moreover, most streams south (now upstream) of the Duck River, based on their angles of entry to the Tennessee River, obviously entered it with a southward impetus until fairly recent geologic times. During the Pleistocene (2,000,000–10,000 years ago), with sea level lowered by retention of earth's water in glaciers, and increased runoff from glacial melting, the Mississippi and Ohio rivers cut huge gorges much deeper than their present channels. The ancestral lower Duck

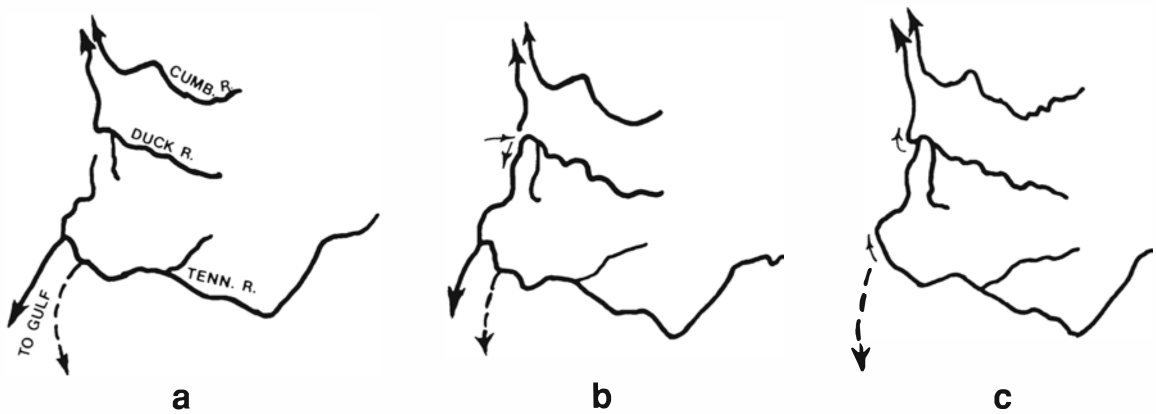


Figure 4. Hypothesized post-Cretaceous drainage evolution of the lower Tennessee River region: a) initial configuration during southward recession of sea from Mississippi Embayment; b) capture of former Duck-lowermost Tennessee rivers segment by south-flowing arm; c) recapture by lowermost Tennessee and reunification into present configuration (from Starnes and Etnier, 1986).

(or present lower Tennessee), entering the deepened Ohio, gained a gradient advantage over the Tennessee, recaptured its northern tributary, and unified these components into the present unusual configuration (Fig. 4c).

A somewhat similar scenario was outlined by Luther (1977), except that he proposed that the middle and upper reaches of the Tennessee were originally disjunct, with the upper Tennessee flowing straight southward to the gulf but eventually captured in the Chattanooga area and diverted westward by that portion entering the embayment. This hypothesis does not propose, as we have, an earlier continuity of the ancestral Duck and lowermost Tennessee (Fig. 4b) prior to the Pleistocene capture event. Whatever the scenario, the implications with respect to the distributional history and speciation of the fish fauna are obviously profound.

A number of authors (Hayes and Campbell, 1894, and several subsequent, including Mayden, 1988) have subscribed to the notion that the upper Tennessee once flowed directly southward to the gulf (the "Appalachian River" concept) in the vicinity of the present Coosa River system. However, the Tennessee has obviously flowed westward through Waldens Gorge near Chattanooga through many geologic periods, based on the dimensions of this passage. Further, sediments deposited along the lower Tennessee's course during the Cretaceous, derived from the Blue Ridge in the upper Tennessee, would indicate that this outlet has existed since at least sometime in the Mezozoic 100 million or more years ago (Starnes and Etnier, 1986). Thus, Tertiary and later connections of the upper Tennessee with drainages to the south (Mobile Basin) have probably been only through minor tributary exchanges.

The natural character of the Tennessee River has been completely altered by the series of impoundments, constructed by the Tennessee Valley Authority from the late 1930s to 1960s (Table 1), that punctuate it over its entire length from just above its mouth in western Kentucky to Knoxville. These are known as "flow-through" impoundments, which generally maintain downstream flows, unlike the storage impoundments on some of the Tennessee's tributaries which often seriously curtail flows below them. Thus, river-like qualities still exist in the upper reaches of some of these impoundments, such as Kentucky Lake and Nickajack and Watts Bar reservoirs, although there are no longer any of the expansive rocky or gravel shoal areas which once abounded in the Tennessee. Also, there are no longer the great spring floods along the river's course for which it was once notorious. These aspects of the river's natural ecology are gone until the dams succumb to the passage of time. The fishes that depended on the river in its natural state will never be completely known; several species are known to be extirpated from the river (Etnier et al., 1979), and some species that were never known to science may no longer be with us. These impoundments have created generally good reservoir fisheries for sport and commercial fishermen over the years, and some have changed character considerably since completion with regard to water conditions and faunal composition. The Tennessee River is now (as of 1985) connected to the Mobile Basin via the Tennessee-Tombigbee Waterway (Fig. 3), which enters the Tennessee through the Yellow Creek arm of Pickwick Reservoir, and which will further alter the river's flow and faunal characteristics in as yet unforeseen ways.

One of the numerous dams on the Tennessee River, Chickamauga Dam, Hamilton Co., TN.

The Cumberland Plateau

To the east of the Highland Rim and Nashville Basin lies the Cumberland Plateau, a roughly 60–100 km wide northeast-southwest trending band of high tableland averaging 700–800 m elevation. On the west, the transition from the Cumberland Plateau to the Highland Rim is steeply sloping while, on the east, a huge escarpment plunges abruptly as much as 400 m to the Ridge and Valley floor. The escarpment is the result of the erosion of the adjacent tilted and broken strata attributed to the great folding events which occurred during the Permian Period 250 million or so years ago. Geologically the plateau is characterized by Pennsylvanian strata of sandstone, shales, and moderately abundant coal deposits. This region is capped by relatively level strata of hard sandstones which have not undergone the uplift and fracturing of the Nashville Dome region or the folding of the Ridge and Valley to the east and have thus resisted erosion. Much of the plateau remains forested with hardwoods and, in some areas, with hemlock and rhododendron. On the plateau proper, streams are generally meandering and deeply incised with low to moderate gradients and have substrates of sand and sandstone and shale bedrock. Waters are clear and low in productivity unless disturbed by siltation from coal surface-mining. Numerous waterfalls occur where resistant sandstone strata overlie softer shales and coals beneath. Two of the most notable are Falls Creek Falls in Van Buren County, highest east of the Rockies, and Cumberland Falls on the Cumberland River in Kentucky. Falls typically recede upstream over the millennia as the soft rocks underlying the resistant caps erode from beneath, causing them to eventually collapse. For instance, Cumberland Falls (Fig. 3) has apparently receded in this fashion some 65 km into the plateau from its original position near the western escarpment of this province (McGrain, 1966).

Much of the Cumberland Plateau in Tennessee, which tilts slightly to the west, is drained in that direction by tributaries to the Cumberland River, including the Big South Fork, Wolf and Obey systems, and Caney Fork River. These larger streams have downcut through the Pennsylvanian plateau rocks sufficiently to reach the Mississippian limestones and cherts beneath, and thus, fingers of Highland Rim–like habitat, with their associated faunal elements, intrude far into the plateau along these rivers. These fingers are fed by small, typical sand-sandstone-shale-dominated plateau tributaries suspended high on either side, which are characterized by different faunas.

In the eastern and southern portions of the plateau only two major tributaries to the Tennessee River have penetrated the province. The Emory River system has exploited a major fault zone and thus surmounts the escarpment to carry drainage to the lower Clinch River. In the lower half of the system, due to downcutting, the Emory's habitat characteristics are a blend of plateau and Ridge and Valley types. The southern plateau straddles a curious feature, the ramrod-straight Sequatchie Valley (Fig. 1); the narrow, fingerlike portion of the plateau east of the valley is known to Tennesseans as Waldens Ridge. The valley, which averages over 300 m in depth beneath the surrounding plateau, is situated upon a collapsed anticline (an upfold or arch of strata). The overlying resistant sandstone strata were fractured during the upwarp event (which may correspond with the late Paleozoic folding events of the Ridge and Valley region) and, once breached, erosion

A typical Cumberland Plateau stream in natural state with sandstone and slate bedrock substrates and hemlock-rhododendron riparian vegetation (Thompson Creek, Pickett Co., TN).

attacked the softer Mississippian limestones lying beneath. By a repeated process of undermine and collapse, the Sequatchie River has eroded headward along the anticline some 120 km into the plateau. The Tennessee River, after gaining exit from the Ridge and Valley by bisecting Waldens Ridge via Waldens Gorge west of Chattanooga, aligns itself along the same collapsed anticline until it exits to the west near Guntersville, Alabama, (Fig. 3) thereby completing its traversal of the Cumberland Plateau region.

In northern Tennessee, an extremely interesting feature of the plateau region is Cumberland Gap, situated at the common borders of Tennessee, Kentucky, and Virginia. This huge passage has intrigued geologists and biologists for many years, and several, including ourselves, have speculated that the gap provided a former major connection between the Powell River portion of the upper Tennessee drainage and the Cumberland River drainage (Hayes and Campbell, 1894; Rich, 1933; McFarlan, 1943; Ross, 1972; Starnes et al., 1977). However, subsequent examination (Starnes and Etnier, 1986) of regional geology has revealed that this passage, as well as the Elk and Cove Creek valleys to the west, lie on the tremendous fault zones demarcating the facies of the Cumberland (or Pine Mountain) Block, a huge mass displaced some 30 km to the west of its original position during the great folding and overthrusting episode of the late Paleozoic. The tilted strata of these zones are easy prey for the erosive forces of local runoff and weathering, and it is doubtful that a major stream has as yet traversed these passages or played a role in their history. Faunal similarities between the Clinch-Powell system and portions of the Cumberland River (e.g., Big South Fork) are probably strictly related to habitat similarities and relictual distributions rather than a former connection between these drainages.

Unfortunately, the Cumberland Plateau's coal reserves have meant devastation for many of its streams. Over the past thirty years, many of its watersheds have been strip-mined for coal. Earlier miners practiced no runoff prevention or reclamation procedures; consequently, many tributaries to the Cumberland and Emory systems, tributaries to the lower Clinch such as Cove Creek, and to some extent the Sequatchie system, have suffered and continue to be degraded by impacts from siltation and acid mine drainage. Some of these have had their fish faunas virtually eliminated. Rivers serving these watersheds, such as the New of the Big South Fork system, have also been seriously affected. Hopefully, reclamation procedures legislated over the past few years will curb some of this degradation in the future.

A Cumberland Plateau stream impacted by acid mine drainage with near total destruction of aquatic life (photo courtesy of Tennessee Valley Authority).

The Ridge and Valley

Bordering the Cumberland Plateau on the east is the Ridge and Valley province, a 60–90 km wide belt of northeast-southwest trending ridges and valleys. Ridges vary considerably in elevation, ranging from less than 300 to over 790 m; valley floors average over 300 m in elevation near Virginia and slope to averages near 200 m in southern Tennessee. Ridge and Valley features are manifestations of the aforementioned extreme folding and faulting events of the late Paleozoic Era around 250 million years ago. The impetus from the southeast, perhaps caused by an episode of continental drift that resulted in the collision of North Africa with eastern North America (Briggs, 1986), or a period of accelerated sea-floor spreading, resulted in the rocks to the east of Tennessee being forced up and over those to the west perhaps 60–80 km (Blue Ridge overthrust belt). To the west of the overthrust, net movement was much less, perhaps on the order of 25 km. Here the rock strata compensated by folding and rippling, like a rug pushed from one side against a wall, or faulting. Subsequently, differential erosion set in on the tilted strata and left ridges along the more resistant ones. Once eroded, the result of these events was one of the world's most complex geological regions with numerous exposures of strata having ages spanning 250 million years or more (Cambrian to Mississippian). The Ridge and Valley is largely devoid of remnants of the Pennsylvanian strata which dominate the immediately adjacent Cumberland Plateau; thus, these strata must have fractured and quickly eroded away in the early stages of the folding episode. Consequently, the area has very little sandstone and is dominated by limestone and dolomite formations.

Except for those rivers exiting the Blue Ridge and transecting both ridges and valleys to join the Tennessee River, larger streams in the Ridge and Valley have their courses structurally guided by the ridges and thus meander along the roughly parallel valley floors; they are joined on either side by numerous "right-angle" minor tributaries draining the ridge slopes (the "trellis" drainage pattern). Gradients of valley floor streams are moderate to low. Smaller streams in this region are characterized by limestone rubble and bedrock riffles and silty sand pool areas; chert gravel occurs in some smaller streams. Larger rivers have, in addition to these habitats, some extensive sand and gravel shoal areas. Waters are relatively productive, and vegetation, such as water willow and river weed, is abundant in many shallow areas. Springs and caves are relatively numerous in the Ridge and Valley. While the springs have typical characteristics, such as cold (15–17 C, or 59–63 F) outflows and abundant vegetation (primarily watercress), and are typified by several fish species, no "true" (trogloditic) cavefishes are known from the region. Overall, the region has great habitat diversity and accordingly supports a very diverse fish fauna rivaled only by that of the Highland Rim region.

The Tennessee River and tributaries drain virtually the entire Ridge and Valley Province in Tennessee. As stated earlier, the main channel of the Tennessee is impounded throughout. Moreover, all major tributaries in the Ridge and Valley except the Emory and Little rivers have large dams on them (Table 1). Only these rivers and the upper portions of the Clinch and Powell rivers have escaped the direct effects of impoundments—inundation of flowing habitats and depressed temperature regimes below dams. On the Clinch River, Norris Dam in particular, because of its great depth, has greatly depressed temperatures in its tailwaters, and a very limited fauna survives there along with a put-and-grow trout fishery. The last river to be impounded was the Little Tennessee in 1979 by the controversial Tellico Dam. The lower reach of this river, whose characteristics were already altered by Fontana and Chilhowee dams upstream, formerly supported one of the most productive trout fisheries in eastern North America. In addition to impoundments, east Tennessee rivers have not escaped impacts from pollution. The upper Holston and lower Watauga systems have suffered heavily from industrial pollutants in the past, and due to paper-mill effluents the Pigeon River, entering the French Broad River from North Carolina, is currently one of the most polluted rivers in all of North America. The Clinch and Powell systems, which have portions of their headwaters in the Pennsylvanian coal regions in Virginia, continue to receive siltation from strip mines in these areas, and the Powell has been particularly impacted by this in recent years. Serious pollutants, such as mercury and PCBs (polychlorinated biphenyls), have at times become significant fish contaminants in some areas, such as Cherokee, Ft. Loudon, Tellico, Watts Bar, and Nickajack reservoirs.

A Ridge and Valley river, Little River east of Maryville, TN, one of the most diverse fish habitats in North America and home to several rare species.

The larger river fish faunas of the Ridge and Valley are now necessarily distributed in extremely fragmented fashion, and several elements are known to have disappeared altogether (e.g., Etnier et al., 1979). Of all rivers in the region, the upper Clinch remains the least altered and supports, along with the Duck River, one of the most diverse fish faunas in North America. Other "best" rivers in the area are the Little River in Blount County, which is one of the last strongholds for several rare fish species, a limited reach of the Nolichucky River below Davy Crockett Dam in the Greene County area, the Little Pigeon system in Sevier County, and, to a lesser extent, the Emory and upper Powell systems which have suffered some from the aforementioned effects of coal surface-mining on the adjacent Cumberland Plateau.

A very small portion of the Ridge and Valley in extreme southeastern Tennessee in Bradley and Polk counties is drained by the Conasauga River system (Fig. 3), tributary to the Coosa River in the Mobile Basin drainage. The headwaters of this system are in the Blue Ridge, and much of its watershed remains forested. Consequently, the Conasauga remains one of the better-quality and most beautiful streams in the southeastern United States. It has clear waters, virtually no siltation, and a diversity of habitats—including gravel shoals, rubble and bedrock riffles, sand and gravel bottomed pools—and numerous types of tributary habitats, with several large springs among them. It supports a diverse fish fauna composed of many Mobile Basin endemics and is in fact the last stronghold of several of these fishes. As such, it contributes substantially to the overall diversity of Tennessee's fish fauna and should be high on everyone's list to visit and protect.

The Blue Ridge

The final province to be discussed in detail is the Blue Ridge, which overlaps Tennessee's eastern border (Fig. 1). As explained in the discussion of the Ridge and Valley, the Blue Ridge is an overthrust belt, extending from Georgia to Maryland, resulting from powerful driving forces originating to the southeast during the late Paleozoic. In the Tennessee–North Carolina area it consists of three major, roughly parallel, ridges. The western crest, along the border of these states, is the highest at 1,500–1,800 m or more, and is often referred to separately as the Unaka Mountains, which includes the Great Smokies.

The Blue Ridge consists of very old (570+ million years) Precambrian rocks thrust on top of younger rocks beneath as evidenced by the deep "cove" areas (e.g., Cades, Tuckaleechee, Wears coves) where the Precambrian rocks have eroded through to the Ordovician limestones below, which are at least 70–140 million years younger. The foothills of the Blue Ridge, such as the Chilhowee, Iron, and Stone mountain areas, are composed of early Paleozoic (Cambrian) rocks (sandstone, shale, dolomite) which are tilted and fractured and differentially eroded to form ridges and valleys and consequently have developed "trellis" drainage patterns as described earlier. The main Blue Ridge is composed of hard Precambrian formations consisting of metamorphosed sedimentary rocks (gneiss, sandstone) and granite. Here streams have dendritic (forked branching) drainage patterns. Small streams are high gradient with numerous riffles and falls over bedrock and boulder substrates interspersed with bedrock and sand and gravel pool areas. Waters are very low in productivity and extremely clear, and aquatic vegetation is virtually lacking. Water temperatures are cool year-round, seldom exceeding 20 C (68 F). The mountains remain largely forested with hardwoods predominating on the lower slopes, superseded by hemlock and rhododendron assemblages and finally, at highest elevations, by spruce forests.

Several Tennessee River tributaries traverse the western crest of the Blue Ridge to serve as drainage for high basins (600–800 m), such as the Asheville and Franklin basins, lying between that crest and those to the east. The Hiwassee, Little Tennessee, French Broad, Pigeon, and Nolichucky rivers have kept pace with the receding basins and maintained their outlets to the west by downcutting deep valleys through the western crest much as those rivers serving the Nashville Basin have done in the Highland Rim. It is also possible that some uplift of the Blue Ridge continues even today, necessitating this downcutting.

Despite the fact that the watersheds of the rivers traversing the Blue Ridge are largely forested, assuring them clear, silt-free flows much of the time, they nevertheless have suffered impacts. Each river except the French Broad in North Carolina has one to several impoundments built on it (Table 1). These "storage" impoundments, unlike the flow-through impoundments of

Stream habitat typical of the Blue Ridge area with high gradients, cool, clear waters, and boulder and bedrock substrates (Roaring Fork, Sevier Co., TN).

the main Tennessee River, are deep, with cold (6–20 C, 43–68 F) hypolimnic (bottom layer) water releases and erratic flows which usually correspond to the needs of electric power generation or flood control. Therefore, these mountain river ecosystems are greatly affected by rapidly fluctuating water levels and cold temperatures. Some reservoirs have provided fair cool-water fisheries (smallmouth bass-trout) but, in general, productivity of the cool, clear waters is low.

Aside from alterations by impoundment, we have already stated that the Pigeon River has been and continues to be severely impacted by pollutants; in addition, the Ocoee River portion of the Hiwassee system in Polk County was severely impacted by industrial effluents and siltation from Copper Hill, Tennessee, and the Nolichucky River above Davy Crockett Reservoir has received a tremendous silt load from mica mines in North Carolina. Fortunately, the reservoir has thus far served as a catchment basin for silt (though it is now virtually filled), greatly improving water quality in the Ridge and Valley portion of the river downstream. Thus, the overall best-quality rivers draining the Blue Ridge in Tennessee are those smaller ones draining only its western slopes, such as Little River, the Little Pigeon system, Tellico River, and portions of the upper Watauga system.

The Blue Ridge of Tennessee contains some of the most beautiful streams in North America. The pristine quality of many of the smaller ones remains although there is some chance that acid rain may be having some effect on these, and naturally occurring high-level acidification through leaching of Anakeesta shales is a local phenomenon in a few creeks. Though lacking the diversity of the adjacent Ridge and Valley, a distinct fish fauna is associated with streams and rivers of the region. Hundreds of miles of trout streams, both natural and stocked, lie within the province. Hopefully, the generally limited accessibility and already established parks and management areas in this region will preserve the beauty and unique fauna of these mountains.

Tennessee's Fish Fauna: Composition and Occurrence

Tennessee has the richest freshwater fauna of any of the United States. At this writing, between 302 and 319 (depending on resolution of persistent taxonomic problems) species of native and introduced fishes have been recorded from the state's waters (Table 2); between 277 and 297 are probably native. Two or more additional modern species are known from probable remains dating to the Pleistocene, indicating their former natural occurrence in the region during that epoch. New species continue to be described nearly every year, though the existence of some of these has been known to ichthyologists for some time, and ongoing and future studies of various species complexes may reveal additional taxa in need of recognition. Many native species have had their ranges greatly reduced by habitat alterations stemming from human activities. At least four native species are now considered extinct in the state, and several more could be considered on the verge of extinction.

Tennessee's fishes represent 29 families and 18 orders ranging from the very primitive lampreys and chondrostean fishes (sturgeons, paddlefish) to more modern perciform groups. The largest family representation is of the Percidae (93 species, 90 of which are darters), followed by the minnows, Cyprinidae, with 83 species. These are followed by the catfishes (Ictaluridae) with 24 species, the suckers (Catostomidae) and the sunfishes (Centrarchidae) each with 21.

The richest fish faunas (Table 2) are found in the Tennessee and Cumberland drainages which respectively contain at least 205 and 161 native species and, combined, harbor approximately 221 species; the Mississippi River and its direct tributaries follow with about 136 species of native fishes. A few species are ubiquitous throughout most of the state. Among species with more restricted ranges within the state, the greatest number (91) are confined to the Tennessee and Cumberland river drainages. Another 24 species are confined to the Mississippi River or its tributaries in the western portion of the state. Approximately six of these are species of very large rivers and are confined to the Mississippi River's main channel. Two mostly peripheral drainages, the Conasauga River portion of the Mobile Basin and the Barren River portion of the Green River (Ohio River) drainage of Kentucky (Fig. 3), barely penetrate the state's borders but harbor 24 and 5 species, respectively, which do not occur elsewhere in Tennessee, thus adding considerably to the total fauna.

In addition to the several faunistically distinct drainages encompassed by Tennessee, the numerous physiographic regions previously discussed under Waters and Geology have doubtless been instrumental in the evolution of so many taxa. Based on regions of principal occurrence (Table 2), the richest provinces are the Highland Rim and Ridge and Valley, with about 168 and 160 native species, respectively; the Coastal Plain follows with about 130. The faunistically most impoverished provinces are the Cumberland Plateau and Blue Ridge, with about 53 and 62 species respectively. Within Tennessee, several species each are largely or wholly confined to one of these provinces, led by the lowland and Mississippi River assemblages of the Coastal Plain with 46, followed by the Ridge and Valley with 24, many of which are attributable to Mobile Basin endemic forms occurring only in the Conasauga River system which enters Tennessee in that province. Approximately 62 species are shared by or confined to either the Ridge and Valley and Highland Rim provinces but are uncommon or absent elsewhere. The cool waters of the Blue Ridge have only about five species largely confined to them but have attracted numerous introductions of salmonids and other fishes. The Cumberland Plateau and Nashville Basin also have about 5 species each primarily associated with them. A few species are common to several or all of the five upland provinces but avoid the Coastal Plain, and some are nearly ubiquitous in all six provinces. Some rare and restricted species (e.g., *Notropis* sp., "the palezone shiner"; *Noturus baileyi*, the smoky madtom; *Etheostoma* (*Catonotus*) sp., the "duskytail darter") occur only near interfaces of two provinces—apparently deriving their habitat requirements from a combination of characteristics (e.g., substrates) provided by both provinces. It should also be noted that a few larger, more mobile species of larger rivers (e.g., gars, some suckers, catfishes) are less affected by physiographic circumstances, and their occurrences in larger rivers of these regions (e.g., larger rivers traversing the Blue Ridge) are not necessarily informative about faunal characteristics of those regions.

Table 2. Systematic List of Fishes Historically Occurring Naturally or Introduced in Tennessee. Occurrence in drainages denotes *any* known occurrence in a river system while physiographic provinces denoted are those of *principal* occurrence only, not including occasional records from atypical habitats in adjacent provinces. Probable extant occurrences are denoted by "0"; probable extinctions by "E"; unsuccessful introductions by "U." Mississippi drainage includes the Mississippi River proper and its direct westward flowing tributaries in western Tennessee (e.g, Hatchie, Obion systems). Barren drainage represents the headwater portion of that system in north central Tennessee (Clay, Macon, Sumner counties) tributary to the Green and Ohio river systems in Kentucky. Conasauga drainage represents the small headwater portion of that system in extreme southeastern Tennessee (Polk, Bradley counties) tributary to the Coosa River portion of the Mobile Basin. Much information on introduced species was provided by L. B. Starnes and P. A. Hackney (in litt.).

Key to Table 2

Origin:
N = Native I = Introduced

Drainage:
M = Mississippi River T = Tennessee River C = Cumberland Rver B = Barren (Green) River C - Conasauga (Coosa) River

Principal Physiographic Provinces:
CP = Coastal Plain HR = Highland Rim NB = Nashville Basin Cu = Cumberland Plateau RV = Ridge and Valley BR = Blue Ridge

		Origin		Drainages					Principal Physiographic Provinces						
		N	I	M	T	C	B	C	CP	HR	NB	Cu	RV	BR	Notes
Order Petromyzontiformes															
Family Petromyzontidae (the lampreys)															
Ichthyomyzon bdellium	Ohio lamprey	X			O	O				O			O	O	
I. castaneus	chestnut lamprey	X		O	O	O		O	O	O	O		O		
I. gagei	southern brook lamprey	X			?			O	?				O		1
I. greeleyi	mountain brook lamprey	X			O	O				O		O	O	O	
I. unicuspis	silver lamprey	X		O	O	O			O	?	O				
Lampetra aepyptera	least brook lamprey	X		O	O	O	O	O	O	O	O	O	O		
L. appendix	American brook lamprey	X			O	O	?			O	O		O	O	
Order Acipenseriformes															
Family Acipenseridae (the sturgeons)															
Acipenser fulvescens	lake sturgeon	X		O	O	O			O	O	O		O	O	2
Scaphirhynchus albus	pallid sturgeon	X		O					O						3
S. platorynchus	shovelnose sturgeon	X		O	O				O				O		
Family Polyodontidae (the paddlefishes)															
Polyodon spathula	paddlefish	X		O	O	O			O	O	O		O	O	
Order Lepisosteiformes															
Family Lepisosteidae (the gars)															
Atractosteus spatula	alligator gar	X		O	O	?			O						4
Lepisosteus oculatus	spotted gar	X		O	O	O			O	O			O		
L. osseus	longnose gar	X		O	O	O		O	O	O	O	?	O	O	
L. platostomus	shortnose gar	X		O	O	O			O	O			?		
Order Amiiformes															
Family Amiidae (the bowfin)															
Amia calva	bowfin	X		O	O	O			O						
Order Osteoglossiformes															
Family Hiodontidae (the mooneyes)															
Hiodon alosoides	goldeye	X		O	O	O			O	O			E		
H. tergisus	mooneye	X		O	O	O			O	O	O	?	O	O	
Order Anguilliformes															
Family Anguillidae (the freshwater eels)															
Anguilla rostrata	American eel	X		O	O	O			O	O	?	?	O		

Table 2—*Continued*

		Origin		Drainages					Principal Physiographic Provinces						
		N	I	M	T	C	B	C	CP	HR	NB	Cu	RV	BR	Notes
ORDER CLUPEIFORMES															
Family Clupeidae (the herrings)															
Alosa alabamae	Alabama shad	X		O	O	O			O	O	O		E		5
A. chrysochloris	skipjack herring	X		O	O	O			O	O	O		O		
A. pseudoharengus	alewife		X		O	O				O			O	O	6
Dorosoma cepedianum	gizzard shad	X		O	O	O	O	O	O	O	O	O	O	O	
D. petenense	threadfin shad	?	?	O	O	O			O	O	O	O	O	O	7
ORDER CYPRINIFORMES															
Family Cyprinidae (the minnows)															
Campostoma anomalum	central stoneroller	X		O	O	O	O	O		O	O	O	O	O	
Carassius auratus	goldfish		X	O	O	O	?	?	O	O	O	O	O	O	8
Clinostomus funduloides	rosyside dace	X			O	O				O	O			O	
Ctenopharyngodon idella	grass carp		X	O		O			O	O					9
Cyprinella caerulea	blue shiner	X						O					O		
C. callistia	Alabama shiner	X						O					O		
C. camura	bluntface shiner	X		O	O				O						
C. galactura	whitetail shiner	X			O	O				O	O	O	O	O	
C. lutrensis	red shiner	X		O	O				O						
C. monacha	spotfin chub	X			O					O		O	O	O	
C. spiloptera	spotfin shiner	X			O	O	O			O	O	O	O	O	
C. trichroistia	tricolor shiner	X						O					O		
C. venusta	blacktail shiner	X	X	O	O			O	O				O		10
C. whipplii	steelcolor shiner	X		O	O	O			O	O	O		O		11
Cyprinus carpio	common carp		X	O	O	O	O	O	O	O	O	O	O	O	12
Ericymba buccata	silverjaw minnow	X				O					?	O			
Erimystax cahni	slender chub	X			O								O		
E. dissimilis	streamline chub	X			O	O				O			O		
E. insignis	blotched chub	X			O	O				O			O	O	
Hemitremia flammea	flame chub	X			O	O				O			O		
Hybognathus hankinsoni	brassy minnow		X		U								U		13
H. hayi	cypress minnow	X		O	O				O						
H. nuchalis	Miss. silvery minnow	X		O	O	?			O	O			E		14
H. placitus	plains minnow	X		O					O						15
Hybopsis amblops	bigeye chub	X			O	O	O			O	O		O	O	
H. amnis	pallid shiner	X		O	?	O			O	O	?				
H. lineapunctata	lined chub	X						O					O		
Hypopthalmichthys molitrix	silver carp		X	O					O						16
H. nobilis	bighead carp		X	O					O						17
Luxilus chrysocephalus	striped shiner	X		O	O	O	O	O	O	O	O	O	O	O	
L. coccogenis	warpaint shiner	X			O					O			O	O	
Lythrurus ardens	rosefin shiner	X			O	O	O			O	O	O	O		
L. fumeus	ribbon shiner	X		O	O				O						
L. lirus	mountain shiner	X			O			O		O			O		
L. umbratilis	redfin shiner	X		O	O				O						
Macrhybopsis aestivalis	speckled chub	X		O	O	E		O	O	O			O	O	18
M. gelida	sturgeon chub	X		O					O						19
M. meeki	sicklefin chub	X		O					O						20
M. storeriana	silver chub	X		O	O	O			O	O	O		O		
Nocomis effusus	orangefin chub	X			O	O	O			O					
N. micropogon	river chub	X			O	O				O		O	O	O	
Notemigonus crysoleucas	golden shiner	X		O	O	O	O	O	O	O	O	O	O	O	
Notropis ammophilus	orangefin shiner	X		O					O						
N. ariommus	popeye shiner	X			O	O				O			O		
N. asperifrons	burrhead shiner	X						O					O		
N. atherinoides	emerald shiner	X		O	O	O			O	O	O	O	O		
N. blennius	river shiner	X		O	O	O			O						
N. boops	bigeye shiner	X			O	O	O			O	O				

Table 2—*Continued*

		Origin		Drainages					Principal Physiographic Provinces						
		N	I	M	T	C	B	C	CP	HR	NB	Cu	RV	BR	Notes
N. buchanani	ghost shiner	X		O	O	O			O	O			O		
N. chrosomus	rainbow shiner	X			?			O					O		21
N. dorsalis	bigmouth shiner	X		O					O						22
N. leuciodus	Tennessee shiner	X			O	O	O			O			O	O	23
N. maculatus	taillight shiner	X		O					O						
N. photogenis	silver shiner	X			O	O	O			O			O	O	
N. rubellus	rosyface shiner	X			O	O	O			O	O	O	O	O	
N. rubricroceus	saffron shiner	X			O									O	
N. rupestris	bedrock shiner	X			O	O					O				24
N. shumardi	silverband shiner	X		O		O			O						
N. spectrunculus	mirror shiner	X			O									O	
N. stilbius	silverstripe shiner	X						O					O		
N. stramineus	sand shiner	X		O	O	O			O			O	O		
N. telescopus	telescope shiner	X			O	O	O			O	O	O	O	O	
N. texanus	weed shiner		X		O				O						25
N. volucellus	mimic shiner	X		O	O	O	O		O	O	O	O	O	O	
N. wickliffi	channel shiner	X		O	O	?			O	O					
N. xaenocephalus	Coosa shiner	X						O					O		
Notropis sp.	"palezone shiner"	X			E	?				?			O		26
Notropis sp.	"sawfin shiner"	X			O	O				O			O		
Opsopoeodus emiliae	pugnose minnow	X		O	O	O			O				O		
Phenacobius catostomus	riffle minnow	X						O					O		
P. crassilabrum	fatlips minnow	X			O									O	
P. mirabilis	suckermouth minnow	X		O	O				O	O	O				
P. uranops	stargazing minnow	X			O	E				O			O		
Phoxinus cumberlandensis	blackside dace	X				O						O			
P. erythrogaster	southern redbelly dace	X		O	O	O	O			O	O	O			
P. tennesseensis	Tennessee dace	X			O								O		
Pimephales notatus	bluntnose minnow	X		O	O	O	O		O	O	O	O	O		
P. promelas	fathead minnow	?	X	O	O	O	O	O	O	O	O	O	O	O	27
P. vigilax	bullhead minnow	X		O	O	O		O	O	O	O		O		
Platygobio gracilis	flathead chub	X		O					O						28
Rhinichthys atratulus	blacknose dace	X		O	O	O	O	O		O	O	O	O	O	
R. cataractae	longnose dace	X			O									O	
Semotilus atromaculatus	creek chub	X		O	O	O	O	O	O	O	O	O	O	O	
Family Catostomidae (the suckers)															
Carpiodes carpio	river carpsucker	X		O	O	O			O	O			O	O	
C. cyprinus	quillback	X		O	O	O			O	O	O		O	O	
C. velifer	highfin carpsucker	X			O	O				O	O		O		29
Catostomus commersonii	white sucker	X		O	O	O	O	O		O		O	O	O	
Cycleptus elongatus	blue sucker	X		O	O	O			O	O	O		O		
Erimyzon oblongus	creek chubsucker	X		O	O	O			O	O					
E. sucetta	lake chubsucker	X		O	O				O						
Hypentelium etowanum	Alabama hog sucker	X			O			O					O		30
H. nigricans	northern hogsucker	X		O	O	O	O	O		O	O	O	O	O	31
Ictiobus bubalus	smallmouth buffalo	X		O	O	O	O	O	O	O	O		O		
I. cyprinellus	bigmouth buffalo	X		O	O	O			O	O	?				
I. niger	black buffalo	X		O	O	O			O	O	O		O		
Lagochila lacera	harelip sucker	X			E	E				E	E		E		32
Minytrema melanops	spotted sucker	X		O	O	O	O	O	O	O			O		
Moxostoma anisurum	silver redhorse	X		?	O	O				O			O		
M. atripinne	blackfin sucker	X					O			O					
M. carinatum	river redhorse	X			O	O		?		O	O		O	O	33
M. duquesnii	black redhorse	X			O	O	O	O		O	O	O	O	O	
M. erythrurum	golden redhorse	X		O	O	O	O	O		O	O	O	O	O	
M. macrolepidotum	shorthead redhorse	X			O	O				O			O	O	
M. poecilurum	blacktail redhorse	X		O				O	O				O		

Table 2—*Continued*

		Origin		Drainages					Principal Physiographic Provinces						
		N	I	M	T	C	B	C	CP	HR	NB	Cu	RV	BR	Notes
ORDER SILURIFORMES															
Family Ictaluridae (the North American freshwater catfishes)															
Ameiurus catus	white catfish		X		?								?	?	34
A. melas	black bullhead	X		O	O	O	O	O	O	O	O	O	O		
A. natalis	yellow bullhead	X		O	O	O	O	O	O	O	O	O	O		
A. nebulosus	brown bullhead	X		O	O	?	?	O	O	O	O		O		
A. platycephalus	flat bullhead		X		?								?		35
Ictalurus furcatus	blue catfish	X		O	O	O			O	O	O		O		
I. punctatus	channel catfish	X		O	O	O	O	O	O	O	O	O	O	O	
Noturus baileyi	smoky madtom	X			O									O	
N. elegans	elegant madtom	X			O	O	O			O					36
N. eleutherus	mountain madtom	X		O	O	O	O			O			O	O	37
N. exilis	slender madtom	X			O	O				O	O				
N. flavipinnis	yellowfin madtom	X			O								O	O	
N. flavus	stonecat	X		O	O	O				O	O	O	O		
N. gyrinus	tadpole madtom	X		O	O				O						
N. hildebrandi	least madtom	X		O					O						
N. insignis	margined madtom		X		O								O	O	38
N. leptacanthus	speckled madtom	X						O					O		
N. miurus	brindled madtom	X		O	O	O	?		O	O	O				
N. munitus	frecklebelly madtom	X						O					O		
N. nocturnus	freckled madtom	X		O	O	O	?		O	O					
N. phaeus	brown madtom	X		O	O				O						
N. stanauli	pygmy madtom	X			O					O			O		
N. stigmosus	northern madtom	X		O					O						
Pylodictis olivaris	flathead catfish	X		O	O	O	?	?	O	O	O	O	O	O	
ORDER SALMONIFORMES															
Family Esocidae (the pikes)															
Esox americanus	grass pickerel	X		O	O	O	O		O	O					
E. lucius	northern pike	?	X	?	O								O	O	39
E. masquinongy	muskellunge	X	X		O	O				O	O	O	O	O	40
E. niger	chain pickerel	X		O	O	O		O	O	O					
Family Umbridae (the mudminnows)															
Umbra limi	central mudminnow	X		O	O				O						
Family Osmeridae (the smelts)															
Osmerus mordax	rainbow smelt		X	O	U				O				U		41
Family Salmonidae (the salmons)															
Coregonus artedi	cisco		X		U									U	42
Oncorhynchus clarkii	cutthroat trout		X		U	U				U				U	43
O. kisutch	coho salmon		X		U									U	44
O. mykiss	rainbow trout		X		O	O	?	O		O		O	O	O	45
O. nerka	kokanee (sockeye salmon)		X		U									U	46
Salmo letnica	Ohrid trout		X		O									O	47
S. trutta	brown trout		X		O	O	O	O		O		O	O	O	48
Salvelinus fontinalis	brook trout	X	X		O	O		O						O	49
S. namaycush	lake trout		X			O				O					50
ORDER APHREDODERIFORMES															
Family Aphredoderidae (the pirateperch)															
Aphredoderus sayanus	pirate perch	X		O	O	O			O	O					

Table 2—*Continued*

		Origin		Drainages					Principal Physiographic Provinces						
		N	I	M	T	C	B	C	CP	HR	NB	Cu	RV	BR	Notes
Family Amblyopsidae (the cavefishes)															
Forbesichthys agassizii	spring cavefish	X			O	O				O	O				
Typhlichthys subterraneus	southern cavefish	X			O	O				O	O				
ORDER GADIFORMES															
Family Gadidae (the cods)															
Lota lota	burbot	X		O					O						51
ORDER CYPRINODONTIFORMES															
Family Fundulidae (the topminnows)															
Fundulus catenatus	northern studfish	X			O	O	O			O	O		O		
F. chrysotus	golden topminnow	X		O					O						
F. dispar	northern starhead topminnow	X		O	O				O						
F. julisia	Barrens topminnow	X			O	O				O					
F. notatus	blackstripe topminnow	X		O	O	O	O		O	O	O		O		
F. olivaceus	blackspotted topminnow	X		O	O	O		O	O	O			O		
F. stellifer	southern studfish	X						O					O		
Family Poeciliidae (the livebearers)															
Gambusia affinis	western mosquitofish	X	?	O	O	O	?	O	O	O	O	O	O		52
ORDER BELONIFORMES															
Family Belonidae (needlefishes)															
Strongylura marina	Atlantic needlefish		X	?	O				O						53
ORDER ATHERINIFORMES															
Family Atherinidae (the silversides)															
Labidesthes sicculus	brook silverside	X		O	O	O	O		O	O	O		O		
Menidia beryllina	inland silverside	X		O	O	O			O						
ORDER MUGILIFORMES															
Family Mugilidae (the mullets)															
Mugil cephalus	striped mullet	X		O	O				O						54
ORDER GASTEROSTEIFORMES															
Family Gasterosteidae (the sticklebacks)															
Culaea inconstans	brook stickleback		X		O	O				O			O		55
ORDER SCORPAENIFORMES															
Family Cottidae (the sculpins)															
Cottus bairdii	mottled sculpin	X			O	O				O			O	O	56
C. carolinae	banded sculpin	X			O	O	O	O		O	O	O	O	O	57
ORDER PERCIFORMES															
Family Moronidae (the temperate basses)															
Morone chrysops	white bass	X		O	O	O			O	O	O		O		
M. mississippiensis	yellow bass	X		O	O	O			O	O			O		
M. saxatilis	striped bass		X	?	O	O				O	O		O		58
Family Elassomatidae (the pygmy sunfishes)															
Elassoma zonatum	banded pygmy sunfish	X		O	O				O						
Family Centrarchidae (the sunfishes)															
Ambloplites ariommus	shadow bass	X						O					O		
A. rupestris	rockbass	X			O	O	O			O	O	O	O	O	

Table 2—*Continued*

		Origin		Drainages					Principal Physiographic Provinces						
		N	I	M	T	C	B	C	CP	HR	NB	Cu	RV	BR	Notes
Centrarchus macropterus	flier	X		O	O				O						
Lepomis auritus	redbreast sunfish	?	X	O	O			O	O				O	O	59
L. cyanellus	green sunfish	X		O	O	O	O	O	O	O	O	O	O		
L. gibbosus	pumpkinseed		X		O									O	60
L. gulosus	warmouth	X		O	O	O	?	O	O	O	O		O		
L. humilis	orangespotted sunfish	X		O	O	O			O				O		
L. macrochirus	bluegill	X		O	O	O	O	O	O	O	O	O	O		
L. marginatus	dollar sunfish	X		O	O				O						
L. megalotis	longear sunfish	X		O	O	O	O	O	O	O	O	O	O		
L. microlophus	redear sunfish	X	?	O	O	O	O	O	O	O	O		O		61
L. miniatus	redspotted sunfish	X		O	O	?			O						
L. punctatus	spotted sunfish	X			O			O	O				O		62
L. symmetricus	bantam sunfish	X		O					O						
Micropterus coosae	redeye bass	X	X		O	O		O		O		O	O		63
M. dolomieu	smallmouth bass	X			O	O	O			O	O	O	O	O	
M. punctulatus	spotted bass	X		O	O	O	O	O	O	O	O	O	O	O	
M. salmoides	largemouth bass	X		O	O	O	O	O	O	O	O	O	O		
Pomoxis annularis	white crappie	X		O	O	O	O	O	O	O	O	O	O		
P. nigromaculatus	black crappie	X		O	O	O	?	O	O	O	O		O		
Family Percidae (the perches)															
Ammocrypta asprella	crystal darter	X				E				E					64
A. beanii	naked sand darter	X		O					O						
A. clara	western sand darter	X			O								O		
A. pellucida	eastern sand darter	X				?				?					65
A. vivax	scaly sand darter	X		O	O				O	O					
Etheostoma acuticeps	sharphead darter	X			O								O	O	
E. aquali	coppercheek darter	X			O					O					
E. asprigene	mud darter	X		O	O	O			O						
E. baileyi	emerald darter	X				O				O		O			
E. barbouri	teardrop darter	X					O			O					
E. barrenense	splendid darter	X					O			O					
E. bellum	orangefin darter	X					O			O					
E. blennioides	greenside darter	X			O	O	O			O	O	O	O	O	
E. blennius	blenny darter	X			O					O					
E. boschungi	slackwater darter	X			O					O					
E. brevirostrum	holiday darter	X						O					O		
E. caeruleum	rainbow darter	X		O	O	O	O			O	O		O		
E. camurum	bluebreast darter	X			O	O				O			O		
E. chlorobranchium	greenfin darter	X			O									O	
E. chlorosoma	bluntnose darter	X		O	O	O			O						
E. cinereum	ashy darter	X			O	O				O			O		
E. coosae	Coosa darter	X						O					O		
E. corona	crown darter	X			O					O					
E. crossopterum	fringed darter	X		O	O	O			O		O				
E. ditrema	coldwater darter	X						O					O		
E. duryi	black darter	X			O					O			O		
E. etnieri	cherry darter	X				O				O					
E. flabellare	fantail darter	X			O	O	O			O	O		O	O	
E. flavum	saffron darter	X			O	O				O	O				
E. forbesi	Barrens darter	X				O				O					
E. fusiforme	swamp darter	X		O					O						
E. gracile	slough darter	X		O	O	?			O						
E. histrio	harlequin darter	X		O	O				O						
E. jordani	greenbreast darter	X						O					O		
E. kennicotti	stripetail darter	X			O	O				O		O	O		
E. luteovinctum	redband darter	X			O	O				O	O				
E. lynceum	brighteye darter	X		O					O						

Table 2—*Continued*

		Origin		Drainages					Principal Physiographic Provinces						
		N	I	M	T	C	B	C	CP	HR	NB	Cu	RV	BR	Notes
E. microlepidum	finescale darter	X				O				O	O				
E. microperca	least darter	?				?				?					66
E. neopterum	lollypop darter	X			O					O					
E. nigripinne	blackfin darter	X			O	O				O					
E. nigrum	johnny darter	X		O	O	O	O		O			O			
E. obeyense	barcheek darter	X				O				O					
E. olivaceum	dirty darter	X				O					O				
E. oophylax	guardian darter	X			O				O	O					
E. parvipinne	goldstripe darter	X		O	O				O						
E. proeliare	cypress darter	X		O	O				O						
E. pseudovulatum	egg-mimic darter	X			O					O					
E. pyrrhogaster	firebelly darter	X		O					O						
E. rufilineatum	redline darter	X			O	O				O	O		O	O	
E. rupestre	rock darter	X						O					O		
E. sagitta	arrow darter	X				O						O			
E. sanguifluum	bloodfin darter	X				O				O					
E. simoterum	snubnose darter	X			O	O				O	O		O		
E. smithi	slabrock darter	X			O	O				O	O				
E. spectabile	orangethroat darter	X		O	O	O	O			O					67
E. squamiceps	spottail darter	X				O	O			O					
E. stigmaeum	speckled darter	X		O	O	O	O	O	O	O			O		68
E. striatulum	striated darter	X			O						O				
E. swaini	gulf darter	X		O					O						
E. swannanoa	Swannanoa darter	X			O									O	
E. tippecanoe	Tippecanoe darter	X			O	O				O	O		O		
E. trisella	trispot darter	X						O					O		
E. tuscumbia	Tuscumbia darter	X			E					E					69
E. virgatum	striped darter	X				O				O	O				
E. vulneratum	wounded darter	X			O								O	O	
E. wapiti	boulder darter	X			O					O					
E. zonale	banded darter	X			O	O	O			O	O		O		
E. zonistium	bandfin darter	X		O	O				O						
E. (*Catonotus*) sp.	"duskytail darter"	X			O	O				O			O		
Perca flavescens	yellow perch		X		O				O				O		70
Percina antesella	amber darter	X						O					O		
P. aurantiaca	tangerine darter	X			O							O	O	O	
P. burtoni	blotchside logperch	X			O	O				O			O		
P. caprodes	logperch	X		O	O	O	O		O	O	O		O		71
P. copelandi	channel darter	X			O	O				O			O		
P. evides	gilt darter	X			O	O				O		O	O	O	
P. jenkinsi	Conasauga logperch	X						O					O		
P. macrocephala	longhead darter	X			O	E	O			O			O		72
P. maculata	blackside darter	X		O	O	O	O		O	O		O	O		
P. nigrofasciata	blackbanded darter	X						O					O		
P. palmaris	bronze darter	X						O					O		
P. phoxocephala	slenderhead darter	X			O	O				O	O				
P. sciera	dusky darter	X		O	O	O			O	O			O		
P. shumardi	river darter	X		O	O	?		O	O				O		
P. squamata	olive darter	X			O	O						O		O	
P. tanasi	snail darter	X			O								O		
P. vigil	saddleback darter	X		O	O				O	O					
P. (*Alvordius*) sp.	"bridled darter"	X						O					O		
P. (*Percina*) sp.	"Mobile logperch"	X						O					O		
P. (*Odontopholis*) sp.	"frecklebelly darter"	X					O			O					
Stizostedion canadense	sauger	X		O	O	O			O	O	O		O	O	
S. vitreum	walleye	X	X	O	O	O		O	O	O	O	O	O	O	73

Table 2—*Continued*

		Origin N	Origin I	Drainages M	T	C	B	C	Principal Physiographic Provinces CP	HR	NB	Cu	RV	BR	Notes
Family Sciaenidae (the drums)															
Aplodinotus grunniens	freshwater drum	X		O	O	O			O	O	O		O		
	Total Native	277-297		135-141	205-213	161-171	58-70	70-74	130-131	168-172	93-98	53-56	160-165	62-64	
	Total Introduced	26-29		8-12	18-20	11	2-5	4-5	10	10	4	6	12-14	12-13	
	Tennessee's total species (depending on taxonomic resolution of several polytypic forms)	302-319		145-149	225-240	172-186	62-72	76-78	140-141	178-182	97-102	59-62	174-182	74-80	

NOTES TO TABLE 2

1. Recorded from Tennessee River drainage in AL and KY.
2. Nearly extirpated from TN.
3. Probably only in Mississippi River proper.
4. Possibly extirpated from TN.
5. Anadromous; now virtually precluded from TN by dams.
6. Introduced into Watauga and Dale Hollow reservoirs, 1976; now dispersing.
7. Introductions probably responsible for at least part of occurrence in TN.
8. Repeatedly introduced bait and aquarium fish.
9. Widely introduced in Mississippi Valley region since 1963; reproductively sterile individuals occasionally stocked in ponds statewide.
10. Recently in lower Tennessee River via Tenn-Tom Waterway.
11. Extremely rare in Mississippi drainage (single occurrence in Obion system).
12. Introduced and established in U.S. since 1877.
13. Single occurrence, Powell River, 1973; probable bait introduction.
14. Virtually extirpated from Tennessee River drainage.
15. Mississippi River proper.
16. Thus far in Mississippi River only.
17. Thus far in Mississippi River only.
18. May represent two or three species.
19. Only in Mississippi River proper.
20. Only in Mississippi River proper.
21. Present in Tennessee River drainage in northern AL (native?) and GA (introduced?).
22. Recent dispersant from north.
23. May represent two species.
24. Possibly introduced in Duck River of Tennessee River drainage.
25. Recent dispersant thru Tenn-Tom Waterway.
26. In TN, known from single collection from Tennessee River drainage in Clinch system (now extirpated); persists in Paint Rock portion of Tennessee River drainage in AL and Little South Fork of Cumberland drainage in KY.
27. Repeatedly introduced bait fish.
28. Only in Mississippi River proper.
29. Possibly extirpated from Cumberland River drainage.
30. Probably introduced in Ocoee River portion of Tennessee River drainage.
31. A single large adult recorded from Conasauga River.
32. Presumed extinct throughout range; last recorded in 1893.
33. Recorded from Conasauga River in GA near TN border.
34. Introduced and established in French Broad River, NC, down to TN border.
35. Same as for *A. catus*.
36. May represent two to three species.
37. Single specimen from Mississippi River.
38. Apparently introduced and established in N. Fork Holston and Watauga rivers.
39. Introduced in Melton Hill and South Holston reservoirs; may occasionally stray southward in Mississippi River.
40. Northern lacustrine form regularly stocked in several TN reservoirs.
41. Introduced to Missouri River ca. 1971; winter migrant to TN in Mississippi River; unsuccessfully introduced in Watauga and S. Holston reservoirs in 1960s.
42. Unsuccessfully introduced to Calderwood Reservoir in 1960.
43. Unsuccessfully introduced to Center Hill and Dale Hollow reservoirs, 1955; Wilbur tailwater, 1956.
44. Unsuccessfully introduced in Watauga Reservoir, 1964.
45. Widely introduced and locally established in some cooler waters.
46. Unsuccessfully introduced in Little Tennessee River reservoirs and Watauga Reservoir in 1950-60s.
47. Stocked since 1971 in Watauga Reservoir.
48. Widely stocked and locally established in some cooler waters.
49. Native status in Conasauga system uncertain, introduced in Cumberland drainage.
50. Currently introduced in Dale Hollow Reservoir.
51. Probable occasional winter migrant.
52. Some populations probably represent introductions; introductions of *G. holbrooki* also remotely possible.
53. A recent invader of Kentucky Reservoir via the Tenn-Tom Waterway.
54. Occasional migrant from Gulf in Mississippi River and Kentucky Reservoir.
55. Repeated accidental introductions in cooler waters; locally established.
56. May represent three to four species.
57. May represent one or two species.
58. Regularly stocked in several reservoirs in Tennessee and Cumberland drainages.
59. Locally introduced in Mississippi River drainage; extensive populations in upper Tennessee River and Conasauga River drainages probably result from old introductions.
60. Introduced and established in S. Holston and Boone reservoirs.
61. Some local populations probably due to introductions.
62. Status of Conasauga River (TN-GA) and Lookout Cr., GA (Tenn. R. drainage) populations uncertain (Warren, 1992).
63. Native to Conasauga River; locally introduced in Tennessee and Cumberland drainages.
64. Probably extinct in TN.
65. Recorded from lower Cumberland River, KY, near TN border, 1890.
66. A questionable record from near Nashville, 1954, represented by one specimen.
67. May represent three to four species (P. Ceas, in litt.).
68. May represent up to five species.
69. A single 1940s record from a spring in Hardin County, now beneath Pickwick Reservoir; presumed extinct in TN.
70. Apparently introduced to Hiwassee system in 1950s; widely established in Tennessee River.
71. In Coastal Plain, only in Mississippi River proper.
72. Possibly extinct in Cumberland River drainage; may occur rarely in Barren system.
73. Most extant TN populations result of introduction of northern lacustrine form; in Coastal Plain, probably in Mississippi River only.

Introduced Fishes

Tennessee's abundant waters and recently constructed reservoirs have attracted resource managers and others to introduce numerous fish species into them and, beyond these, a number of accidental introductions have occurred. As a consequence, several extralimital North American species, and even some Eurasian species (Courtenay et al., 1986), have been transient residents of the state's waters, and some have become permanently established. Some are regarded as "beneficial" game fishes, some are nuisance species, and some may be distinctly detrimental to the native fauna (e.g., Courtenay and Robins, 1989). Better known among these are such fishes as the carp, alewife, rainbow and brown trouts, striped bass, yellow perch, the non-native forms of muskellunge and walleye, and possibly the threadfin shad. Additional species have been accidentally introduced along with these, or from anglers' bait buckets, or by dispersing from introduced populations in nearby states. Movement of Mobile Basin species into the Tennessee River drainage via the Tenn-Tom Waterway (see Possible Additions section below) may technically be considered introductions stemming from human activities, and *Cyprinella venusta* and *Notropis texanus* are known to have done so, as have probably others. From 29 to 32 species of fishes (Table 2) are known to have been introduced or redistributed in Tennessee's waters at various times, of which 25 are certainly or probably extralimital. Eighteen of these extralimital species are sufficiently established, maintained, or repeatedly introduced by accident to be accorded full treatment in the species accounts of this book, and others are treated more briefly at appropriate junctures. Additional intentional or accidental introductions may be expected in the future, though one would hope that resource managers will carefully consider the potential impacts of these on existing faunas before proceeding.

Possible Additions to Tennessee's Fish Fauna

In addition to indigenous and introduced species, several "peripheral" species may eventually be recorded from Tennessee's waters and should be watched for (Table 3). These are native or introduced species known from near the state's borders in adjacent states in drainages which enter Tennessee, transient species in the Mississippi River, or Mobile Basin species which might be expected to negotiate the recently completed Tenn-Tom Waterway (Fig. 3) between that basin and the Tennessee River. Four species that were in this "possibility" category until relatively recently—the weed shiner, *Notropis texanus*; the bigmouth shiner, *N. dorsalis*; the rainbow smelt, *Osmerus mordax*; and the burbot, *Lota lota*—have since appeared in the state's waters, probably resulting from movement through the Tenn-Tom Waterway (weed shiner), winter migrations down the Mississippi River (smelt and burbot), and downstream colonization of the Mississippi River during drought years (bigmouth shiner). Northern species, as well as principally plains-dwelling species from the Missouri River and proximate Mississippi River, should be expected to continue to appear sporadically in western Tennessee, though their coincidence with collecting efforts will obviously be rare.

The Tennessee-Tombigbee Waterway, completed in 1985, has now created a direct conduit for fishes sufficiently tolerant of large, slack water habitats to disperse through it. A number of Mobile Basin species will probably meet these requirements and eventually disperse into the lower Tennessee River and vice versa. One rather surprising transient, the relatively small stream-dwelling weed shiner, *Notropis texanus*, has already been recorded from a Tennessee River tributary in Hardin County and the Atlantic needlefish, *Strongylura marina,* has been recorded from the Tennessee River just south of Tennessee (H. T. Boschung, in litt.).

Perhaps most surprising to readers will be the potential rare occurrence of sharks in the Mississippi River along western Tennessee. Several bull sharks, *Carcharhinus leucas*, have been recorded from the lower Mississippi River area in Louisiana and an "84 pound, about five foot long" specimen was taken from that river in Illinois in 1937 (Thomerson et al., 1977), well north of Tennessee! This species is relatively tolerant of fresh waters and regularly ascends rivers over much of the world, sometimes for considerable distances.

Table 3. Possible and Probable Additions to the Fish Fauna of Tennessee. Distributional comments are based on accounts in Lee et al. (1980) unless otherwise noted.

Charcharinidae (requiem sharks)

Charcharhinus leucas bull shark
Recorded from Mississippi River both north and south of TN (Thomerson et al., 1977).

Acipenseridae (sturgeons)

Acipenser oxyrinchus Atlantic sturgeon
Gulf Coast anadromous species with remote possibility of negotiating Tenn-Tom Waterway.

Cyprinidae (minnows)

Campostoma pauciradii bluefin stoneroller
Occurs in upper Hiwassee River system, GA, near TN.

Hybognathus argyritis western silvery minnow
Missouri River species already recorded in Mississippi River south to KY.

Nocomis leptocephalus bluehead chub
Occurs in Tennessee River drainage in Bear Creek system, AL and MS; remote possibility of dispersal into TN; also occurs in Coosa River system in northern GA but not recorded from Conasauga arm of that system.

Notropis baileyi rough shiner
Occurs in Tennessee River drainage in Bear Creek system AL, MS, in proximity to TN.

Lythrurus bellus pretty shiner
Same as for *N. baileyi* in addition to Yellow Creek, MS.

Notropis candidus silverside shiner
Inhabitant of large rivers in Mobile Basin (Suttkus, 1980) which may flourish in Tenn-Tom Waterway.

Notropis chalybaeus ironcolor shiner
Occurs in acidic, vegetated lowland streams in MO and AR adjacent to western TN, which is relatively well collected; suitable habitats may not exist in TN.

Notropis edwardraneyi fluvial shiner
Large river species of Mobile Basin which will surely negotiate Tenn-Tom Waterway.

Notropis hubbsi bluehead shiner
Mississippi Valley swamp species known from AR and IL; remote possibility of western TN occurrence.

Notropis hudsonius spottail shiner
Ubiquitous northern and East Coast species known in Mississippi River south to KY.

Scardinius erythrophthalmus rudd
Eurasian species widely established in other regions; cultured for bait in AR and escaped during flooding (Burkhead and Williams, 1989); potential for establishment and dispersal in Southeastern U.S. presently uncertain.

Ictaluridae (North American freshwater catfishes)

Ameiurus brunneus snail bullhead
Occurs (introduced?) in Etowah River portion of upper Coosa system, GA (Bryant et al., 1979); may be expected to disperse into Conasauga system.

Amblyopsidae (cavefishes)

Speoplatyrhinus poulsoni Alabama cavefish
Thusfar known only from Key Cave north of Tennessee River in Lauderdale County, AL; Cooper and Kuehne (1974) believed possibly restricted to that locality, but labyrinth of caves in Highland Rim may offer other possibilities.

Percopsidae (trout-perches)

Percopsis omiscomaycus trout-perch
Northern species occurring southward to KY and occasionally in Mississippi River to southern IL; Bauer and Branson's (1979) record from the Barren River system, KY, adjacent to TN is apparently in error based on other species present in that collection.

Belonidae (needlefishes)

Strongylura marina Atlantic needlefish
Marine form commonly entering freshwater and penetrating far up Mississippi and especially Tombigbee rivers; has traversed Tenn-Tom Waterway to Tennessee River in AL (H. Boschung, pers. comm.). Collected in Kentucky Reservoir, TN, in 1992.

Poeciliidae (livebearers)

Gambusia holbrooki eastern mosquitofish
East Coast species widely introduced for mosquito control (see *G. affinis* species account).

Elassomatidae (pygmy sunfishes)

Elassoma sp. "spring pygmy sunfish"
Occurs in springs in Tennessee River drainage of northern AL in association with Tuscumbia darter *(Etheostoma tuscumbia)* which occurred in Hardin County, TN prior to Pickwick impoundment; former occurrence uncertain, present occurrence doubtful.

Percidae (the perches)

Etheostoma maculatum spotted darter
Ohio River drainage species that occurs in Barren River system of Kentucky just downstream from Tennessee border.

Percina lenticula freckled darter
Gulf coastal species occurring throughout Mobile basin and recorded from Conasauga River, GA, within few km of TN (Bryant et al., 1979a).

Percina (Percina) sp. "gulf logperch"
Undescribed large river form (Thompson, 1985) which may negotiate Tenn-Tom Waterway as may the "Mobile logperch" which already occurs in TN in Conasauga River.

Fossil Fishes in Tennessee

In past geologic eras, aquatic habitats and the kinds of fishes inhabiting them were very different from those found today. Much of North America, including Tennessee, was covered by seas at various times throughout geologic history. These environments, and ancient freshwater habitats, had very different faunas from those found in Tennessee today. The link we have with these past faunas is the fossil record. Unfortunately, the fossil record for fishes revealed thus far in Tennessee (much of which is treated in Corgan, 1976) is not a particularly extensive one. However, not a great deal of effort has been expended to discover additional fish fossils in the state, a situation which will hopefully change in the future.

Fishlike animals were the first vertebrates to appear in the fossil record, over 500 million years ago (mya) in the late Cambrian period. These were jawless fishes which were very different and probably not closely related to jawless fishes of today, the lampreys and hagfishes. Lamprey-like fossils are known from as far back in time as the upper Devonian period 350 or more mya, and definite lamprey fossils date from the Mississippian period 325 mya (Nelson, 1984). However, none of these fishes is known as yet in the Tennessee fossil record, though they doubtless resided here.

In the late Silurian period (400 mya), primitive chondrichthyans (cartilagenous fishes) first appear in the fossil record and shark- and chimaera-like representatives of this group appear in the mid to upper Devonian (365–345 mya). One of the most primitive of all elasmobranchs (shark-like fishes), a cladoselachian (Fig. 5), was discovered in a Devonian shale deposit at Dale Hollow Reservoir in Clay County, Tennessee (Maher and Dunkle, 1955). Fossil shark teeth and chimaeriform remains are known from the Mississippian (325–345 mya) from several localities (e.g., Dekalb, Franklin, Hancock counties) in middle and east Tennessee (Safford, 1869; Greene, 1959; Kellberg and Maher, 1959). In west Tennessee, where epicontinental seas persisted until much later geologic times, a few shark and skate remains are known from Cretaceous deposits in McNairy County (Safford, 1869) and the well-known Coon Creek formation in Decatur County (Corgan, 1976), which is very rich in invertebrate fossils but so far has yielded only a few vertebrate remains. In more recent deposits of the Paleocene epoch (54–65 mya), shark remains, including possible sand sharks (*Odontaspis*), were recorded from Hardeman County (Safford, 1869), and Eocene (38–54 mya) shark teeth have also been found in the Jackson Formation along the Mississippi River in Lauderdale County (Corgan, 1976).

From the early Devonian period until the lower Mississippian (400–340 mya), great armored fishes called "placoderms" roamed the seas. One group, the arthrodires, was worldwide in distribution. One of the largest arthrodire specimens ever found, of the ostensibly predatory genus *Dunkleosteus* (Fig. 6), is from Devonian deposits in Jackson County, Tennessee (Conant and Swanson, 1961); this specimen, now in the U.S. National Museum of Natural History, was estimated to have exceeded 20 feet. A second specimen (also in the U.S.N.M.) was recorded from Mississippian deposits in Moore County. Arthrodires lacked true teeth but instead had razor-sharp projections from the bony head shield with which to seize prey. They may have eventually been outcompeted by the more mobile sharks which remain among our largest marine predators today.

Bony fishes of the now extinct class Acanthodii may have arisen as early as Ordovician times (500 mya), but forerunners of modern bony fishes (class Osteichthyes)

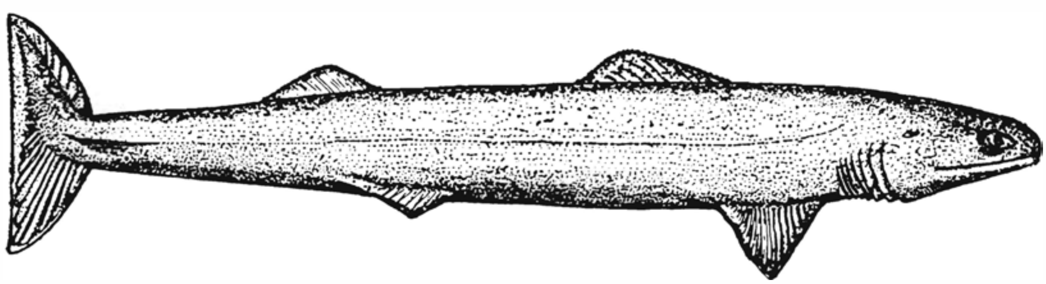


Figure 5. A primitive shark-like fish, a cladoselachian (*Cladoselache*), typical of Devonian deposits (modified from Dean, 1895).

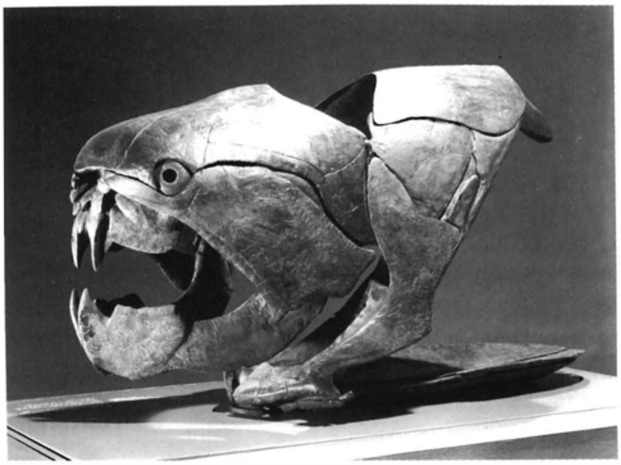


Figure 6. Reconstructed head region of a huge arthrodire (genus *Dunkleosteus*), estimated total length 20 feet or more, of the kind taken from Devonian deposits in Tennessee (U.S. National Museum of Natural History, photo, Chip Clark).

do not appear in the fossil record until the early Devonian, about 375 or more mya (Nelson, 1984). Possible remains of an acanthodian, fishes which generally had great spiny structures associated with the fins and projecting from the body (Fig. 7), were recorded from the Mississippian of Dekalb County (Kellberg and Maher, 1959). Very few fossil remains of ancient osteichthyan fishes are known thus far from Tennessee. Kellberg and Maher reported scale remains of palaeoniscoid fishes from the Dekalb County Mississippian deposits. These primitive chondrostean fishes (Fig. 8), covered with thick ganoid scales, occurred in the fossil record from the early Devonian to the early Cretaceous (380–120 mya). Chondrostean fishes, once abundant, are represented today only by sturgeons and paddlefishes (Nelson, 1984).

During the Pennsylvanian Period (325–280 mya), the sea receded from much of the eastern two-thirds of Tennessee, and this region was transformed from a chiefly marine depositional environment to a coastal one with freshwater swamps and streams. Strata of this age, now mostly restricted to the Cumberland Plateau, are primarily sandstones, shales, and coal as opposed to the principally limestone marine deposits of previous eras. No fish fossils have been reported so far among the many others (primarily plants) that are plentiful in some coal and shale formations of freshwater origin in the Plateau region. In similar-age strata of Ohio and Illinois, numerous fossils of another chondrostean group, the Haplolepidiformes, have been found (Westoll, 1944). These fishes (Fig. 9), which were similar to the aforementioned palaeoniscoids, were believed to have inhabited freshwater swamps. Their fossils should definitely be looked for in the Plateau region.

During the late Mesozoic Era, in the Cretaceous Period, the Tennessee fish fauna was composed in part of primitive members of many of our modern bony fish groups. Fossils of these ancestors are thus of extreme interest in studies of the evolutionary history of those groups. In western Tennessee, where marine environments persisted well into the Tertiary, a few osteichthyan fossils have been reported. Corgan (1976) reported fossils of "three genera" of bony fishes, with no further identification, from the Coon Creek formation in Decatur County. Wade (1926) and Corgan (1976) reported several osteichthyan fossils from the Cretaceous Ripley Formation in McNairy County. These included a possible pyncnodont, a member of a primitive, mostly Mezozoic group, the halecostomes, which may be represented today only by the bowfin (Amiidae) (Nelson, 1984); also included was an ancient osteoglossiform (see Family Hiodontidae) fossil. Safford (1869) reported a potentially very interesting fossil from the Cretaceous of McNairy County, now reportedly housed in the Vanderbilt University Department of Geology collection (Corgan, 1976). This fossil was initially identified as that of a barracuda and, if correctly identified even to order (Perciformes), would be of great interest, as perciform fishes are poorly known

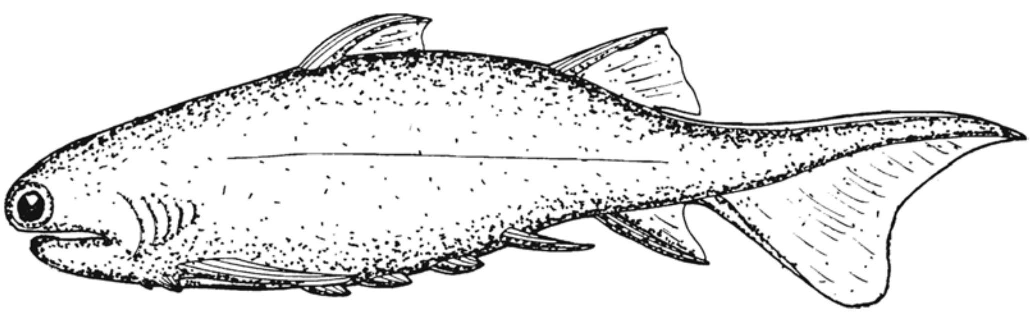


Figure 7. Reconstruction of an acanthodian (genus *Ptomacanthus*), an early bony fish of the mid Paleozoic era (modified from Miles, 1973).

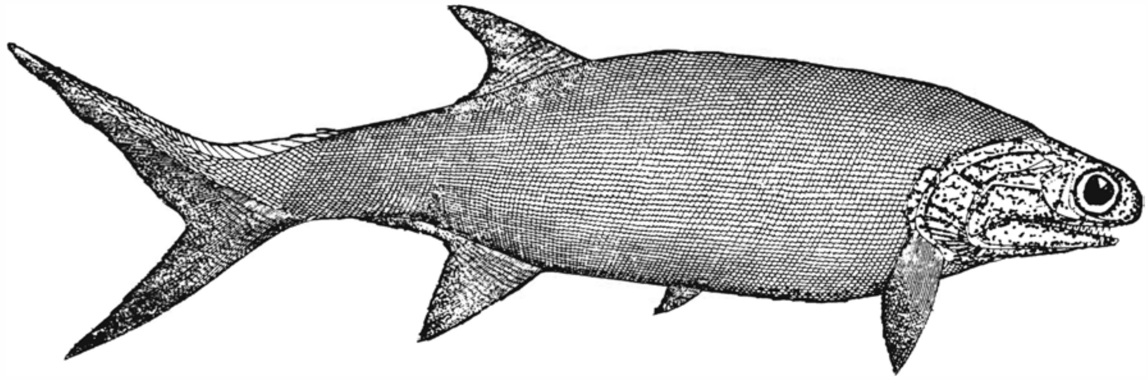


Figure 8. Reconstruction of a palaeoniscoid (genus *Pygopterus*), an early chondrostean fish (modified from Aldinger, 1937).

in the fossil record previous to the Tertiary. Lundberg (1975a) identified a partial fossil from Cretaceous or early Paleocene (65–60 mya) deposits in Carroll County as possibly that of either a primitive herring or minnow. If the latter, it would represent the earliest occurrence of cyprinids in the fossil record by far.

Extensive fish fossil finds from the adjoining state of Alabama (Thurmond and Jones, 1981) would suggest that more fossils should be found in Tennessee, particularly in the Cretaceous and early Tertiary deposits of the western portions of the state. Remains of ancient sturgeons, bowfin relatives, elopiform (tarpon-like) fishes, bonefishes, barracudas, puffers and porcupine fishes, and several other groups have been found in similar-age strata of Alabama. Though the fossil-rich chalk deposits of that state do not extend northward into Tennessee, and the fossilization characteristics of different environments varied widely, fossils of some of these groups and several others should nevertheless eventually emerge from Tennessee's geologic formations.

Geological formations representing most of the Tertiary epochs (Eocene to Pliocene) are rare or absent in Tennessee, and fossils are accordingly lacking. In fact, pre-Pleistocene fossil representatives of present-day freshwater groups are essentially nonexistent in eastern United States (Cavender, 1986). We are thus without much potential insight into the history of the region's fish fauna over that great period of time. It is not until the Pleistocene Epoch (10,000–2,000,000 years ago) that fishes reappear in the region's fossil record. These are mostly from late Pleistocene deposits in caves along major watercourses. The species of the late Pleistocene were little, if at all, different from those of today. However, the distributions of many of these fishes apparently varied during and since that epoch in response to climatic changes and perhaps alterations in drainage patterns. This is evidenced by subfossil remains of species that no longer occur in Tennessee or are now restricted to drainages in the state remote from the fossil localities. For example, from cave deposits along the Duck River (Dickinson, 1986), bones of several species not known to occur in that drainage today were present in Pleistocene and early Holocene deposits. The now more northerly distributed yellow perch (*Perca flavescens*, recently reintroduced to Tennessee) and hornyhead chub (*Nocomis biguttatus*) were represented in these deposits, indicating that Tennessee's rivers may have served as a refugium for these fishes during glaciation. Bones, possibly of a checkered madtom (*Noturus flavater*), a species now restricted to the Ozarks, were also found, as

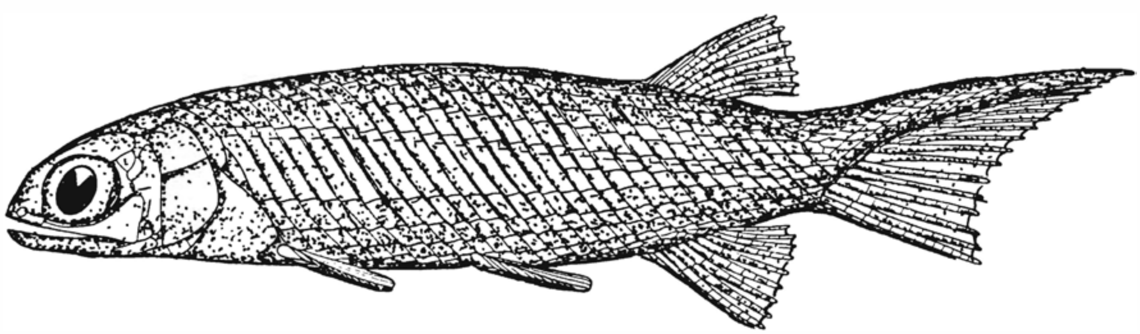


Figure 9. Reconstruction of a haplolepidiform fish (genus *Haplolepis*), small (45-75 mm total length), early chondrostean fishes whose fossils are associated with Pennsylvanian deposits believed to be of freshwater origin (modified from Westoll, 1944).

were those of several other species now extinct or restricted to other portions of the state, such as the harelip sucker, lake sturgeon, muskellunge, and others. Thus Pleistocene fish remains potentially offer a tremendous amount of insight into the distributional history of the region's fishes and should be studied thoroughly.

It is hoped that this brief treatment of Tennessee's fossil fish record will instill an interest in readers to be on the alert for further fossils to add to the state's rather sparse data base or to report those they already may know of. Amateurs can explore many areas which the few professional paleontologists will never have opportunities to prospect. Once a fossil locality is found, however, further excavations should be supervised by trained personnel to minimize damage to specimens and obtain accurate stratigraphic data. When reported to the proper authorities, the finds of amateurs have already made substantial contributions to the fossil records of many areas.

Ichthyology in the Region of Tennessee

The study of North American fishes had its beginnings in the eighteenth century. These early contributions were accomplished by European naturalists to whom occasional specimens of New World fishes were returned by interested explorers and settlers. Among the more significant of these early works was the tenth edition of *Systema Naturae* published by the Swedish naturalist Carolus Linnaeus at Paris in 1758, a work describing a broad spectrum of organisms and giving us our system of binomial scientific nomenclature. Linnaeus's fish descriptions were based primarily on the conceptions of Peter Artedi, as were the later works of J. J. Walbaum. Among the many species described in these works were several from North America. French naturalists made important early contributions to North American ichthyology into the nineteenth century, as exemplified by the turn-of-the-century works of B. G. E. Lacepede and later works of LeBaron Cuvier and M. A. Valenciennes, whose 22-volume *Histoire Naturelle de Poissons*, published from 1828 to 1849, is one of the most important contributions to worldwide ichthyology. Charles Lesueur and Constantine Rafinesque began studying fishes in France in the early 1800s, and both later (around 1820) moved to North America to work in the Ohio River region—Lesueur at the intellectual colony town of New Harmony, Indiana, and the eccentric Rafinesque at Transylvania University in Lexington, Kentucky. Rafinesque's 1820 work *Ichthyologia Ohiensis* described many fishes of the region for the first time. In the mid 1800s, Albert Guenther of the British Museum described several North American fishes which had been deposited at that institution.

Early American naturalists contributing substantially to freshwater ichthyology were: Samuel L. Mitchill, who worked in the New York region during the early 1800s; Jared P. Kirtland, who studied the fauna of the Ohio region in the 1830s and 1840s; Louis Agassiz of the Museum of Comparative Zoology at Harvard; Edward D. Cope of the Academy of Natural Sciences in Philadelphia; and the early stewards of the U. S. Fish Commission, Spencer F. Baird and Charles Girard. While none of the works of these early American or European ichthyologists—excepting Agassiz, Cope, and Rafinesque—dealt specifically with fishes from near Tennessee, many wide-ranging North American species which occur in the state were treated by these authors, and the reader may note their names in association with many of the fish species discussed in this book. For a broader history of ichthyology in North America, see Hubbs (1964) and Myers (1964).

Works dealing specifically with fishes of the Tennessee region did not appear until the mid 1800s. D. H. Storer (1845), of the Boston Society of Natural History, published a paper on fishes of Tennessee River tributaries near Florence, Alabama, collected by Charles A. Hentz. One species described therein, the rare ashy darter, *Etheostoma cinereum*, has not since been reported from the state of Alabama. Louis Agassiz of Harvard published (1854) a report on a collection of fishes from the Huntsville, Alabama, area. Edward D. Cope collected Tennessee River tributaries and other systems in western Virginia in 1867 and published several works based thereon (1868a,b, and 1870).

In the late 1800s, David Starr Jordan and his associates, including A. W. Brayton, Charles H. Gilbert, Barton W. Evermann, and Joseph Swain, made the largest single contribution of knowledge ever to North American ichthyology; many of their findings are summarized in the four-volume *Fishes of North and Middle America* (Jordan and Evermann, 1896–1900). Jordan and his students and associates made long forays southward from Butler and Indiana universities, traveling on foot, by horse, and by train during the years 1876 to 1888 to collect and study the fauna. Many of the ventures are colorfully accounted in Jordan's (1922) autobiography, *Days of a Man*. Several important works on regional ichthyology resulted from these treks (Jordan 1877a, 1877b, 1888, 1889; Jordan and Brayton, 1877, 1878; Jordan and Swain, 1883; Gilbert, 1887, 1891). Independent of Jordan's associates, James A. Henshall (1889) of the Cincinnati Society of Natural History reported on fishes collected near Chattanooga by Charles Dury.

In the 1890s, Jordan had moved westward to Stanford University, and with him much of the emphasis on ichthyology had shifted away from the East. However, from 1889 to 1893, Phillip H. Kirsch of Columbia, Kentucky, made several surveys of tributaries to the Cumberland River in Kentucky and Tennessee (Kirsch 1892, 1893), and Albert J. Woolman (1892) reported on fishes collected at various localities in the Tennessee and Cumberland river systems. Both Kirsch and Woolman were associates of Jordan.

Minimal work was conducted on fishes of the Tennessee region over the fifty-year period from the early 1890s to the 1940s. However, Evermann and Hildebrand (1916) reported on fishes collected in eastern Tennessee much earlier in 1893, and Evermann (1918) published a very important summary compendium of all known previous surveys of the region, from which much of the historical information herein is drawn. During this so-called "doldrums" period of North American freshwater ichthyology, when Jordan's attentions were focused elsewhere, and after his death in 1931, the science was left largely in the hands of a few ichthyologists with cosmopolitan interests. Little fieldwork was conducted in the streams of the United States, and, in the face of the great exploitation and alteration of aquatic ecosystems that occurred over those years, many changes in the country's ichthyofauna occurred undetected. Many species were depleted to various degrees, and several extinctions are known to have occurred. In the eastern United States for instance, the harelip sucker, *Lagochila lacera*, was collected at several localities (some in Tennessee) in the 1890s but did not reemerge from the doldrums period as an extant species, having disappeared throughout its wide range. Perhaps some species, not discovered previous to this era, will never be known to science.

Two ichthyologists were somewhat active in the study of southeastern fishes during the 1920s and 1930s. Carl L. Hubbs of the University of Michigan, a former associate of Jordan and student of C. H. Gilbert, conducted some fieldwork in the region and wrote a number of taxonomic works on southeastern fishes. Henry W. Fowler of the Academy of Natural Sciences, Philadelphia, published survey reports (1923, 1936, 1945) pertinent wholly or in part to fishes occurring in Tennessee. J. G. Carlson of the University of Tennessee, an associate of Fowler's, made a few collections in eastern Tennessee in the early 1930s. C. L. Baker (1937, 1938, 1939), then director of the Reelfoot Lake Biological Station, made several surveys of that lake's unique habitat during the 1930s. The first book on the fishes of Tennessee, published by a student of Hubbs's, was E. R. Kuhne's (1939) *A Guide to the Fishes of Tennessee and the Mid-South*. Its coverage, treating only 168 species compared to the 300 or so treated herein, reflected the state of knowledge of the fish fauna at that time. Of course, a tremendous number of changes in taxonomic conceptions, nomenclature, and distributional knowledge have occurred since.

The 1940s saw a moderate amount of ichthyological investigations in the Tennessee region. Shoup and Peyton (1940) and Shoup, Peyton, and Gentry (1941), of the former Tennessee Division of Fish and Game (now Tennessee Wildlife Resources Agency), reported on important collections made from rivers tributary to the Cumberland, such as the Roaring, Obey, and Wolf, which have since been affected by coal surface-mining and other factors. A large survey effort was mounted during those years by the Tennessee Valley Authority to assess the faunal composition in streams to be affected by the many impoundments of the Tennessee River system under construction during that time. Unfortunately, most of these efforts were concentrated in small tributary streams, and little was learned about the fauna of the larger rivers. However, these collections, which were deposited at the University of Michigan Museum of Zoology and many of which remained unsorted until 1977–78, did yield a few important insights into former fish distributions (Etnier et al., 1979). It also seems that earlier ichthyolgists of the 1800s had an aversion to collecting larger rivers. Therefore, our knowledge of the faunal composition of the main Tennessee and Cumberland rivers prior to their impoundment is practically nonexistent beyond educated speculation.

Through the remainder of the 1940s and into the early 1960s, sporadic collecting was conducted in Tennessee by workers from various institutions, such as the University of Michigan, Cornell University, and the U.S. National Museum. These ichthyologists, such as C. L. Hubbs, R. M. Bailey, E. C. Raney, E. A. Lachner, W. R. Taylor, B. B. Collette, R. H. Gibbs and C. R. Robins, published a number of taxonomic works treating species occurring in the Tennessee region. Aside from these efforts, D. W. Pfitzer (1954) of the former Tennessee Fish and Game Division reported investigations of the fish faunal composition of various tailwaters below reservoirs in the Tennessee River system and reported a few species which are now rare or absent in these areas. In addition to these ichthyological pursuits, other studies devoted primarily to ascertaining the biologies and population characteristics of game and commercial species were conducted over these years. Early studies of reservoir fisheries following impoundment were accomplished by Tennessee Valley Authority biologists, such as R. W. Eschmeyer and R. H. Stroud. Repetitive studies were also conducted, by R. J. Schoffman and others, at the former Reelfoot Biological Station facility on the biologies of the lake's fishes from the late 1930s until the early 1960s.

In 1965, after the arrival of David A. Etnier at the University of Tennessee at Knoxville, a relatively sustained effort was mounted to collect the waters of Tennessee and adjacent areas and to build a research collection of fishes based on those collections and on a few earlier collections of J. G. Carlson and J. T. Tanner. Over the ensuing 20 years, much of the state was surveyed with several entire river systems being systematically and thoroughly sampled while other areas were visited opportunistically. The University of Tennessee Research Collection of Fishes has grown to include over 200,000 specimens, a large percentage of which provide geographic and taxonomic coverage of Tennessee and adjacent areas. A historical and compositional synopsis of the collection was presented by Etnier and Krotzer (1990).

Surveys of Tennessee's waters were accomplished by the authors and several undergraduate and graduate students of the University of Tennessee as well as workers from other institutions such as the Illinois Natural History Survey, Southern Illinois University, Memphis State University, Tennessee Technological University, the University of Alabama, the University of Tennessee at Martin, and Virginia Polytechnical Institute. Among the first systems surveyed were the Conasauga (Stiles and Etnier, 1971), Wolf of western Tennessee (Medford and Simco, 1971), caves and springs of the southern Highland Rim area (Armstrong and Williams, 1971), Big South Fork of the Cumberland (Comiskey and Etnier, 1972), and Elk (Jandebeur, 1972). These were followed by surveys of the Hatchie (Starnes, 1973), Obion (Dickinson, 1973), Hiwassee (Hitch and Etnier, 1974), lower Tennessee River western tributaries (Clark, 1974), Clinch (Masnik, 1974), and Forked Deer (Boronow, 1975), and to some extent, Little Pigeon (L. B. Starnes, 1977) systems. More recently, the Duck River system was surveyed by D. L. Nieland (unpublished) as were Tennessee River tributaries of the Chattanooga area (Haines, 1982). Recent surveys have also been conducted in Cumberland Plateau coal-region streams tributary to the Big South Fork and Sequatchie river systems (O'Bara and Estes, 1984a,b).

In addition to efforts put forth from the University of Tennessee and other academic institutions, the Tennessee Valley Authority (TVA) initiated a program of river-system fish surveys during the late 1960s and early 1970s which provided much additional information on fish distribution in the Tennessee River drainage. Surveys were conducted of the Emory, Powell, Flint, upper Little Tennessee, Sequatchie, Buffalo, Bear Creek (Ala.), and Duck systems (TVA, 1968–1975) and the French Broad system (Harned, 1979). In addition, in the later 1970s, TVA inventoried and prepared survey reports on several of the reservoir fisheries in its system. TVA biologists, such as J. Feeman, R. B. Fitz, and C. F. Saylor, have provided valuable information on fish distribution in Tennessee, and others have provided information on the difficult taxonomy of larval fishes in the region (Hogue et al., 1976). Biologists of other state and federal agencies have also contributed to the knowledge of fish occurrence and distribution in Tennessee (e.g., Lennon, 1962; Myhr, 1977).

In addition to the surveys reported above, we have made an effort to sample streams in areas interlying their coverage. We have repeatedly sampled habitats on some of the more diverse rivers, such as the Conasauga, Clinch, and Duck, in an effort to fully realize the richness of these systems. We have also conducted considerable fieldwork in the Mississippi River along Tennessee's western border where essentially no prior sampling for smaller fish species had occurred; these efforts were rewarded with several surprising discoveries. Fisheries programs begun at Tennessee Technological University and the University of Tennessee at Knoxville over the past two decades have fostered studies that provided much information on game fish biology cited within this book.

Surveys of portions of river systems in adjacent states have also been informative with regard to Tennessee's particular faunal characteristics and relationships to other areas, including those of the Tennessee River drainage in Virginia, North Carolina, Georgia, Alabama, and Kentucky (Satterfield, 1961; Richardson et al., 1963; Ross and Carico, 1963; Richardson, 1964; Crowell, 1965; Wall, 1968; Sisk, 1969), several Mobile Basin tributaries (Boschung, 1961; Caldwell, 1969; Barclay and Howell, 1973; Dycus and Howell, 1974; Mettee et al., 1987; Boschung, 1989; Pierson et al., 1989), the Mississippi River in Kentucky (Smith and Sisk, 1969; Webb and Sisk, 1975; Burr and Mayden, 1979), and the upper Cumberland drainage in Kentucky (Carter and Jones, 1969; Harker et al., 1980; Branson and Schuster, 1982).

Several comprehensive works have been published in recent decades, or are in preparation, on faunas of states neighboring Tennessee which provide further information on fishes of the region, including species or their relatives which also occur in Tennessee. Among these are works on fishes of Missouri (Pflieger, 1975), Arkansas (Buchanan, 1973; Robison and Buchanan, 1988), Mississippi (Cook, 1959), Alabama (Smith-Vaniz, 1968), Kentucky (Clay, 1962, 1975; Burr and Warren, 1986), and North Carolina (Menhinick, 1991). New books are currently in press or in preparation on fishes of Alabama (H. T. Boschung and R. L. Mayden), Georgia (D. C. Scott and B. J. Freeman), Virginia (R. E. Jenkins, N. M. Burkhead), and Kentucky (B. M. Burr, L. M. Page, M. L. Warren). An additional excellent reference is a recently published field guide to

North American freshwater fishes (Page and Burr, 1991). Two recent books on darters (Page, 1983a; Kuehne and Barbour, 1983) have provided much distributional, biological, and taxonomic information on the many percid species which inhabit Tennessee and adjacent states.

Information gathered here from the many sources cited above, spanning a century and a half of investigations, has provided a relatively good data base with which to analyze fish distribution in the region of Tennessee and study their systematics. However, after all of these years of effort, we continue to be occasionally surprised by new discoveries. Some of our rarer species are extremely "fickle" in their occurrence, even at known localities; these occurrences and suitable collecting efforts may seldom coincide, delaying their discovery for years. There will be continued modifications to our knowledge of the regional fish fauna, hopefully facilitated by an increased awareness in those who read works such as ours as to what might be significant new information. On a sadder note, because of the failure of our early predecessors to adequately sample large river habitats, followed by the degradation and alteration of these ecosystems by human activities, we will never know completely the surely magnificent fish fauna that once inhabited them.

Although there will always be additions to our knowledge concerning the distribution and species-level taxonomy of freshwater fishes in Tennessee and elsewhere in North America, the vast majority of work that remains to be done in the future lies in other pursuits. The phylogenetic relationships within and between many groups of our fishes are still poorly understood. Once hypotheses have been formulated and tested, we can better reconstruct the probable evolutionary history of our fauna and, by correlation with geological information, we can also formulate theories pertaining to the biogeography (see the section, Ichthyology: The Science) of these fishes. With regard to ecological factors, we have only rudimentary knowledge of how many of our fishes relate to the ecosystems in which they occur. It will take many more years of comprehensive empirical studies of aquatic ecosystems as well as experimental hypothesis testing to understand more fully these interrelationships. Such an understanding will be vital to future efforts to conserve and preserve our aquatic resources, including the abundant and diverse fishes of Tennessee.

About Fishes

Fishes are by far the largest group of vertebrate animals. Their numbers may approach 28,000 extant species (Nelson, 1984), well over half of all vertebrates, and thousands of other fish species lived in past geologic times. Over half the world's species of fishes live in marine environments; these are most diverse in the seas of the tropical Indo-Pacific region and in the Caribbean. Freshwater fishes are most diverse in South America, which may harbor 5,000 species, and in southeastern Asia. North America, including Mexico, has a moderately diverse native freshwater fauna of about 1,000 species.

However, it should be pointed out that "fishes" is a collective term for actually three very different groups of currently living vertebrates and thus is not a "natural" group, as, for instance, the mammals (class Mammalia) are presumed to be. Included in fishes are the class (or superclass) Agnatha, the primitive jawless vertebrates represented today by the lampreys and, under older classifications, hagfishes; the class Chondrichthyes, which includes the sharks, chimaeras, skates, and rays, characterized by a cartilagenous rather than bony skeleton; and the class Osteichthyes, the bony fishes. Osteichthyes alone contains over 25,000 species, making it the largest vertebrate class. All tetrapod vertebrate groups are believed to have evolved from the bony fishes, though the exact fish lineage (lungfishes, lobefins, or other) from which they evolved has been in dispute. To put this into perspective, "higher" vertebrates, including humans, are more closely related to bony fishes than these fishes are to some other "fish" groups, such as sharks.

All fish groups are characterized by gills, which evolutionarily gave rise to various structures, including the jaws of chondrichthyans and bony fishes and the ear bones of tetrapods. Chondrichthyans and bony fishes share paired fins, which gave rise to the limbs of tetrapods. These adaptations and many others allow fishes to respire, move, feed, excrete, reproduce, and otherwise function in their watery environment.

Habitats and Lifestyles

Over half of the species of fishes, including many whole families, are restricted to the marine environment. Some families are virtually restricted to fresh water (e.g., percids) while others with many freshwater representatives may show some tolerance for brackish environments or have a few members occurring primarily in marine habitats (e.g, cyprinodontiform families). Still other, primarily marine, groups have a few members which have invaded freshwater environments (e.g., gobies, atheriniform fishes). These latter are best represented in regions where strictly freshwater groups are absent or less common, such as Australia, lower Central America, and oceanic islands. Groups that are able to move freely between waters of varied salinity are termed *euryhaline*. Examples are the cyprinodontiform fishes (topminnows, mollies, and related groups). Many fishes are migratory, especially in response to reproduction, and some are *diadromous*, spending portions of their lives in both marine and freshwater environments. Fishes that live most of their lives in the ocean but spawn in rivers (e.g., salmon, herrings) are termed *anadromous*; those that do the opposite (e.g., freshwater eels) are *catadromous* fishes.

Most fishes spend much of their life in one or two basic habitat types, such as rivers or smaller streams (lotic habitats), springs, lakes, and swamps (lentic), estuararies, coral reef, oceanic, and so on. A few are so generalized in habitat that they may be encountered in several habitats within freshwater or marine realms.

For purposes of general reference, roughly based on dimensions, stream habitats include very large rivers a half kilometer or more in width, such as the Mississippi or lower Tennessee, large rivers averaging 200–400 m in width (e.g., lower Cumberland, upper Tennessee), medium rivers 50–200 m width, (e.g., lower Duck or Clinch), small rivers under 50 m width (e.g., Little, Buffalo), large and small creeks, and spring runs. Creeks and small rivers may be montane (high gradient, fast-flowing, predominately rocky substrate), upland (moderate gradient and flow, substrate variable but generally with extensive rocky areas), or lowland (low gradient, sluggish current, predominantly depositional substrates such as sand and silt) in character; larger streams may be upland or lowland in character. All of these basic categories and subcategories of stream types have characteristic fish faunas associated with them which are further modified in composition by prevailing habitat types associated with regional geology (see general descriptions in previous section, Waters and Geology of Tennessee). Because fishes have evolved such close associations with these habitat types, many species show great fidelity to physiographic provinces. This fidelity can promote fragmentation and isolation of populations over time as the surface geology changes, and it probably has resulted in the evolution of several new species.

Natural lentic habitats consist of several kinds of lakes (lacustrine habitats), swamps, and backwaters of larger streams. Natural lakes are created in a variety of ways, including glacial modification of the land surface (as in much of northern North America), subsidence due to tectonic activity (e.g., Reelfoot Lake) or dissolution of underlying strata (e.g., karst lakes of Florida), changing river courses (oxbow lakes), or natural damming of streams by landslides or beavers. Humans have added a large contingent of unnatural lentic environments through the impoundment of streams in which some lentic fish species have flourished while stream fishes largely disappeared.

Swamps or marshes are characterized by expanses of shallow, standing water which may fluctuate seasonally with rainfall. Permanent swamp habitats usually have submergent or emergent vegetation and may be forested (e.g., cypress, tupelo). Waters may be clear, stained brown by tannic-acid, or seasonally turbid (muddy). A number of fish species are strictly or often associated with swampy environments.

Caves constitute an additional unique habitat type. A few species of fish lead a strictly subterranean (hypogean or trogloditic) existence. Other species (troglophilic) are often associated with caves but may lead an epigean (surface) existence part of the time. Hypogean fishes, which are typically blind and devoid of pigment, have evolved several specializations to cope with their lightless and low-nutrient environment, as discussed in the section herein on amblyopsid fishes.

Beyond general habitat preferences, fishes demonstrate a variety of basic behaviors and physical adaptations. Some fishes are rather sedentary, spending much of their time near a favored haunt or moving about a small area. Such fishes tend to be solitary or occur in small, loose aggregations, and some may be constantly or seasonally territorial. Other fishes rove freely over large areas and are constantly on the move. These tend to be schooling fishes and may frequent the midwater (pelagic) realm or cruise very near the surface or bottom. Many midwater species are filter feeders (e.g., shad, paddlefish), straining plankton from the water with special gill rakers, while others actively feed on midwater organisms or dash to the surface to take fallen prey (e.g., many minnows). Still others, such as striped bass, are roving predators feeding on other midwater fishes. Surface-oriented fishes (e.g., topminnows, some silversides) cruise just beneath the surface, feeding on fallen or emergent organisms; such fishes usually have an upturned mouth and flattened dorsal profile to facilitate this life-style. Many fishes are bottom-oriented (benthic) in behavior, swimming just above the bottom (epibenthic; e.g., suckers), resting upon it (e.g., darters and sculpins), or even burrowing into it. Some of these species have a downwardly oriented mouth to facilitate feeding. Those benthic species that frequent swifter waters may have several hydrodynamic adaptations, including a depressed or streamlined body profile, modified fins, and reduction of the swimbladder to lessen buoyancy. Benthic and epibenthic species are generally very closely associated with a specific substrate type (gravel, sand, small or large rocks, vegetation, detritus) and current regime. Though none occur in North America, a few fishes (e.g., mudskippers, climbing perches) have remarkably evolved adaptations permitting them to spend short periods of time on land!

Because they feed on a variety of organisms and, in turn, are preyed upon by a diversity of predators, including terrestrial ones, fishes are vital links in nature's food web, especially between the aquatic and terrestrial environments. Fishes of different kinds or life-stages feed on everything imaginable—including microscopic organisms, such as diatoms and bacteria; plankton; plants; macroinvertebrates (e.g., insects, crustaceans, mollusks); other fishes of all sizes; and other vertebrates, both aquatic and terrestrial. In turn, they are fed upon by everything from large aquatic insects to other fishes and reptiles and a variety of birds and mammals, including humans, for whom they have provided one of the most important protein sources for thousands of years.

Like nearly every living organism, fishes are host to a variety of parasites, both external and internal, including: fungi; protozoans; acanthocephalan, cestode, trematode, and nematode worms; and various arthropods, such as mites, copepods, and isopods (see Hoffman, 1967). Perhaps among the most obvious to collectors of freshwater species are the immature stages (metacercariae) of certain trematode worms which form conspicuous black cysts on the skin and may be extremely abundant on fishes in some populations. Also conspicuous when present are such external parasites as leeches, "anchor worms" (females of certain copepods which attach to the skin or fins), and "fish lice" (copepods). Copepods and large isopods may sometimes be found living in the gill cavity of fishes. When dissecting a fish, it is not uncommon to find worms (trematodes, nematodes, cestodes) living in the gut or freely in the body cavity, or to find immature stages encysted in the flesh. Perhaps one of the most interesting parasites is the larval stage (glochidia) of freshwater mussels (Unionidae), which are discharged by the female mussel on the gills or fins of passing fishes where they undergo early development; subsequently these drop to the stream bottom to begin their sedentary lifestyle after having had their dispersal facilitated by the fish host. Some mussels have actually evolved color patterns to lure fishes in proximity to facilitate larval infestation. Though sometimes unsightly, when in natural equilibrium, fish parasites seldom have an impact on the health of their hosts.

Anatomy and Function

In the following sections we attempt to acquaint readers with the basic physical features of fishes and how they function to facilitate their existence in the aquatic environment. Many terms will be introduced which will be of use to those who wish to identify fishes through the keys and descriptions in this book. Much of the information presented here, plus much additional detailed information, is inferable from the general works of Lagler et al. (1977), Bond (1979), and Moyle and Cech (1982, 1988), and from specialized works such as those of Alexander (1967), Hoar and Randall (1969–1984), Harder (1975), and Caillet et al. (1986).

Head, Body, Fins, and Locomotion. The body forms and fin configurations and positioning in fishes constitute an almost endless array; some of the more basic forms are illustrated in Figure 10. In lateral profile, basic body shapes range from horizontally elongate, or extremely attenuate, to deep-bodied (vertically exaggerated); in cross section, elongate fishes may be *terete* or *fusiform* (cylindrical) (e.g., chub minnows, gar, mackerel), somewhat *laterally compressed* (parallel-sided) (e.g., striped bass), or *dorsally depressed* (flattened from above; e.g., sculpins). Deep-bodied fishes are all laterally compressed to varied degrees; dorsally depressed fishes range from relatively elongate (e.g., sculpins) to extremely broad (e.g., skates and rays) in dorsal view.

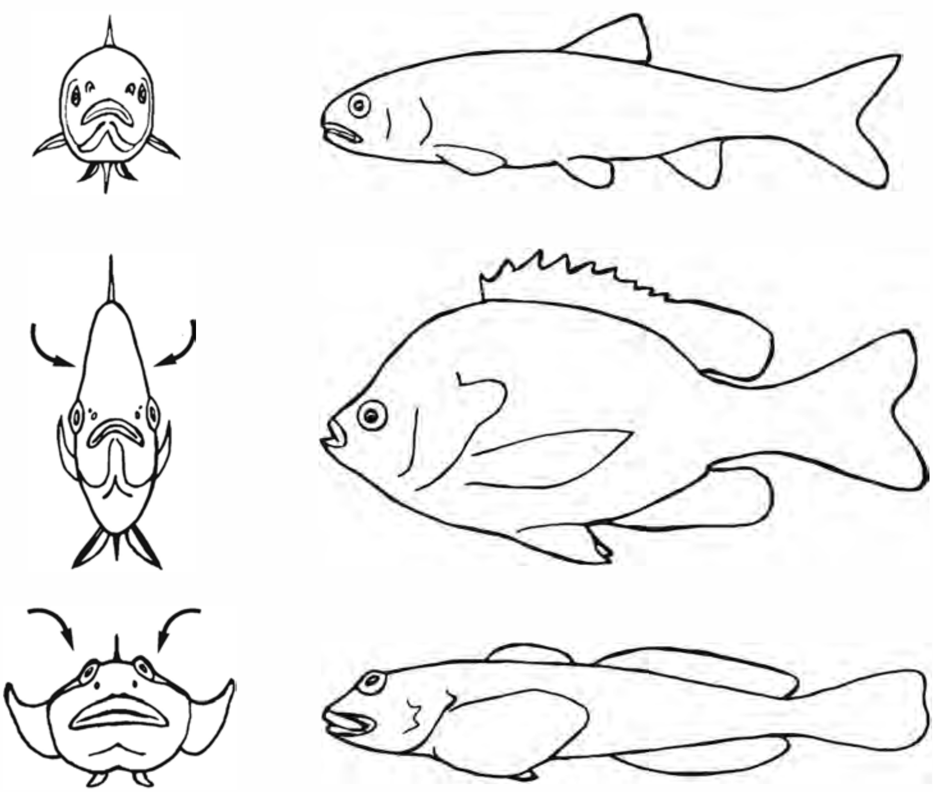


Figure 10. Some basic body forms of fishes: top, terete (chub minnow); middle, laterally compressed (sunfish); bottom, dorsally depressed (sculpin).

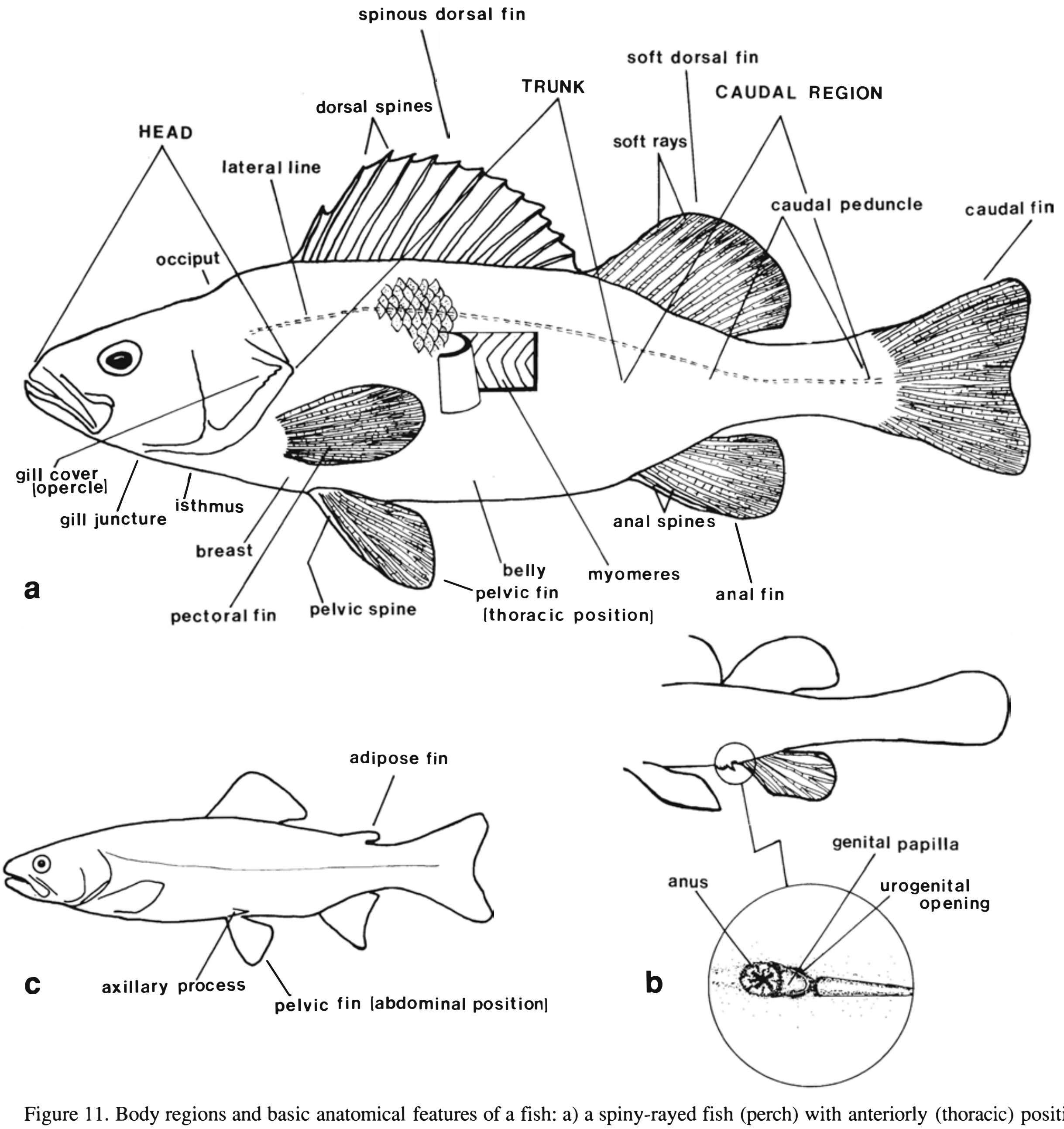


Figure 11. Body regions and basic anatomical features of a fish: a) a spiny-rayed fish (perch) with anteriorly (thoracic) positioned pelvic fins; b) a darter (small percid) showing details of urogenital area; c) a soft-rayed fish (trout) with abdominally positioned pelvic fins and other fin features shown.

The body of a bony fish is divided into three main regions: the head, trunk, and caudal (Fig. 11a). The head includes that region from the tip of the snout to the posterior extremity of the gill cover. Dorsally, it is generally delimited by the area where dorsal body musculature attaches to the rear of the skull (the *occiput*) and is generally discernable as a transverse line anterior to a hump in the dorsal profile. Ventrally, the juncture of the gill flaps generally serves to demarcate the rear of the head. The trunk, which contains the abdominal cavity, lies between the head and caudal region. Dorsally, the region of the trunk lying between the occiput and the dorsal fin is termed the *nape*. Ventrally, the trunk subregions are the narrow *isthmus* (interposed between the gill flaps), the breast (anterior to the pelvic fins), and belly. In most fishes the body is distinctly constricted just behind the anal fin to form the *caudal peduncle*. In some fishes the caudal region, the beginning of which technically corresponds internally to the first vertebra with a ventral spine (haemal spine) rather than ribs (see Fig. 17), simply tapers from somewhere near midbody without a distinct peduncle being formed; this is especially true in groups in which the anal fin is reduced or lacking, as in eels.

In lampreys (Fig. 12a), the head is considered to extend posterior to and include the body segment bearing the seventh (last) gill aperture. The trunk extends from behind the head to the muscle segment (*myomere*) bearing the anus or urogenital opening, and the remainder is considered the caudal region.

The main external features of the head of bony fishes and bones of the interior of the mouth are illustrated in Figures 13a and b. Mouth shapes and positions vary greatly among fishes. In many fishes the mouth is *terminal*, located at the anterior extremity of the head, but in others it may be slightly overhung by the snout (*subterminal*), far beneath the snout (*inferior*), or upturned (*superior*) for surface feeding. In general, terminally located mouths are utilized for biting and seizing (e.g., sunfish), or water intake for filter feeding (e.g., shad), while more inferior mouths may be suctorial or modified for scraping algae and associated organisms from the bottom (e.g., sturgeon, suckers). The jaws may be *protractile* (extendable) or nonproctractile; in the latter case the premaxilla is either broadly or narrowly connected to the snout by a fleshy median *frenum* (Fig. 14). In some fish groups (e.g., gars, needlefishes) the jaw bones may be greatly modified into beaklike or other structures. In other groups (e.g., catfishes, some minnows), *barbels*, which are usually well endowed with taste buds, may be present on the maxillary and mandibular areas (Fig. 15).

The presence, locations, and types of teeth also vary greatly among fishes. They may be present or absent on any of the jaw or interior mouth bones (Fig. 13b), and a few fish groups (e.g., minnows) lack teeth in the mouth region altogether. Various tooth types are shown in Figure 16.

In lampreys, jaws are lacking; instead, the mouth consists of a *buccal funnel*, a suction device, which has variously developed toothlike structures (see terminology in Fig. 12b). In parasitic species, the buccal funnel and tooth structures function in attaching and holding to slippery host fishes and to rasp a hole from which blood

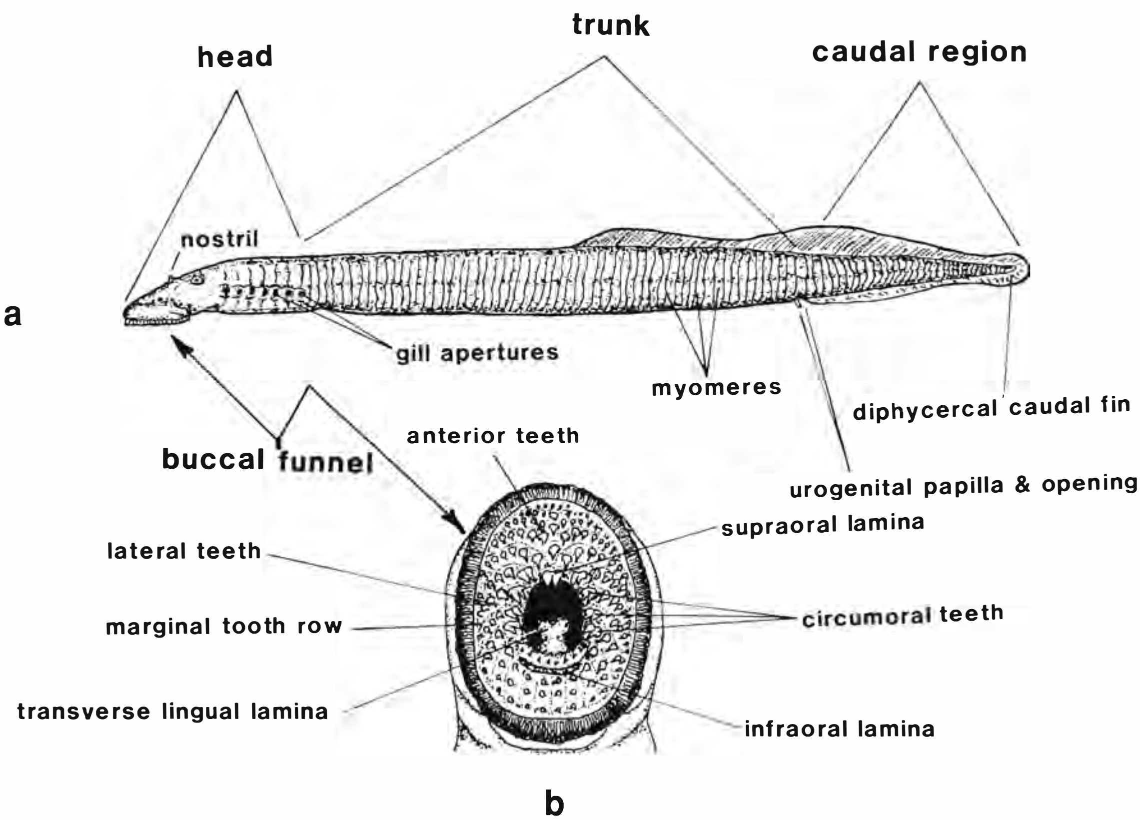


Figure 12. Lamprey anatomy: a) body regions and external features; b) features of oral region.

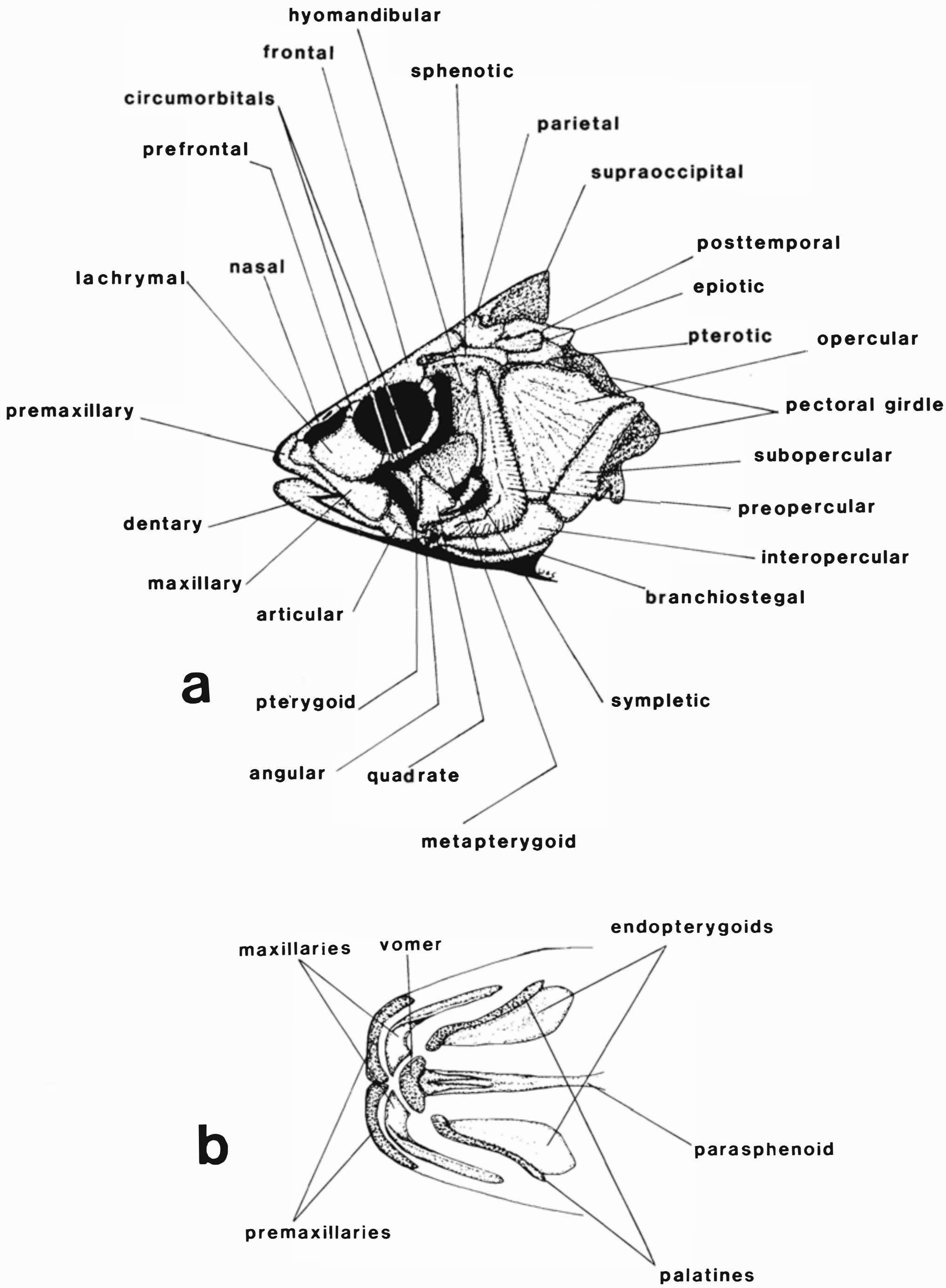


Figure 13. Bones of the head region of a fish: a) jaw bones and superficial skull bones (redrawn and modified from Lagler et al., 1977); b) bones of the roof of the mouth region (ventral view).

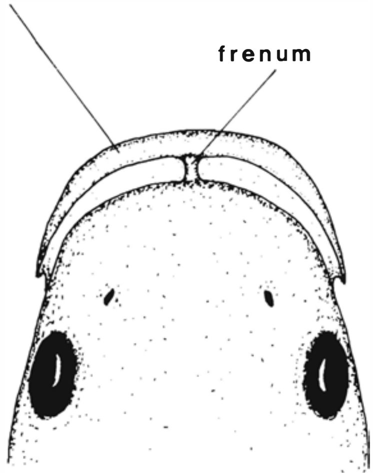


Figure 14. Dorsal view of head of fish with non-protractile upper jaw showing connection of frenum.

can be drawn. In nonparasitic lampreys, this organ facilitates attachment to the substrate. It should be noted that, unlike bony fishes, the nostril in lampreys is a single median opening before the eyes. On the sides of the head are seven circular openings which serve as the gill apertures. The lateral line pores of a lamprey's head are mainly microscopic and may not be visible as illustrated.

The superficial facial bones and sensory canal system of a bony fish are shown in Figure 13 and 26. The size of the eye, or *orbit*, varies greatly among fishes and varies with growth (allometry) in an individual, with the eyes of larvae and juveniles usually being proportionately larger than those of adults. The infraorbital (or suborbital) bones may be poorly developed or partially absent in some fishes with corresponding alterations of the canal system borne by those bones. The sensory canal system (*cephalic lateralis system;* see Fig. 26) varies in development among fishes, and some canal portions may be elaborated, interrupted, or absent, or even cavernous, as in fishes of the drum family. The bones (opercle, preopercle, and others) associated with the gill flap region vary widely in shape and may or may not bear spines or other features.

The body of a fish is composed of sequential muscle segments termed *myomeres* (Fig. 11a) which, in small-scaled or scaleless species, may be visible through the skin or as creases on preserved specimens. In lampreys (Fig. 12a), they are usually quite evident, and their numbers are important in identification of species.

In many bony fish groups a *lateral-line* canal (see Sense Organs section, below) is evident along the side of the body near the midline (Fig. 11a) extending from the cephalic system on the head near the top of the gill opening to the base of, or onto, the caudal fin. It may

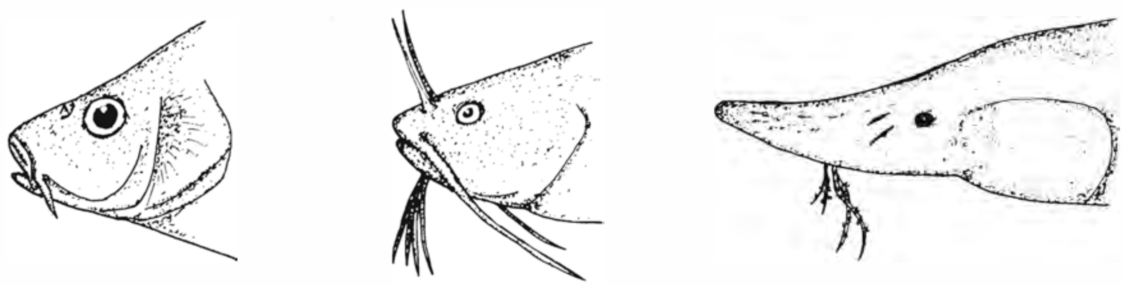


Figure 15. Barbels of fishes: left, a minnow (carp); center, a catfish; right, a sturgeon.

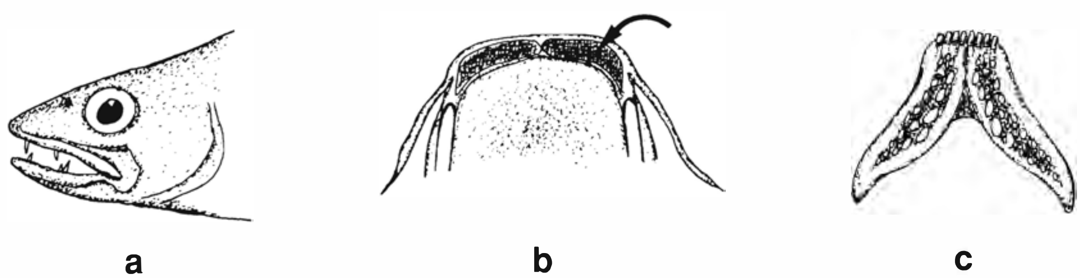


Figure 16. Some basic types of dentition in fishes: a) caniform; b) villiform or cardiform (ventral view of upper jaw of catfish); c) anterior incisiform and posterior molariform teeth of lower jaw of a marine porgy (Sparidae).

be borne in a row of scales, or in the dermis of scaleless species, and may be incomplete, interrupted, or absent in some groups and is even variable within species in some groups. In some fishes (e.g., cavefishes) the lateral line has vertical elaborations.

Also externally visible on the body are the *urogenital opening* and *anus* (Fig. 11b). In most groups these openings are just before the anal fin, but in two families (pirateperch, cavefishes) these migrate forward during development to a jugular position just behind the isthmus. The urogenital opening is posterior to the anus and serves both the kidneys and gonads; it is well separated from the anus or even produced into a tube called a *genital papilla*. The term *genital papilla* is used when the opening is on an elevated mound or tube.

The most prominent external features on the body of most fishes are the fins. Individual and collective terminology for fins and their support structures are shown in Figures 11a,c, and 17. Fins vary greatly in shape and size among and within fishes, and some groups lack certain fins. Dorsal fins are present in most fishes; soft-rayed fishes (e.g., trout, minnows) typically have a single dorsal fin (two or three in cods and relatives) while spiny-rayed fishes (e.g., perch) may have two separate fins or a single continuous fin. Anal fins are single in most fishes. The dorsal and anal fins are supported principally by the bladelike *pterygiophores*, inserted medially between the lateral body musculature, and the fin rays. *Soft rays* consist of bilaterally paired, segmented structures which, except for the anterior one or few, are usually branched one or more times toward the extremities. "True" spines, such as those of perciform fishes, are solid, unpaired, and unsegmented structures. The "spines" of catfishes, some minnows (e.g., carp), and a few other "lower" bony fish groups, which are generally single, differ in that they develop from hyperostosis (profuse bone tissue deposition) and fusion of segmented rays.

The caudal fin, or tail fin, is well developed in the majority of fish groups but may be reduced or absent in some (e.g., some eels). The three basic types of caudal fin are shown in Figures 17 and 18. Lampreys have a *diphycercal* caudal fin in which the rays radiate from and surround the tip of the notochord. Certain primitive groups, including the sturgeons, paddlefishes, gars, bowfin, and sharks, have a *heterocercal* caudal fin in which the upper lobe emanates from the upturned terminal vertebrae and the lower from the ventral aspects of those bones. Typical of most bony fishes is the *homocercal*, usually relatively symetrical, configuration emanating entirely from bladelike modifications of the upturned terminal vertebra termed the *hypural plate complex* (Fig. 17). Homocercal caudal fins may have a variety of shapes, including rounded, truncate, forked, crescentic, and others.

Numerous families of lower teleosts (e.g., smelt, trout, catfish) have an additional median fin, the *adipose fin*. It is a fleshy fin lacking rays or spines and is typically located between the dorsal and caudal fins.

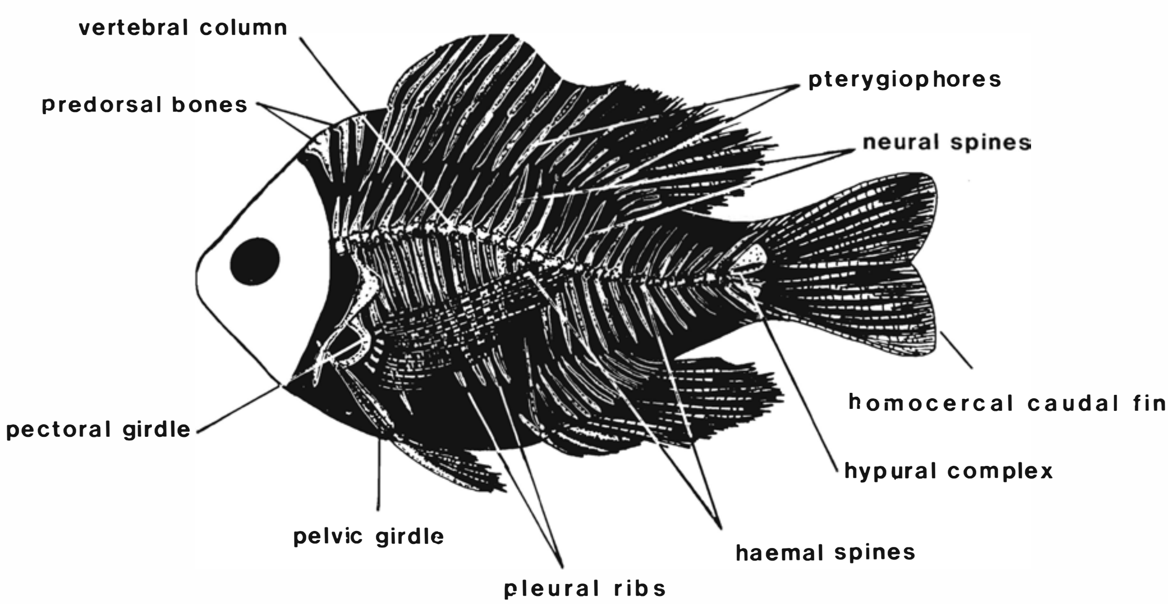


Figure 17. Axial skeleton, fin support structures, and caudal fin type of a bony fish (centrarchid sunfish).

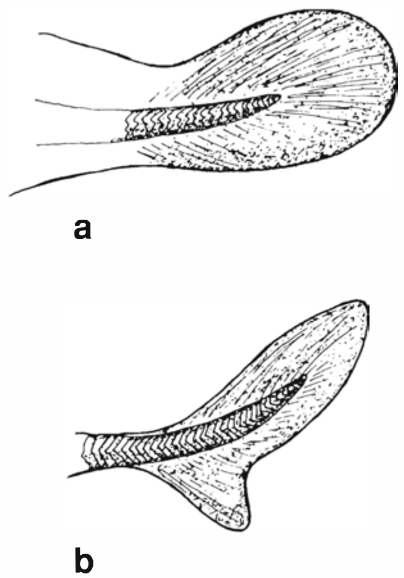


Figure 18. Primitive caudal fin types: a) diphycercal; b) heterocercal.

The paired fins (Fig. 11a), the pectorals and the pelvics, are bilateral appendages which vary considerably in placement among fish groups. Pectoral fins are always just behind the head but may be inserted relatively low (e.g., suckers) or high (e.g., silversides) on the sides of the body. The pelvic fins (also called ventrals) may be situated near midbody (abdominal; e.g., trout, minnows), which is thought to be the evolutionarily more primitive positioning, or they may be situated anteriorly (thoracic or jugular) beneath or in advance of the pectoral fins (e.g., perch, sunfish), as is characteristic of "higher" fish groups. The pectoral and pelvic fins are supported internally (Fig. 17) by complexes of large bones (girdles) which are not directly associated with the vertebral column. In most groups only soft rays are present in the pectoral fin, but in some (e.g., catfishes) the first rays may be fused into a spine. In many spiny rayed fishes the pelvic fin has a single spine. The *axillary processes* shown in Figure 11 are characteristic of only a few fish groups, such as salmonids and herrings, and a small axillary process occurs in many cyprinids.

Fishes move through the water by using both body movements and the fins. Primarily, forward motion is attained by side-to-side flexure of the body, caused by alternating contractions of the myomeres, culminating in thrust from the caudal fin. Fins are used primarily for short bursts, stabilization, and stopping or reversing. Median fins serve as stabilizers and, when curled to the side, as brakes. Paired fins are for short maneuvering, ascending, and descending. Some species with very long-based dorsal fins, such as bowfins, achieve some propulsion by wavelike undulations of this fin.

Gills and Respiration. In bony fishes the gills consist of five arches, each composed of several bones, suspended posteriorly beneath the skull (Fig. 19). These *pharyngeal arches* and their associated structures are collectively sometimes called the *branchial basket*. Each arch bears numerous filaments posteriorly that are richly supplied with arterial blood. Anteriorly, the major bones (limbs) of the arch usually have inwardly directed *gill rakers* of varied numbers and shapes which serve to strain food or other matter passing over the gills. In many fish, especially perciforms, teeth are present on various pharyngeal bones; these may be patches of small teeth for grasping or large molariform (rounded, molarlike) teeth for grinding prey, such as mollusks. In minnows and suckers, in place of the gill rakers, the fifth arch has developed large *pharyngeal teeth* (Fig. 20) which lie just ahead of the esophagus and serve to tear or grind food, and which vary in shape from sharp-pointed to hooked to molariform.

The heart of a bony fish is located just posterior to the gills in the ventral portion of the body cavity (see Fig. 23), and blood is pumped directly into the gill arches. Respiration is achieved by pumping water over the gills with alternating expansions of the mouth cavity and opening of the gill flaps or by passage of water through the gill chamber while swimming. Gaseous exchange (oxygen uptake, carbon dioxide release) occurs in the gill filaments, and oxygenated blood is pumped to the rest of the body. Gill filaments are also the site of chloride cells which serve to maintain salt balance in fishes. In many fishes, additional filamentous organs, the *pseudobranchs*, are located on the lining of the gill chamber in the preopercle area (Fig. 19). These may provide oxygen to the eyes and possibly augment gas production for the swimbladder.

In lampreys, the gills consist simply of seven paired pouches on either side of the alimentary tract which open medially to this tract and have small external vents visible along the sides of the head (Fig. 12a). These pouches are lined with filaments through which gas exchange takes place when water is pumped over them by contractions and expansions of the pouches. Gills of sharks, rays, and their relatives are more similar to those of bony fishes, consisting of arches, but the chamber has multiple slits opening to the outside rather than a single gill flap, and a spiracle (reduced anterior gill slit) may be present dorsally for intake of water.

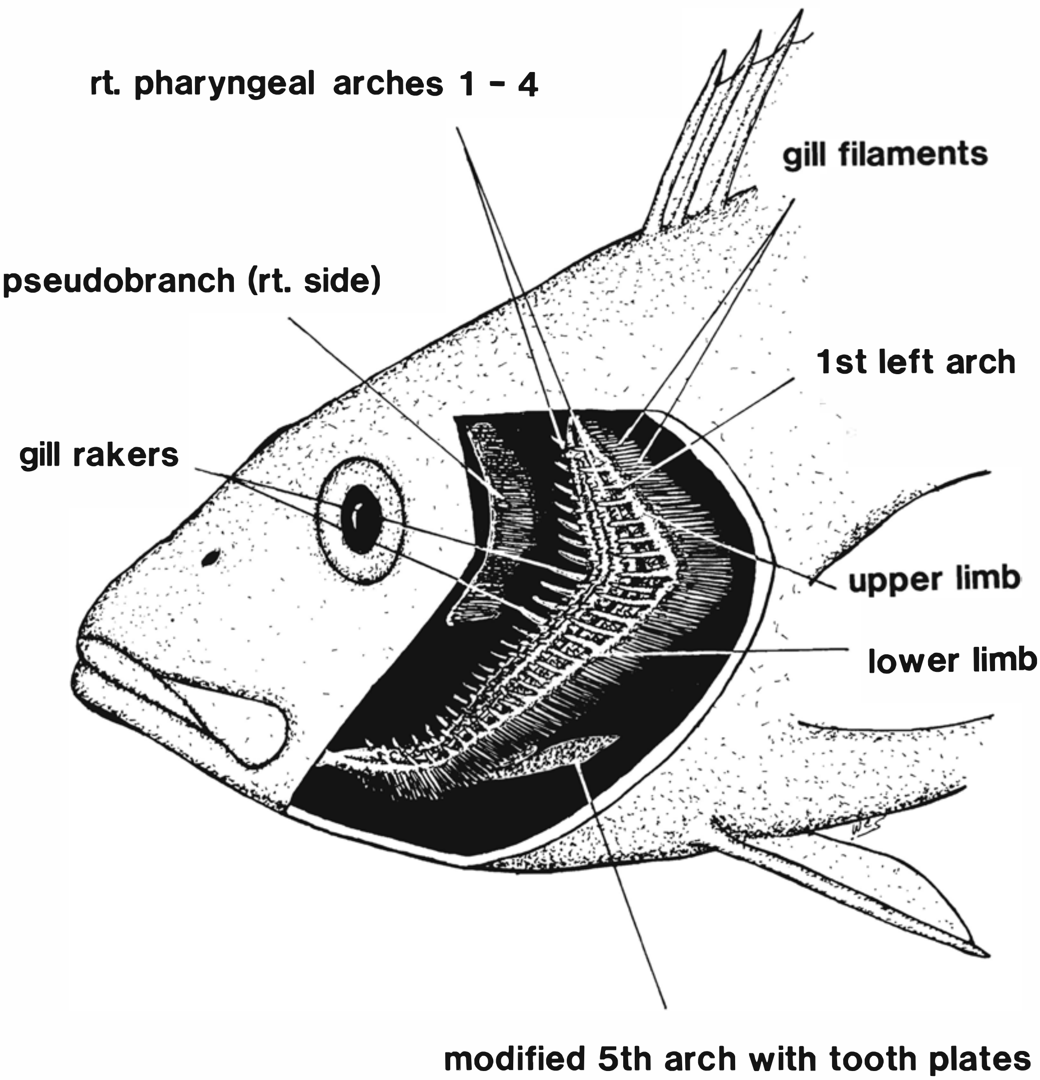


Figure 19. Gill chamber region of a fish showing gill structures and pseudobranch location.

Skin and Scales. The bodies of fishes are covered with a somewhat permeable skin, and most have bony scales or derivitive structures on much of the skin surface, but a few groups (e.g., freshwater sculpins and several catfish families) lack scales. The skin is endowed with mucous cells which produce the characteristic slime of fishes; this secretion may function as a sealant against infections and to reduce friction in swimming. Also present in the skin are the organs of color, the *chromatophores* and *iridocytes*. The former are capable of contraction and expansion to change coloration and impart true color through the possession of different pigments (e.g., *melanophores* have black pigment, *erythrophores* red, and so on). Iridocytes reflect external light sources and result in silvery reflections and iridescent effects.

The basic scale types (Fig. 21a–d) are *placoid* (sharks and relatives), *ganoid* (gars, sturgeons), and *cycloid*, the more familiar type found on most fishes. The first two types are thick and enamel-like and lack the circular bony ridges characteristic of cycloid scales. The parts of a cycloid scale are shown in Figure 21c. The concentric growth rings and annual growth checks (*annuli*) are important in age studies of fishes. In many fish groups (primarily spiny-rayed) cycloid scales are modified (Fig. 21d), having tiny spines on the posterior surface either as an integral part of the scale (few marine groups) or attached at the base by platelets (*ctenoid*), giving the fishes a rough texture (e.g., perch, sunfish). Some specialized derivatives of scales are the external armorlike platings of seahorses and pipefishes,

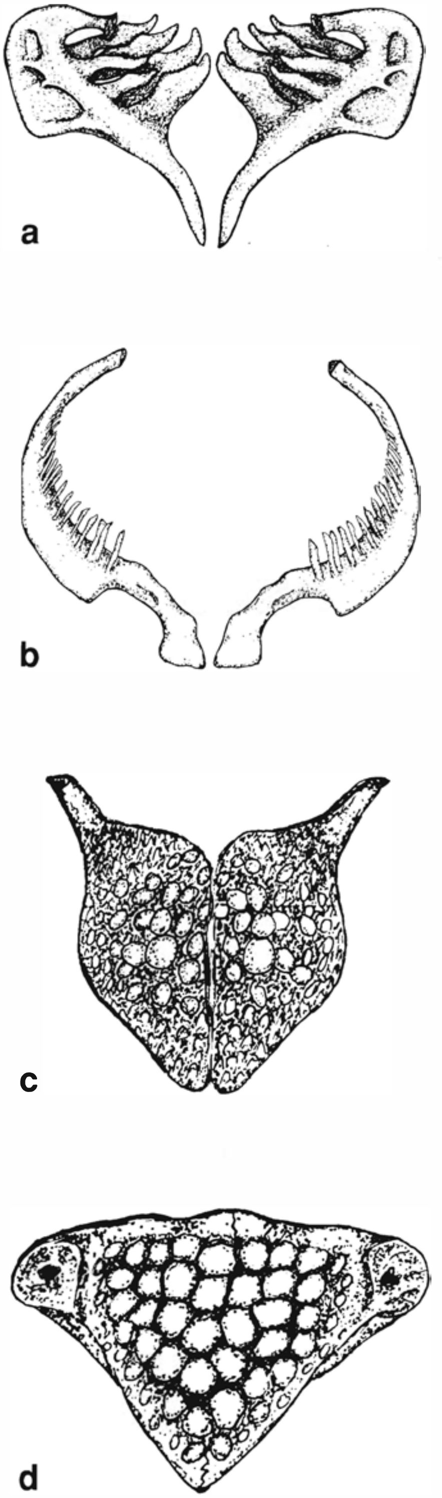


Figure 20. Modified fifth pharyngeal arches of fishes: a) with partly hooked teeth for ripping and tearing (minnow); b) with comb-like teeth (sucker); c) with molariform teeth (redear sunfish, a snail-eater); d) heavily modified with molariform teeth for crushing mollusks (freshwater drum).

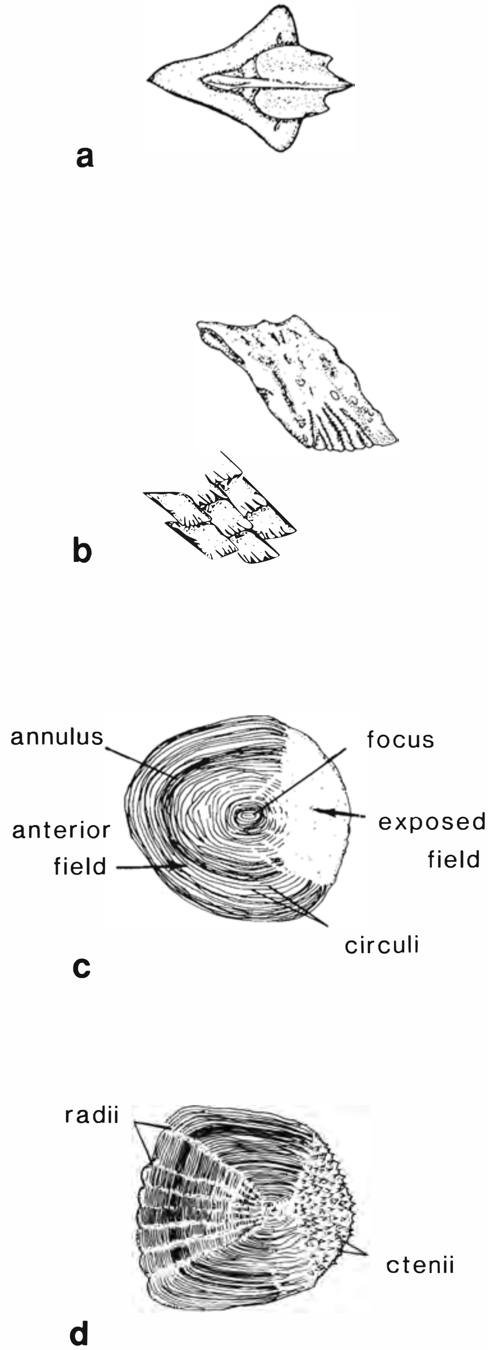


Figure 21. Basic fish scale types: a) placoid; b) ganoid; c) cycloid; d) ctenoid (drawn, in part, by P. Yarrington).

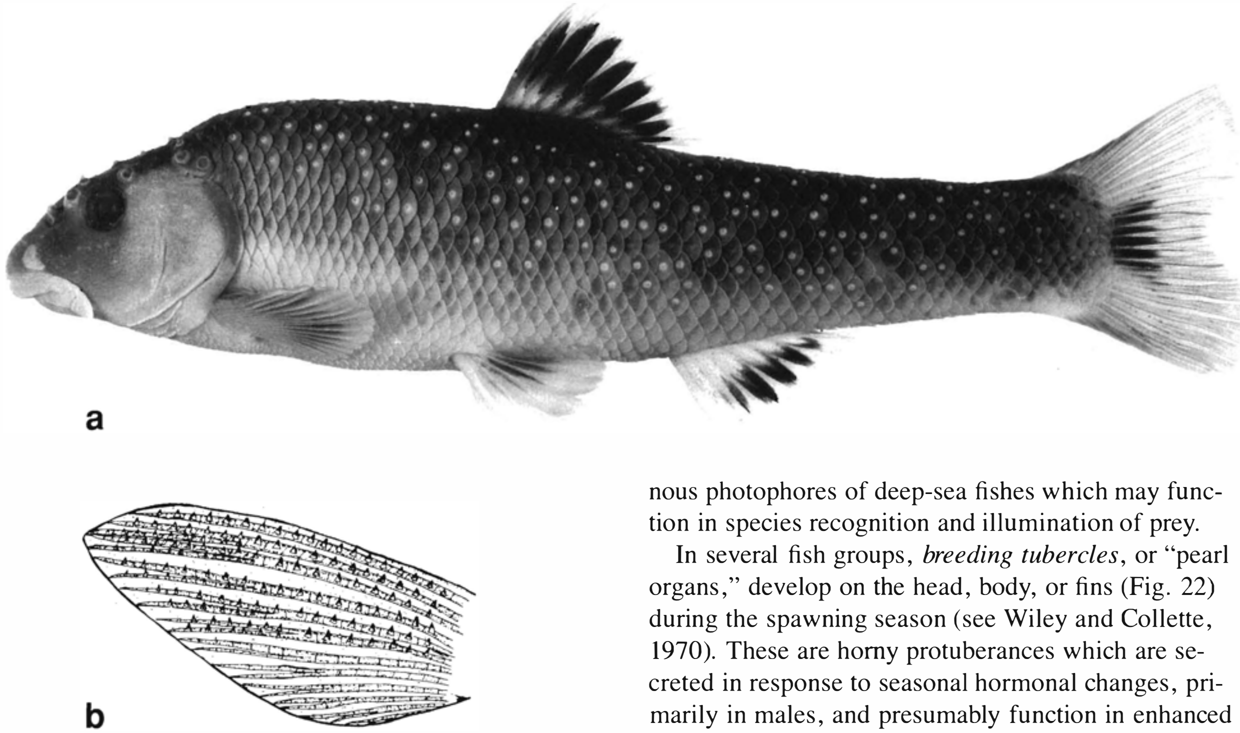


Figure 22. Examples of fish breeding tubercles: a) head and body tubercles of a stoneroller minnow (genus *Campostoma*); b) tubercles on pectoral fin rays of a cyprinid in uniserial (one per fin-ray segment) configuration.

belly scutes of herring, and the scalpel-like spine on the caudal peduncle of the marine surgeonfishes.

Scales vary tremendously in size between and within fish groups and may be firmly attached or easily lost (deciduous). The coverage of scales (*squamation*) also varies greatly among fishes. When present, scales are usually distributed on much of the sides and back of the body but may be present or absent on the belly, breast, and nape (dorsal surface from occiput to dorsal fin origin). On the head, they may be completely absent, or present or absent on the opercles, cheek area, and top of the head. Only a few groups have the head almost completely scaled.

A variety of other features may be found on the skin of fishes. Many species have external taste buds, usually visible only microscopically as tiny bumps, located on the skin surface, particularly on the ventral portion of the head, and some even on the body. Small fleshy appendages, such as *lappets* or *papillae*, are present on the skin of some fishes (e.g., sculpins). Perhaps some of the most remarkable organs of the skin are the luminous photophores of deep-sea fishes which may function in species recognition and illumination of prey.

In several fish groups, *breeding tubercles*, or "pearl organs," develop on the head, body, or fins (Fig. 22) during the spawning season (see Wiley and Collette, 1970). These are horny protuberances which are secreted in response to seasonal hormonal changes, primarily in males, and presumably function in enhanced contact during spawning. These tubercles slough off after the spawning season.

Sense Organs and Senses. The sensory systems of fishes are necessarily quite different from those of terrestrial vertebrates. For instance, in bony fishes, the cephalic lateralis system is instrumental in detection of sound or vibrations. The canals of the head and lateral line are equipped with cells called *neuromasts* which have hairlike cilia oriented in such a way as to detect directionality of vibrations. This information is transmitted directly to the brain via nerves which lie in proximity to the canals. Thus the "ears" of fishes are in part very different from those of terrestrial vertebrates. The function of this system and its relationships to behavior were treated extensively by Disler (1960).

There is also an inner ear, more analagous to those of other vertebrates, but which, instead of containing ear bones or ossicles, has three calcareous "ear stones" or *otoliths*. One of these (the *lapillus*) functions in maintaining body orientation and the remaining two (*astericus*, *sagitta*) in sound reception. In several fish groups, features have evolved to enhance transmission of vibrations to the inner ear area. In minnows, suckers, catfishes, and relatives (*ostariophysan* or *otophysan* fishes), the anterior vertebrae are modified to form a chain of bones, the *Weberian ossicles*, interlinking the swimbladder, which is very sensitive to vibrations, to the inner ear area. In a few other groups the swimbladder has forward extensions to the auditory region. Lampreys lack an elaborate inner ear system, having only a small auditory capsule. Thanks to the aid of sensitive hydrophonic equipment, many fishes, including even small minnows, are now known, to produce sounds (see Tavolga, 1971). Sound communications may be much more important in fishes than was previously thought.

Chemoreceptors are well developed in fishes. Taste buds, or *gustatory organs*, may occur externally on the skin of fish (e.g., some catfishes) and on barbels about the mouth; these organs are variously distributed on the fins, lips, and in the mouth cavity and throat area as well. Intimately related with taste in the location of food is the sense of smell, which also is important in orientation, communication, and perhaps predator detection. The olfactory senses are extremely well developed in fishes, and some species of fishes are believed capable of detecting substances at a few parts per trillion. For example, salmon homing to their natal streams to spawn after years at sea are believed to locate these waters over hundreds of miles through smell which was imprinted soon after hatching. Odiferous chemicals, called *pheromones*, are emitted by some fishes (e.g., the "fright" substance of minnows) for communication through the water to signal danger, locate one another, or perhaps facilitate courtship. The organs of smell, the *nasal rosettes*, are located in the capsule served by the incurrent and excurrent *nares* (Fig. 13a) through which water is funneled. The single nasal opening of lampreys (Fig. 12a), through which water is alternately taken in and expelled, leads to a sac lined with olfactory tissue.

Vision in fishes is of varied utility among groups. Many fishes are sight feeders (e.g., minnows, trout, sunfishes), and many depend on well-developed vision for not only feeding but species recognition and locating cover. Other species, which inhabit turbid or very deep waters, or subterranean waters, may have the eyes and visual capacity much reduced or even nonfunctional with concommitant increased development of other senses, such as sound detection (e.g., cave fishes) or taste (e.g., catfishes). In other fishes (e.g., walleye, some marine groups) which are nocturnally active, the eyes have evolved a brilliant reflective layer (*tapetum lucidum*) on the inner surface of the eyeball to maximize light gathering and, in some of these groups, the eyes are very large. Several species of fishes are known to be capable of color recognition and, based on the bright color patterns, which probably facilitate recognition in many species, this capability may be pervasive among at least species inhabiting well-lighted environments.

The eye of a fish, like that of a terrestrial vertebrate, is a ball-shaped organ with a transparent cornea and circular opaque iris; however, unlike the eye of terrestrial vertebrates, the iris of the fish eye is scarcely dilative and the lens is essentially spherical rather than elliptical to compensate for the refractive properties of water. The eyeball bulges somewhat from the head, and the lens protrudes from within it, to give the fish virtually a circular field of vision; within the field, the lens focuses at some distance to the sides but at close range to the front, presumably to facilitate feeding. In some groups (e.g., herrings) vertically oriented, fixed eyelids (*adipose eyelids*) have evolved (Fig. 33).

As for other senses, fishes are capable of temperature perception, and many species remain closely associated with certain temperature regimes. The sense of touch is thought to be somewhat limited in fishes, but some species (e.g., some catfishes) are known to be sensitive to tactile stimuli. Finally, one sensory system that may be very important in fishes is that of electroreception. The extent of development of these capabilities to sense extremely weak currents is not well known for many fishes, but it is known to be developed to varied degrees in a number of families, reaching its highest state in such groups as the South American electricfishes (Gymnotiformes) which are also capable of emitting weak charges. (The ability to emit stunning voltage levels has developed in the notorious electric eel genus, *Electrophorous*.) Catfishes have microscopic pit organs in the skin for reception of minute electrical currents. This system may be very important in location of objects or prey as well as in communication, orientation, and navigation in some groups.

Skeleton and Internal Organs. We have already touched on various skeletal components associated with the head and fins and will only briefly further discuss the fish skeleton. In higher bony fishes (Osteichthyes) the body is supported internally by a more or less completely ossified (bony) skeleton (Fig. 17). However, in chondrostean fishes (sturgeons, paddlefishes) much of the skeleton is cartilagenous. In lampreys, the skeleton is even less developed, consisting of a cartilagenous cranial structure and gill complex and a spinal cord around which vertebrae do not completely form; thus the embryonic *notochord* is retained through adulthood. In bony fishes, skeletal features vary considerably among groups. The presence and number of *predorsal bones* varies, as does the number of *epipleural ribs*, and *epineurals*, also known as "intramuscular" bones, which are common to such groups as herrings, pikes, trout, suckers, and minnows but not to "higher" groups, such as perches and sunfishes; these are often responsible for complaints about some of these fishes being "too bony to eat."

When one dissects a fish, or guts one while cleaning, several internal organs are readily apparent (Fig. 23). The organs are contained within the thin layer lining of the body cavity, the *peritoneum*, which is usually silver or whitish but may be speckled with black pigment or virtually black, in which case it is usually visible as such through the body wall. Dark peritonea are typical of some detritivorous and herbivorous species. The more variable organs to be discussed are the alimentary tract, gas bladder, and gonads.

The alimentary tracts of many fishes have a well-developed stomach (e.g., trout, perch, sunfishes) while those of others are not well defined, appearing as part of the tubular intestine. In such species as detritivorous and herbivorous minnows, the gut may be extremely long with many loops or coils. In species with well-defined stomachs, *pyloric caeca* often append from the union between the stomach and gut; these vary in size and number among groups.

In many fishes the *gas bladder*, or "swimbladder," is one of the largest internal organs, located dorsally in the body cavity and having the appearance of a white balloon. This organ functions in regulating buoyancy and is thus reduced or even absent in fishes that have more bottom-oriented life-styles. There are two basic types of gas bladder. In many "lower" bony fishes, such as minnows and trouts, a *physostomous* gas bladder exists, which maintains a primitive connection to the alimentary tract, and which is presumably initially filled during early development by gulping air; the bladder is regulated in later life by gas secretions from the blood. The tubular connection between the esophagus and swimbladder (pneumatic duct) allows some of these fishes (e.g., gars, bowfins) to use the swimbladder as a lung and breathe by gulping air at the water surface. The primitive connection has been completely lost in higher fish groups (*physoclistous* condition). Gas bladders may be single chambered but are multichambered in many species. The gas bladder also serves as a resonating chamber for the reception and production of sound. Connections from this organ to the inner ear

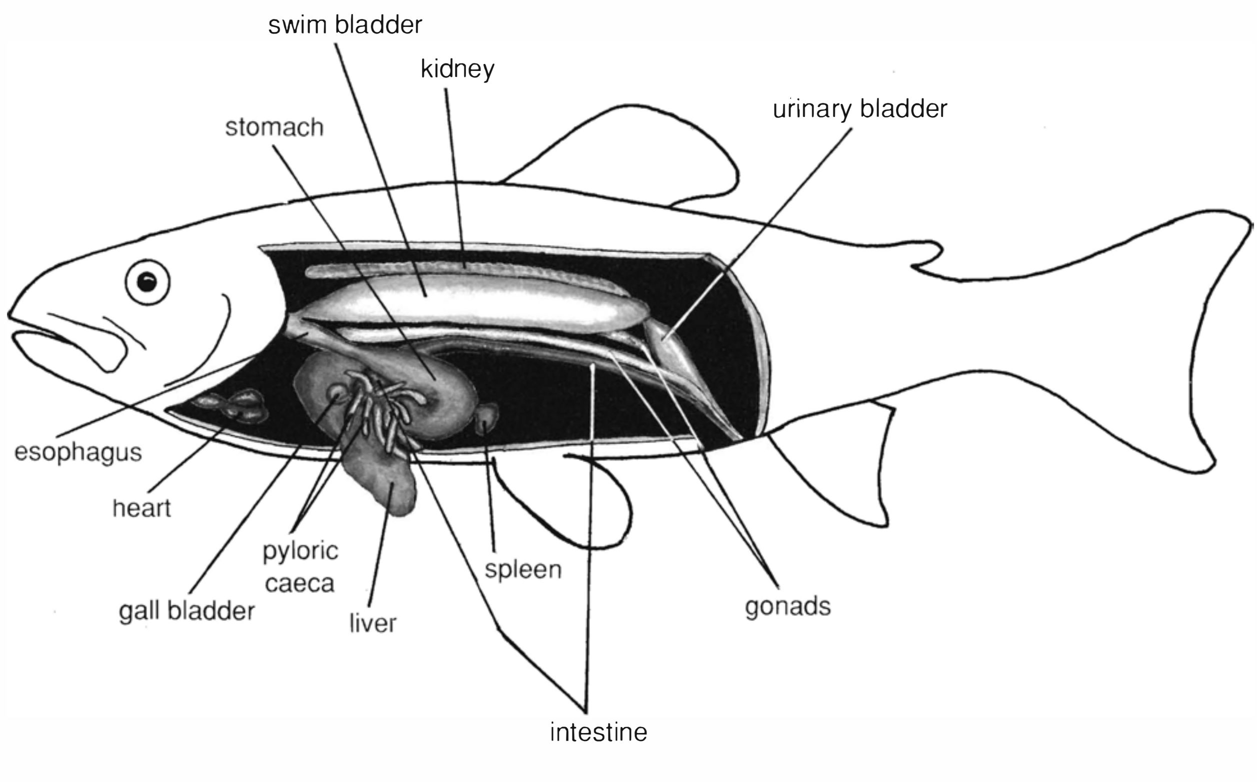


Figure 23. Major internal organs of a fish (trout). Liver is distended ventrally to reveal underlying organs; kidney is generally bound in tissue along ventral aspect of vertebral column.

area are discussed above under Sense Organs and Senses. For sound production, in some groups, specialized muscles have evolved externally or internally about the swimbladder to generate vibrations (e.g., in the drum family).

In most fishes the gonads are tubular organs lying on each side of the body cavity and terminating at the urogenital opening, though they have different shapes in a few fish groups. In some primitive groups (e.g., bowfin, paddlefish) and salmonids and relatives, they do not connect directly to the oviducts, with the eggs first being shed into the body cavity and funneled into the ducts. The gonad of lampreys is a single tubular organ which is also remote from the urogenital opening. Near the spawning season, the gonads of fishes are obvious and, in the case of females, may fill a substantial portion of the body cavity; out of the spawning season the gonads may be flaccid and difficult to discern. Ovaries are recognizable by their typically yellowish color and the granular appearance caused by the spherical egg bodies within them, while testes are usually white and contain thick fluid (*milt*).

Reproduction and Early Development

Fishes exhibit diverse modes of reproduction; for a systematic treatment of these, see Breder and Rosen (1966). The majority of fishes spawn by having the female extrude eggs, which are externally fertilized by sperm-bearing milt from the male (*oviparous* reproduction). These fishes may simply broadcast buoyant eggs in midwater (e.g., shad) or sinking (demersal) eggs on the bottom (e.g., walleye), in which case the number extruded is generally extremely high. Other species utilize crevices in rocks or submerged logs while others construct gravel nests in which to deposit a lesser number of eggs and abandon (e.g., salmonids) or guard them (e.g., catfish, some darters); this latter task is often accomplished by the male. A few fishes (e.g., amblyopsid cavefishes) incubate eggs in the mouth or gill cavity until hatching. Some groups (e.g., the "livebearers," Poeciliidae) have internal fertilization accomplished by a male intromittant organ, the *gonopodium*, formed from a modified anal fin, with eggs incubated internally in the female and born fully developed (*viviparity*). This process is described more fully under the family Poeciliidae.

In a few species (e.g., some poeciliids, cyprinids) reproduction by *gynogenesis* or *hybridogenesis* has evolved in which all-female clonal populations have resulted from certain hybrid crosses (Dawley and Bogart, 1989; Allendorf and Ferguson, 1990). In gynogenesis, females of the hybrid "species" develop diploid eggs such that, while sperm from the males of one of the original parental species stimulates initial development of the eggs, none of their genetic material is incorporated into the zygote, thus resulting in exact clones of the females. In hybridogenesis, diploid females of hybrid origin produce haploid eggs containing the unaltered genome of only one of the original parents. These are fertilized by normal males to produce "hemiclonal" progeny that are all female and will repeat the process to produce additional, different hemiclones.

Some fishes are *hermaphroditic*, possessing both male and female gonadal tissues, and functioning both as males and females in successive spawning acts (synchronous hermaphroditism); this condition is common in some marine groups and is known occasionally in such groups as topminnows (Fundulidae) and striped bass (Moronidae). Other species (mostly marine) undergo complete sex reversal, functioning as one sex when younger and the other as an older adult (consecutive hermaphroditism).

With a few exceptions, most temperate fishes spawn sometime between late winter and midsummer when waters are warming. Before spawning, fishes generally engage in some form of courtship, which may range from simple following behavior to elaborate displays—especially by the males—which can consist of swimming patterns, physical contact, fin-flaring, and coloration changes. Before and after spawning, males of nesting species often vigorously defend territories about their nests against intruders of the same or different species. Some nest-building species (e.g., sunfishes) engage in "cuckoldry," in which younger males posing as females enter the nests and fertilize some of the eggs.

During the actual spawning act, in midwater spawners, the spawning pair usually just swim upward in close proximity extruding eggs and sperm. In benthic spawners, it is usual for the male to press the female to the substrate in some fashion with the urogenital openings in close proximity. Fishes are generally observed to vibrate briefly at the time of releasing gonadal products. In species that bury eggs, the female or both sexes may vigorously vibrate the anal fin to entrench the eggs.

The eggs of midwater spawners may drift for several days and undergo early development while in transit. Demersal (heavier than water) eggs, which may be adhesive, generally develop while on the substrate. Newly hatched fishes (Fig. 24a,b) are termed *larvae* or "fry." These have little resemblance to adult fishes and continue to undergo development (*ontogeny*) after emergence from the egg. Earliest stages usually survive for

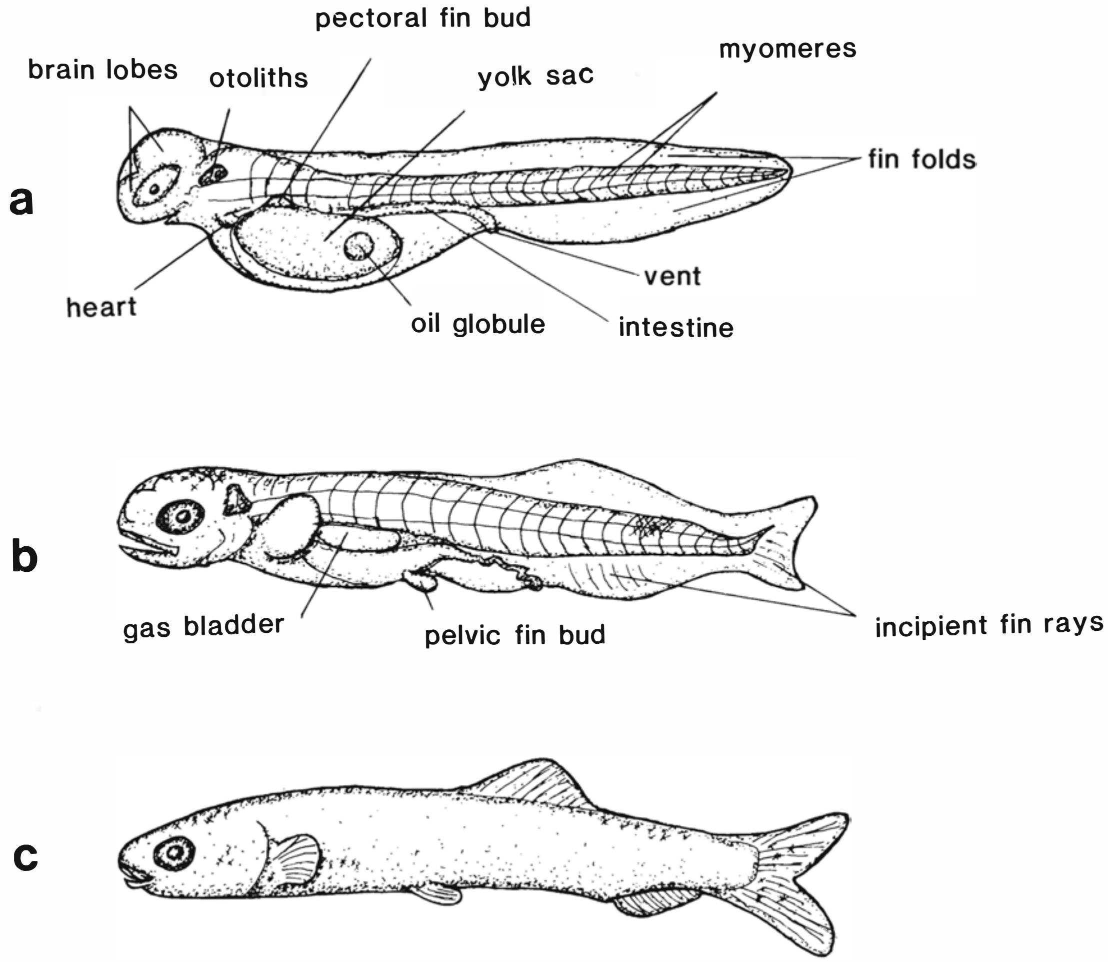


Figure 24. Early life history stages of a fish: a) yolk-sac larva; b) postlarva; c) early juvenile.

several days on nutrients gained from absorption of the yolk sac. This stage is followed by a transition to an actively feeding stage (usually on microinvertebrates) termed a *postlarva*. Eventually, postlarvae transform into small fishes, more or less resembling adults, termed "juveniles." The time of early development from spawning through hatching and transition to the postlarval stage ranges from a few days to several weeks and, in general, is inversely related to water temperatures. These early life-stages of a fish lead a very tenuous existence, and a large percentage of fishes fall victim to predation or other perils during this period and thus never reach adulthood. References of particular interest on the early development of fishes are Fish (1932), Hogue et al. (1976), Snyder (1983), Moser et al. (1984), and the series of volumes in preparation by Wallus et al. (e.g., 1990) on Ohio River drainage larval fishes.

Ichthyology: The Science

The study of fishes, broadly termed "ichthyology," encompasses many aspects. Some ichthyologists are most concerned with studies of the diversity, distribution, and interrelationships of fishes. Others concentrate on the physiology or functional morphology of fishes, seeking to determine how the various body parts of fishes interact to facilitate feeding, locomotion, respiration, or other vital functions. Studies of fish genetics have become numerous in recent years and offer much potential information to those studying both the diversity and relationships of fishes as well as insights for those attempting to manage fish population resources. Still other ichthyologists specialize in behavioral studies, gathering and analyzing both qualitative and quantitative data, based on observations of fishes in natural environments and aquaria, to learn more of their movement patterns and behavior associated with feeding, courtship and spawning, schooling, protection, and other aspects. Studies on fish biology, including basic life histories and fish ecology (how fish interact with their environments), are very important to a better understanding of these animals. Within the past couple of decades, a great deal of emphasis has been placed on the study of the early life history (larval development) of fishes. Other kinds of studies include those of fish population dynamics, management techniques for economically important species, propagation, fishing techniques, and fish diseases. Those who specialize in these latter, somewhat more applied, aspects are most often referred to as "fisheries biologists." Nearly all aspects of ichthyology or fishery biology are germane to the subject matter of this book at some level, but those of central interest are the systematics, taxonomy, and distribution of fishes, as well as basic biological information. The following sections are intended to acquaint the readers with these aspects in particular. Those wishing to find more extensive information on ichthyology or fishery biology should consult the works of Lagler (1956), Lagler et al. (1977), Bond (1979), Moyle and Cech (1988), Nielsen and Johnson (1983), and Schreck and Moyle (1990). Extensive bibliographic information on fishes can be found in Dean (1916–1923) and in the Pisces section of the *Zoological Record*.

Systematics and Taxonomy of Fishes

Systematics is the theory or practice of discerning the orderliness of nature or other systems. Taxonomy is the theory and practice of classifying that orderliness in a worded system (Mayr, 1969). Systematists work with units, collectively called "taxa," which may consist of the smallest recognizable units (usually a population or group of populations), often referred to as species, subspecies, or races, or they may consist of groupings of species into more inclusive taxa such as genera, families, and orders. Information follows on nomenclature of these taxa, and additional information is given in the section "How to Use the Family and Species Accounts." Readers who want to obtain information beyond what follows on systematics and taxonomy, as well as on the evolution of different ideas and approaches to systematics, and the controversies surrounding them, should consult the works of Simpson (1961), Sokal and Sneath (1963), Hennig (1966), Blackwelder (1967), Mayr (1969), Eldredge and Cracraft (1980), Nelson and Platnick (1981), Wiley (1981), Lundberg and McDade (1990), and many papers published in the journals *Systematic Zoology* and *Cladistics*.

Alpha Taxonomy and Zoological Nomenclature. In taxonomy, the species is the most generally accepted basic unit, and studies that strive to discern these basic units are known as "alpha taxonomy." Readers should be aware that species concepts vary among taxonomists. Also, some choose not to name units below the level of species while others subscribe to subspecies concepts, which may also differ among workers. Perhaps one of the oldest and most widely adhered to concepts is that of the "biological species" which defines a species as a group of interbreeding or potentially interbreeding populations reproductively isolated from all others (Mayr, 1969). Such a concept is, of course, very difficult to test or perceive in nature for many groups of organisms, such as freshwater fishes isolated in different drainage basins. Subjective decisions must be made concerning whether some populations may be capable of interbreeding, or "intergrading," with others, and subspecies designations are often invoked under this concept. A second concept is that of "evolutionary species" (Simpson, 1961) which views species as representing lineages maintaining identities from other such lineages and having their own evolutionary tendencies and historical fate. Polytypic (having subspecies) species are often recognized under this concept as well. A third concept is that species are populations or groups of populations of monophyletic (common ancestral) origin which have differentiated from others (sometimes referred to as the "phylogenetic" or "cladistic" concept) (Rosen, 1978, 1979; Cracraft, 1983; Lundberg and McDade, 1990). Differentiation is detected by the presence of presumed apomorphic (uniquely derived) traits. In practice, all of these concepts involve some degree of subjectivity; the species is thus an arbitrary unit of taxonomic convenience. No matter what the concept, in most cases what taxonomists really must do is identify populations of organisms and what they feel to be consistent variation (morphological or genetic) between these populations, arbitrarily specify acceptable limits to variation in a species, and make decisions based on these limits, perhaps lending credence to Regan's (1926) statement that a species "is what a competent taxonomist says it is." This, of course, has been a simplified explanation of species concepts; there are numerous, much more involved, philosophical treatments of such matters (e.g., Rosen, 1978; Wiley, 1978; Cracraft, 1983, 1987; Loevtrup, 1987; Chandler and Gromko, 1989; deQueiroz and Donoghue, 1988, 1990; several works in Ott and Endler, 1989; and Wheeler and Nixon, 1990).

A taxonomist who believes he or she has identified a species new to science gives it "official" status (according to the International Rules of Zoological Nomenclature) by publishing a formal description in the scientific literature and giving it a unique name, the *species epithet*. In that publication, a museum specimen, called a *holotype*, is designated to forever serve as the standard of reference for the new species. Under older practices, multiple types (syntypes or type series) were designated which, in some cases, later proved to comprise more than one actual species, and the practice was discontinued. Other specimens used in the description may be designated as *paratypes*. When the type of a species is lost, or syntypes are polytypic, and clarification is needed, a revising taxonomist may designate a new one, a *neotype* in the former case or a *lectotype* in the latter, to serve the same function as the holotype. Another term, *topotype*, is often seen in taxonomic literature and simply refers to specimens collected from the same locality as the holotype, either concurrently or at other times; topotypes have no formal taxonomic status but are occasionally employed in resolving nomenclatural problems in the absence of type material.

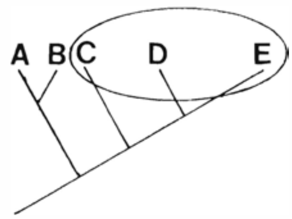
In the system of binomial nomenclature formalized by the Swedish biologist Carolus Linnaeus in the 1700s, the name of a species (always italicized or underlined) consists of the name (capitalized) of the genus it is placed in, plus the species epithet (lowercase) (e.g., *Etheostoma blennioides*). Subspecies names (trinomials) follow the species epithet (e.g., *Etheostoma blennioides blennioides*). When subspecies of a species are recognized and published by a taxonomist, the subspecies encompassing the population from which the species was originally described must retain that species's name, as in the above example, and is known as the *nominate subspecies*, while other populations may be given other names (e.g., *Etheostoma blennioides gutselli*). Only names published since 1758, beginning with Linnaeus's *Systema Naturae*, are considered valid under the international rules of nomenclature (ICZN, 1985), which govern taxonomic practices. When a taxonomist judges two previously published species to be the same, the first (older) published name has priority and the newer (more recent) name may be placed in *synonymy* in a subsequent revision.

Classification. Systematists attempt to reflect evolutionary relationships in hierarchical classification systems. In the most basic classification system, modified from that first erected by Linnaeus in the 1700s, species hypothesized to be closely related are grouped within genera, related genera within families, families into orders, and orders into classes. Beyond the basic classificatory levels of the Linnaean hierarchy, the systematist may choose to recognize intermediate-level catagories (e.g., subgenera, tribes, subfamilies, superfamilies, suborders, or superorders). With respect to nomenclature, each genus has a *type species* to serve as the standard for that grouping and with which the generic name must always remain, regardless of what other species might be assigned to it. A large percentage of the fish genera ever described are listed in Jordan (1917–1920), Golvan (1962), and Eschmeyer (1990). If subgenera are to be recognized, a nomenclatural convention similar to that of subspecies applies. The subgeneric grouping containing the type species retains the name of that genus, as for example, *Etheostoma* (*Etheostoma*) *blennioides*, while other subgeneric groupings may receive other names, as in *Etheostoma* (*Nothonotus*) *rufilineatum*; species names are most often written as binomials, but if the subgeneric allocation is to be indicated, it is placed in parentheses as above. In the literature, when a genus and its nominate subgenus are being interchangeably discussed, they may be distinguished by referring to the genus in its entirety as "sensu latu" (in the broad sense) (e.g., *Etheostoma* s.l.) and the subgenus in the restricted sense, "sensu strictu" (*Etheostoma* s.s.). At higher levels, each family has a type genus. Family names (all ending in "idae") are extensions of the type genus name (e.g., *Perca*—Percidae); names of orders stem from one of the component families and end in "iformes" (e.g., Perciformes). Like species, genus and subgenus names and names of higher rank may be synonymized or resurrected as deemed necessary by taxonomists publishing revisionary studies.

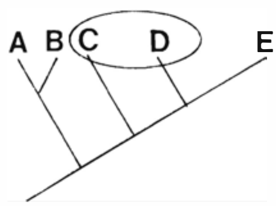
There are three basic approaches or schools of thought on how to arrive at classifications: *evolutionary*, *phenetic*, and *phylogenetic*. The relative merits of these have been hotly contested among systematists in recent years. Evolutionary systematists take a varied (sometimes referred to as "synthetic", e.g., Nelson, 1984) approach to classification, placing taxa into groups both according to relative similarity within and between groups, interpreted as the degree of change between common ancestors and descendant groups, and, to the extent that these are based on a phylogenetic framework, on probable "derived" characters (see below). In some cases, these classifications may also be influenced by opinions as to where taxa are most likely to fall into hypothetical lineages perceived in the fossil record or according to processes believed to be acting on these lineages, such as geological history. Pheneticists construct groups purely on overall similarity within and between groups with no regard to either historical information or the advanced or primitive natures of those individual features which contribute to similarity. This method has been most commonly applied at lower taxonomic levels (species relationships, etc.). On the other hand, phylogenetic systematists, or *cladists*, strive to construct groups defined strictly on what are believed to be shared evolutionary novelties, or "shared derived" characters (synapomorphies), characters passed down through common lines of descent, which denote the genealogy of the group. In this way they hope to attain "natural" classifications based solely on *monophyletic* groups, that is, groups descended from common ancestors.

In cladistic analyses, conditions, such as a particular type of bony structure or color pattern, shared between organisms under study which are candidates for inclusion in a group (ingroup) at a particular level of classification, are deemed primitive or derived by comparison to an "outgroup," consisting of species presumed to be more distantly related than the organisms under study are to one another. Conditions also found among the outgroup are considered to be primitive (i.e., attributable to a distant common ancestor) while those that are not present in that group might be considered derived evolutionary novelties indicative of more recent common ancestry and, hence, closer relationship. Decisions must also be made, often aided by the sum of overall evidence in a *phylogeny* (branching scheme of relationships), as to whether similar attributes are *homologous* (of common genetic origin) or *homoplasous* (of separate genetic origin but similar because of evolutionary convergence or happenstance); only the former can be considered shared derived characters. Only derived characters are used in support of hypotheses of close relationships and the identification of closest relatives or "sister groups"; those deemed to be primitive, while they may contribute to the overall similarity of the organisms, are not considered important at the level of the ingroup. Though somewhat controversial (see Nelson, 1978, 1985; Mabee, 1989a,b), developmental (ontogenetic) information is also sometimes used in character analysis, with those features that develop later in the ontogeny of, for example, a larval fish, generally considered more derived. Whatever the method of character analysis, among the possible "phylogenetic trees" arrived at, the one with fewest branchings or steps (the "most parsimonious") is usually accepted as the most tenable hypothesis of relationships. Cladistic methodology was introduced to the United States by Willi Hennig (1965, 1966) and is gaining acceptance in recent years among fish systematists as the preferred approach to determining phylogenies on which to base truly natural classifications.

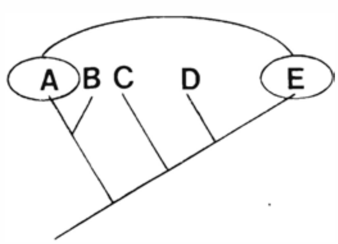
Systematists may make two kinds of "mistakes" in erecting classifications and naming groups. Rather than attaining the desired monophyletic groupings, some classifications may result in *polyphyletic* or *paraphyletic* groupings. Polyphyletic (error of inclusion) groups contain members which do not share most recent common ancestors, thus stemming from separate lines of descent and not being one another's closest relatives. Paraphyletic (error of omission) groups do not contain all of the descendants of a given ancestor necessary to result in a "complete" monophyletic group because some actual descendants remain arbitrarily assigned to another group. Thus systematists must continually attempt to resolve relationships among organisms and update classifications to reflect these relationships in order to avoid



monophyletic group



paraphyletic group



polyphyletic group

Diagrams (i.e., cladograms) of actual evolutionary (phylogenetic) relationships among five taxa, A-E, showing different kinds of groupings a systematist may hypothesize: **monophyletic group**—a correct hypothesis that taxa C, D and E have a common most recent ancestor (i.e., a correct natural grouping); **paraphyletic group**—an incorrect hypothesis that taxon E does not share a most recent common ancestor with taxa C and D and thus E omitted from group; **polyphyletic group**—an incorrect hypothesis that taxa A and E have a most common recent ancestor when, in fact, three most recent common ancestors are not shared.

such groupings. Classifications are always provisional and constantly changing to reflect new hypotheses. Several groupings, especially higher groupings of fishes, are strictly provisional, erected for practical convenience, until such time as higher relationships are better understood.

Classifications of fishes have evolved for over three centuries, beginning even before the concepts published by Linnaeus (1758) in *Systema Naturae*, which were based primarily on those of Linnaeus's fellow Swede, Peter Artedi, and a few even earlier (mid-1600s) concepts of Englishman Francis Willoughby. In the late 1700s and early 1800s, European ichthyologists greatly expanded on the knowledge of Linnaeus's time and published several comprehensive faunal works reflecting their ideas of classification. From 1798–1803, the French ichthyologist B. G. E. Lacepede published his *Histoire Naturelle des Poissons*, and German ichthyologists Marcus E. Bloch and Johann G. Schneider published *Systema Ichthyologiae* in 1801. Later came one of the great classifiers of the animal kingdom, the Frenchman Georges Cuvier, who published *Le Regne Animal* (1816) and began the classic 22-volume work *Histoire Naturelle des Poissons* with Achille Valenciennes (1828–1849). In the 1830s, the Swiss zoologist Louis Agassiz (later of Harvard) published fish classifications with particular emphasis on fossil forms, and English ichthyogist William Swainson (1839) published a work devoted strictly to fish classification; he may have been the first to formalize the "idae" endings to family names within fishes. Classifications of higher groups of fishes were hypothesized by Mueller (1844) and Agassiz (1862). More comprehensive works reflecting then-current views of classification ensued in the following decades (Gill, 1872; Guenther, 1859–1870; Boulenger, 1904). Jordan (1923) and Berg (1940) published major classifications based in a large part on previous concepts of C. T. Regan (1909) of the British Museum. Jordan's classification included genera in addition to families, an effort repeated by Norman (1957). A new, considerably revised, provisional classification was attempted by Greenwood et al. (1966) with a particular focus on attempting to reflect the genealogy of groups. Most recently, classifications somewhat modified from those of Greenwood et al. were published by Nelson (1976, 1984). The order of the latter publication is largely followed in this book. The sequence of listing of groups within a higher classification of organisms, once relationships are hypothesized among the groups to determine proximity in the listing, is generally from what is deemed evolutionarily most primitive to most derived (e.g., from the primitive sturgeons to the "higher" perciform fishes).

Biogeography. Studies attempting to discern the distributional history of lineages are termed "biogeography." Geographical distributions of these lineages are considered in light of relationships hypothesized from systematics studies to infer the distributional history of ancestral forms and possible causal factors, such as geologic or climatic events, for their subsequent speciation. For instance, closely related fishes in adjacent drainages may have had a continuously distributed common ancestor occurring at a time when both drainages were interconnected; subsequent isolation of the drainages and division of the ancestral population resulted in speciation into two forms (*vicariant* event). Or the ancestor may have initially occupied only one drainage and subsequently entered the other through some temporary connection where it evolved into a second species (*dispersal* event). These scenarios are often debated among biogeographers and, in the cases of freshwater fishes, the distinction between them can sometimes be unclear. Problems with interpreting the distributional history of North America's freshwater fishes are made abundantly clear in the several works published in Hocutt and Wiley (1986) and those of Tennessee in particular in Starnes and Etnier (1986).

To learn more about biogeography in general, and the evolution of the many perceptions and theories associated with this science, readers should consult the works of Darlington (1957), Simpson (1965), Udvardy (1969), Pielou (1979), Nelson and Platnik (1981), Nelson and Rosen (1981), and papers found in the journals *Systematic Zoology* and *Biogeography*.

Methods for Fish Taxonomic Studies. Ichthyologists use several approaches to study distinctions and relationships among fishes, including "traditional" morphological methods, biochemical methods, chromosomal studies, and, most recently, molecular approaches. In morphological studies, *meristic* data (counts that relate to body segments such as scales and fin rays) and other counts (e.g., gill rakers, sensory pores and other features) and *morphometric* (body measurements) data are extremely important (see Counts and Measurements section). The ichthyologist may gather such data on large comparative series of specimens and subject it to a variety of techniques, including univariate and multivariate statistics, in order to understand the variation within and among populations. Detailed analyses of shapes in fishes using body measurements, often using computer-assisted multivariate analyses such as principal components or discriminant functions, are termed *morphometrics* and have been of some utility in distinguishing closely similar forms (see Bookstein et al., 1985; Strauss and Bond, 1990). Increasingly, video-camera images of fishes are fed directly into a computer and are then digitized in Cartesian coordinates to facilitate easy designation of landmarks for instantaneous distance and angle measurements (e.g., Ehlinger, 1991). In addition, more qualitative attributes, such as color patterns, fin configurations, skeletal and muscular features, and distributions of breeding tubercles may be utilized in the analysis of differences and similarities among fishes under study.

Skeletal (*osteological*) and muscular (*myological*) studies have been extremely important over the years, particularly in the study of higher (intergeneric, interfamilial etc.) relationships among fishes. Dried skeletons were used in early studies and are still used to a lesser extent for certain information, particularly from larger specimens. These are prepared by either boiling and picking flesh from the skeleton, a very time-consuming technique, or by allowing bacterial decomposition or carrion-eating organisms to clean the bones. Large specimens may be left out-of-doors, covered by hardware cloth or similar arrangement to prevent removal by larger scavengers, where insects will clean the skeleton over a period of several weeks. Institutions that prepare large numbers of skeletons maintain colonies of dermestid beetles whose larvae perform this function. Also, see Mayden and Wiley (1984) for an additional method of skeletal preparation. Nowadays, most ichthyologists study specimens that have been cleared and stained and stored in glycerin rather than dry skeletons. These specimens, which necessarily must be relatively small, are usually cleared with potassium hydroxide solution and have the flesh digested away with an enzyme, such as trypsin. The bones may be stained red with alizarin solution, and cartilage may be counterstained with alcian blue. Several papers are available on clearing and staining techniques, including Taylor (1969a), Dingerkus and Uhler (1977), and Taylor and Van Dyke (1985). Radiographs (X rays) are also used in osteological studies; these do not usually have sufficient resolution for detailed studies but can provide information on presence or absence of structures and facilitate vertebral counts on series of specimens without damaging them. In addition to figures herein (13,17) Lagler et al. (1977), Bond (1979), and Caillet et al. (1986) provided reasonably good illustrations of fish skeletons. Other guides are Gregory (1933) and Weitzman (1962), though it should be noted that the former has several errors.

Myological studies require careful dissection to ascertain and compare the origins and insertions of various muscles of fishes being studied. Winterbottom (1974) provided a valuable guide to muscle nomenclature among various groups of fishes.

The advent of powerful microscopes that can magnify thousands of times, such as light transmission and scanning electron scopes, has opened up a new area of investigation for fish systematists. Knowledge of the microstructure of features such as scales, teeth, gill rakers, and many others, promises to add a great deal of new insight to studies of fishes.

In the past two decades, protein data has become very important to fish systematics. Analyses of variation in proteins within and among fish groups by electrophoretic techniques has become commonplace. Variation can be compared visually by the banding patterns that result when extracts from fish muscle, liver, eyes, or other tissues are subjected to electric current passed through a bed of starch gel or other medium treated with buffers and stained for specific proteins. Differences in banding patterns result from differences in electric charges associated with different protein molecules which determine mobility. Data from electrophoretic studies, aside from its utility in discrimination between different "electromorphs," and thus species-level taxonomy, can be, as with morphological data, subjected to both phenetic and cladistic methods to assess relationships among organisms. Much more information on electrophoretic techniques is available in Brewer (1970), Buth (1984), Richardson et al. (1986), Aebersold et al. (1987), Hillis and Moritz (1990), and Leary and Booke (1990).

More recently, DNA techniques have entered the realm of systematic studies. Analysis of maternally inherited genetic material (mitochondrial DNA) or nuclear DNA from cells of fishes or other animals is now possible through the use of restriction enzymes which recognize specific codon sequences and, with repeatable consistency, cut DNA into fragments at these sites. Fragment sizes may be compared through the use of electrophoresis to detect differences in sequences between organisms. It is also possible, by recombinant methods too detailed to discuss here, to clone and sequence the DNA fragments for further comparative studies. DNA "probes," prepared from bacteriophages or in a mechanical synthesizer, can be "hybridized" to fish DNA to allow detection of variation down to the level of individuals (see Wilson et al., 1985; Ferris and Berg, 1987; Gyllensten and Wilson, 1987; Moritz et al., 1987; Hallerman and Beckman, 1988; Hillis and Moritz, 1990). Extremely refined data results from such studies, to the point that, based on mitochondrial DNA, maternal "pedigrees" can be reconstructed for animals studied. Such studies will offer a tremendous new source of data for studies of relationships among fishes as well as addressing questions pertaining to hybridization phenomena and population biology.

Finally, some ichthyologists have conducted systematics studies of fishes by comparing chromosome number and morphology. In a process called "karyotyping" (see Denton, 1973; Blaxhall, 1975; Kligerman and Bloom, 1977; and especially Thorgaard and Disney, 1990), spreads of metaphase (undergoing division) chromosomes from individual cells are prepared so that they may be counted and compared with respect to configuration. Some surprising information with regard to chromosome numbers among closely related fishes has emerged from these studies. For example, some may have evolved twice as many chromosomes as others through a process called tetraploidy. Further, unisexual species, such as those discussed herein under Poeciliidae, may be triploids. Karyotypy, which examines only the gross morphology of chromosomes, may have somewhat limited utility in elucidating relationships of fishes, but recently developed techniques to reveal banding patterns on chromosomes have some promise of revealing additional variation for analyses.

It should be pointed out that, no matter what the methods and data source utilized in systematics studies of fishes or other organisms, the interpretation of that data among different workers is always subject to controversy. The concept of what constitutes sufficient variation among populations for formal recognition as a species or other taxon varies among taxonomists. What constitute "significant characters" on which to base ideas about relationships are always in dispute. Moreover, relationships hypothesized on the same body of data treated by the different approaches to classification (phylogenetic or other) may result in very different outcomes. These same basic problems have arisen successively in morphological, chromosomal, and protein studies and are emerging in DNA studies as well.

Biological Studies of Fishes

Ichthyologists who study the biology of fishes may be concerned with any of several aspects, including reproduction, early life history, age and growth characteristics, population dynamics, food and feeding habits, predation and parasitism, habitat parameters throughout the year, and other ways in which fish interact with their environment and the community of organisms they live with (ecology). The results of such studies have provided much valuable information cited throughout this book's species accounts.

Studies of reproduction include determination of spawning season and habitat, *fecundity* (number of ova spawned by a female), courtship and actual spawning behavior, and post-spawning behavior, such as nest-guarding by males. Actual "reproductive success" is a function of how many progeny survive to an age to contribute to production of subsequent generations and is thus related to "recruitment" (see discussion of population characteristics, below). Much of what is known about reproduction in fishes was summarized in systematic fashion by Breder and Rosen (1966).

Spawning season can generally be determined by collecting individuals as the year progresses and observing the increasing fullness of the females as the ovaries become expanded with maturing eggs, a condition known as being *gravid*. Males of many species have secondary sexual characteristics, such as breeding colors or tubercles, which heighten in development. More precise estimates of spawning season can be obtained when females are so "ripe" that eggs flow freely from the vent with the application of a little pressure to the abdomen. Males, too, may flow milt at this time, but sometimes some flow can begin well before the females reach actual spawning condition. For fecundity estimates, it is generally necessary to dissect the ovaries of a series of females at the beginning of the season in order to obtain an average of mature ova; fecundity generally increases with the size and age of the female. These estimates are probably often confounded by the fact that, in species with extended spawning seasons, more ova may have matured in a given female as the season progressed. The general spawning habitat of fishes is relatively easy to ascertain as they will congregate in that area, in some cases after a long migration, during the height of the season. On the other hand, spawning microhabitats for more specialized spawners can be much more difficult to ascertain and may require lengthly observations and searches for egg deposition sites. These are still not known for many fishes that spawn in habitats with poor accessibility.

Observations of pre-spawning behavior, such as nest construction, courtship and spawning behavior, and post-spawning can be relatively easily obtained for a few species which are tolerant of life in aquaria, but this information must be gotten in the natural habitat of the majority of fishes, either by stream-side observation, snorkeling, or diving. It requires a tremendous amount of time and luck to encounter sufficient behavior for detailed observations, and many fishes spawn in habitats that are of limited accessibility or visibility. Consequently, this information is nonexistent or fragmentary for many fishes.

Early life history studies of fishes entail a great deal of tedious work with fragile organisms. With some species it is possible to gather eggs from the natural spawns of known parents or to "strip" (extrude eggs by massaging the abdomen) from a ripe female and artificially fertilize them with milt extruded from a male; this method is also very often used for artificial propagation of fishes in hatcheries. Often, spawning is induced by administering gonadtropic hormones (e.g., pituitary extracts) to fishes nearing spawning condition. Eggs are then hatched in captivity and periodically observed microscopically to gather data on development times and the progressive morphology of the developing larvae. Rearing of larvae has proved very difficult in some groups of fishes, limiting collection of such data. In other groups it has been necessary to collect larvae periodically over a season with fine mesh plankton nets (either towed or situated in current) and then attempt to determine development from a preserved series by "backtracking," beginning with specimens large enough to definitely identify to species and associating them with progressively younger stages. Such associations facilitate larval taxomony, and together with collection data, provide valuable information on habitats essential to the fishes' early life history. While there has been tremendous progress with such studies in the last two decades, detailed data are still only available for a small percentage of all fishes. For further information on methods see Snyder (1983) and several papers presented in Moser et al. (1984).

Biologists studying the age and growth characteristics of fishes use a variety of techniques ranging from simple to rather sophisticated. One of the simplest methods is to collect large series of individuals from a population over a short period of time and try to infer age classes from histograms of length data (*length frequency*); for example, a trimodal histogram would indicate three year classes. Because populations are usually heavily skewed towards younger individuals, and because growth increments are often small in older fishes, discerning older length (age) classes can be difficult with this method, especially in longer-lived species. Length-weight data is also sometimes utilized as an estimator of fish growth.

Other methods of determining growth in fishes usually involve relating growth rings in hard parts to fish lengths. Scales have been most commonly used for this form of analysis with measurements made by placing slide-mounted scales in some type of projector and measuring the image from the focus of the scale to various annuli (see Anatomy and Function section, above). The age-length relationship, based on measurements from scales removed from a large series of fishes of known lengths, facilitates a "back-calculation" procedure so that lengths at certain ages can be predicted and fishes from that population can be aged approximately by simply noting their length. However, there are often problems with this procedure because growth rates may not be uniform (*isometric*) over time or between body parts (thus being *allometric*) and, in some populations, scale annuli, for various reasons, can be difficult to discern. Other structures that have been used for aging studies are cross-sectioned fin spines (particularly of catfishes), opercular bones, vertebrae, and otoliths (see Anatomy and Function, above). Otoliths, sectioned and projected on a scanning electron microscope, can provide extremely refined growth information, with even daily growth rings discernible. For more information on aging of fishes consult the works of Lagler (1956), Weatherly (1972), Bagenal (1974), Moyle and Cech (1982), Jearld (1983), and Summerfelt and Hall (1987).

Studies of population characteristics include estimates of density, total population, age structure, recruitment of young into the population, survival, and predator-prey density relationships, as well as studies of distribution and movements. Such studies require considerable sampling over several seasons and the analysis of much data. Sampling methods (see fish collection methods in following section) include intensive netting of an area with unbiased gear, trawl surveys, and ichthyocide applications to a given area, and investigation of anglers' catches. Such sampling facilitates the extrapolation of density estimates of varying validity, and age analysis of the fishes caught yields data on age structure, recruitment (and thus overall reproductive success), and survival. Fishery biologists have attempted to better understand and perhaps predict trends in fish population dynamics by modeling them with computer-assisted techniques. Tagging and marking (catch, tag, release, recapture) studies have been very important in gathering data on movements, as have radio telemetry studies in which a tiny transmitter is surgically implanted in a fish which is then released and tracked. There is still a great deal to be learned about the vagaries of fish populations, especially among those species not in the mainstream of economic importance. Further information on fish population studies appears in Weatherly (1972), Weatherly and Gill (1987), and Cushing (1983); instructions on related techniques appear in several chapters of Nielsen and Johnson (1983).

Studies of food and feeding may involve direct observation of feeding behavior and food selection as well as detailed analysis of stomach contents. The differences in feeding behavior and specific feeding sites among fishes may be subtle; to ascertain them can require many hours of observation in the natural habitat, and of course, some habitats do not lend themselves to this kind of observation at all. Stomach contents, coupled with detailed knowledge of the distribution of food organisms, such as immature aquatic insects, in the habitat can offer tremendous insight, not only to food preferences but to specific feeding habitats. Periodic coincidental sampling of both fishes and potential food organisms in the habitat through the seasons, and moreover, periodic sampling of fishes over the course of a day, can provide detailed data on seasonal and chronological trends in consumption and diet preferences. Fishes and samples of potential food organisms are generally preserved in the field and returned to the lab until such time as the fishes can be dissected for stomach contents and these contents, as well as the samples from the environment, sorted and identified. Of course, an ability to sort and identify potential and actual food items—such as aquatic insects, mollusks, small fishes, or others—is critical. Potential food organisms should be carefully sampled both qualitatively and quantitatively to ascertain specific sites of occurrence (to reveal where fishes are eating) and estimates of density, which can be compared with occurrence in stomachs to give indications about food selection. Stomach contents of predatory species also, of course, are a key source of information on predator-prey relationships. A good introduction to these methods is found in Bowen (1983) and further information is given in Ivlev (1961).

While the biology and ecology of economically important species have been studied for many years, and there has been some emphasis on lesser-known species in recent years, a tremendous amount is yet to be learned. Even some of the well-studied species continue to surprise us with unexplainable fluctuations in population levels, reminding us how little we presently know about their interactions with the environment; of course, we have barely scratched the surface for many, more obscure, fishes.

Collection and Preservation of Fishes

In order to conduct studies on the systematics and biologies of fishes it is often necessary to make collections. When making a general collection of fishes from a locality it is advisable to thoroughly sample all habitat types and, if possible, to preserve large series, representing all size classes, of each species collected. In this way, potentially new information on distribution and habitat of fishes can be discovered, and adequate sample sizes are assured for any studies that might ensue. Of course, in some cases, restraint should be used in the collecting of rare species with localized populations. When conducting more specialized collecting, as in targeting a particular species under study, it is advisable to also retain those fishes incidentally collected as they are always potentially informative to another study. For some research, such as population dynamics or ecological studies of various kinds, repetitive sampling at a given locality is necessary. In such cases, the sampling regimen and the kinds and numbers of fishes that will be retained in collections should be carefully considered previous to conducting fieldwork.

Collecting Permits

For most types of collecting, it is necessary to obtain a scientific collecting permit from the state agency governing fish resources (e.g., the Tennessee Wildlife Resources Agency). In some states, including Tennessee, it is permissable to collect non-endangered fishes and non-game fishes with a small seine (up to 10 ft) with an ordinary fishing license. However, for most of the other methods discussed below, a special collecting permit is necessary, and it is advisable to obtain a permit in any case if one is to be engaged in frequent fish-collecting activities.

Collecting Techniques

Ichthyologists collect fishes by a variety of techniques, including several kinds of nets and traps (see several chapters in Nielsen and Johnson, 1983), chemicals, and electroshocking. In some cases, even angling has provided valuable specimens for study.

Use of twelve-meter seine to beach seine small fishes in Mississippi River.

One of the most common techniques, particularly for smaller fishes, is with small-meshed nets called seines. These nets have mesh sizes ranging from a few millimeters to over a centimeter and may be from less than 1 to many meters in length and 1 to 3 or so meters in depth. Such seines are weighted with lead along the bottom edge so as to maintain contact with the substrate and have floats along the top edge to keep the net extended vertically. The float and lead lines are usually tied to poles (sometimes called brail poles) at each end to facilitate pulling the seine through the water. Practice and skill come into play in maneuvering the seine through the water in such a way as to trap fishes within it. The poles should be angled backward at all times so that the bottom of the seine is in the lead; fishes are usually trapped by landing the seine smoothly on shore or quickly lifting it horizontially. Maintaining contact with the bottom for as long as possible is essential; it may be necessary to "walk" the lead-line by hand over obstructions or vegetation, forcing it to the bottom as much as possible. Kicking the substrate or vegetation just ahead of the seine to scare up fishes is productive in areas of substantial current. Long seine-hauls relative to the length of the net are generally not more productive than shorter ones and increase the chances of snagging. When seining in moderate current, it is advisable to pull downstream a little faster than the current velocity to avoid current resistence and take advantage of fishes' natural tendencies to escape upstream, although occasionally it is very productive to seine upstream to an obstruction and trap fishes against it. In riffle habitats, fishes that live on the substrate, such as darters, can be collected by stretching the seine across a portion of the riffle and vigorously disturbing the substrate upstream of it by kicking, followed by a quick lift. In slack waters, shoving a seine beneath cover, such as brush or tree roots, as far as possible without impeding retrieval—followed by kicking that cover and quickly lifting the seine—can be very productive.

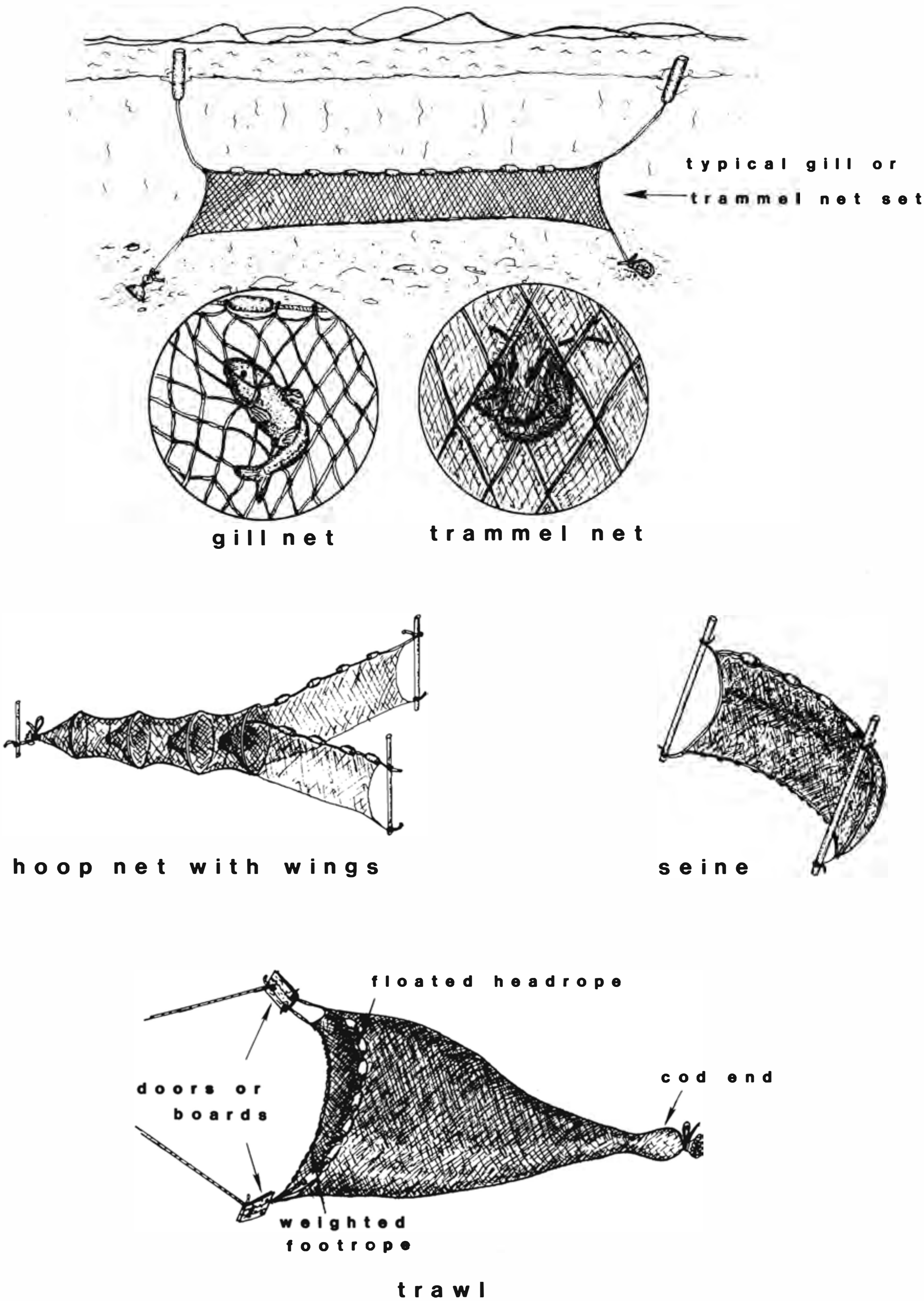
Some species of stream fishes, such as active darters or those living beneath boulders, can be very difficult to collect with seines. If water clarity permits, a very effective way of selectively collecting these fishes is by snorkeling with a face mask and carefully pursuing them with a dark-colored (green is best) dip net. The 8–10 inch varieties available from aquarium dealers work reasonably well, though a slightly larger mesh size (such as seine material) is more maneuverable in water. It is relatively easy to approach most benthic fishes with such a net and, with a little practice, maneuver them into it. It is usually better to wear sneakers rather than swim-fins when working in shallower areas.

Other types of nets sometimes used for collecting, particularly larger species, are gill nets, trammel nets, hoop or trap nets, and trawls. Gill nets are constructed of fine material, such as monofilament, with mesh sizes ranging from one to several centimeters, depending on what the targeted catch is. They are weighted along the bottom and have floats along the top, and lengths may range from a few to hundreds of meters; depths are usually about 1 to 3 or 4 m. Nets with alternating panels of varied sized mesh, called "experimental gill nets," are sometimes used for sampling a habitat. Fishes that encounter a gill net usually pass partway through a mesh opening and become ensnared behind the gills and further entangled from the subsequent struggling. Gill nets are usually set out for a few hours, often overnight when reduced visibility improves their effectiveness. Trammel nets, which are somewhat similar, consist of one small-mesh net suspended closely parallel to two large mesh nets. Fishes encountering the net force the small-mesh net through one of the large mesh openings, becoming impocketed on the opposite side. Gill and trammel nets may be fished suspended from the surface by the float-line or heavily weighted at either end and fished at the bottom or in midwater. They are most often used in slack-water habitats but may be fished in rivers if anchored parallel to the current. An example of a good set of a net would be the downstream tip of an island at dawn or dusk. Cross-current sets will usually quickly fill with floating debris and be rendered ineffective.

Hoop or trap nets are somewhat similar to the familiar minnow trap consisting of netting stretched over a frame or hoops to form a box or cylinder with an inwardly tapering funnel entrance. Fishes entering the traps through the funnels have difficulty relocating the small apertures in order to escape. Sometimes wing nets are added to further funnel fishes toward the trap net, and the traps may be baited but most often are not. In streams, these nets are anchored with the funnel entrance facing downstream. They are most effective when fishes are "on the move," such as during spawning migrations.

Trawls are bag-shaped nets that are towed behind boats. They range in size from 2 to 3 m (such as the "try" nets used by shrimpers) to 20 m or more in width (large vessels). The bottom lip of the bag is weighted and the top floated to keep it open in the vertical dimension. "Doors" or "otter boards" are attached to the tow bridles on each side of the net; these "flare out" when towed through the water to widen the mouth of the net and stabilize it. Trawls may be fished on the bottom or in midwater. Trawling is the only method for making large collections from deeper waters. Obviously, there are numerous hazards to these operations; they are successful only on relatively snag-free bottoms. Methods of rigging trawls for collection from small boats were elucidated by Lopez-Rojas et al. (1984).

The most effective collecting techniques for thoroughly sampling shallower fish habitats involve the use of chemicals called "ichthyocides." It is absolutely necessary to have a scientific collecting permit and additional special permission from authorities to utilize such techniques, and they should be performed only by experienced personnel. Ichthyocides affect and immobilize fishes that are virtually inaccessible to other collecting techniques and facilite much more accurate quantitative sampling than other methods. These chemicals usually act by inhibiting oxygen uptake in the gills. One of the most widely used ichthyocides is "rotenone," a derivitive of certain leguminous plant roots, such as derris root. South American Indians discovered the powers of this chemical and have fished with it for centuries. Concentrated commercial preparations are very powerful, and a liter or two can effectively sample 50–100 m or more of stream or a portion of a lake; marine collectors have used it effectively in tidepools and on reefs. However, effectiveness is greatly reduced at lower water temperatures, and strength of rotenone preparations varies a great deal, particularly with age. It is possible to neutralize the effects of rotenone by the addition of other chemicals (e.g., potassium permanganate). In streams, in addition to dip-netting, it is usual practice to



Basic types of fishing nets (trawl is shown from above).

place a block net, such as a long seine, across the stream at some distance below the chemical application site to collect immobilized fishes. In slack-water habitats, an area is usually enclosed by netting before sampling with chemicals. See Davies and Shelton (1983) for detailed information on the use of rotenone and other chemicals.

Another chemical which has been effectively used for general sampling, but to a lesser extent than rotenone, is sodium cyanide (Lewis and Tarrant, 1960; Tatum, 1969). Though far less toxic than potassium cyanide, it is still necessary in many states to have a special permit to handle this chemical in addition to the usual scientific collecting permits. The chemical comes in powder or briquette form, and a small amount applied to a stream can effectively sample a reach. Breakdown of the chemical occurs quickly after placing in water, and it is thus not necessary to neutralize it with additional chemicals as with rotenone applications; thus the effects on most fishes is temporary and the survival rate of those not collected appears to be quite high, though the benthic invertebrate community may be temporarily affected. Saltwater fishes collected with cyanide have low long-term survival, and the chemical has a deservedly bad reputation in the aquarium trade. Saltwater fishes drink sea water to compensate for loss of body water by diffusion, and cyanide apparently destroys digestive tissues and results in eventual starvation. An additional advantage of sodium cyanide over rotenone is uniform strength and thus more predictable results, though, like rotenone, effectiveness is positively correlated with water temperature. We have found this chemical a particularly useful tool in collecting difficult-to-sample habitats, and its use has made some important contributions to the knowledge of fishes in Tennessee. Again we emphasize that such chemicals are to be used only by experienced and properly permitted collectors with tasks at hand that justify their use.

Finally, another method sometimes used for fish collecting is electroshocking. Backpack units or small stream-side generators are used in smaller streams; larger boat-mounted units are used in rivers and lakes. In simplest terms, shockers consist of a generator unit or battery connected to electrodes which are placed in the water to produce an electric field. Both AC and DC current types have been devised, with DC being generally less harmful to fishes. Commercially available designs can be operated relatively safely. Fishes within the electric field of a shocker are generally temporarily immobilized by electrotetanus, though some mortality can result. In DC fields, fishes are literally drawn to the anode via *galvanotaxis* (forced orientation and swimming) as the electric current acts upon their sensory systems. Effectiveness of shocker units depends, of course, on the strength (voltage) of the unit and, especially, conductivity of the water. Like ichthyocides, electroshocking permits collecting in some habitats where seines are ineffective and has the advantages both of limiting coverage to a very specific area and of not being affected by water temperatures. On the other hand, shocker units are cumbersome, noisy, expensive, and less effective for thorough collecting of larger areas. See Reynolds (1983) for further information on electroshockers.

Electroshocking for brook trout in Smoky Mountains with gasoline-powered backpack unit.

Treatment of Collections

When collecting fishes, it is important to quickly preserve them to insure their usefulness for scientific studies. The usual way of preserving fishes for systematics research, and many kinds of biological studies requiring subsequent dissection, is to fix them in a formalin solution. Formalin is a commercially available liquid prepared from formaldehyde gas which stabilizes tissues by cross-linkage of proteins, thus preventing decomposition. Formalin is very irritating to the eyes, nasal membranes, and open cuts of the skin, and some persons develop extreme sensitivity after repeated use. Caution must be exercised by using it in well-ventilated areas and washing off after contact. If accidentally splashed in the eyes, repeated bathing with water will usually relieve the irritation in a few minutes. Some forms of formaldehyde are known carcinogens, and any unnecessary contact should be avoided.

The usual concentration of formalin for preservation is a 10% solution (5% buffered for larval fishes). Since fishes will dilute the liquid with their own fluids, it is advisable to begin with a 15–20% solution to achieve the desired strength if many fishes are to be preserved. Filling the collecting container (jar or sealable bucket) to 10–20% capacity with pure formalin before collecting, and then adding sufficient water at the collecting site to bring to 50–60% capacity before adding fishes, usually results in adequate preservation. Fishes should be placed directly in the preserving fluid, preferably while alive, to insure maximum preservation. If preferred, it is possible to anesthetize fishes before preservation with a solution of tricaine methanesufonate (often commercially sold as "MS-222"). Specimens should not be so overcrowded as to distort body shape, crimp fins, or overtax the preservative. Larger specimens should be injected with fluid or slit along the right side of the abdominal cavity soon after initial preservation to assure penetration of the preservative. It is possible to preserve in formalin fishes that have been dead a few hours or frozen, but all but the smallest of these should be injected. Some ichthyologists prefer to use buffered formalin to offset its acidic properties, which may cause some skeletal and melanophore deterioration. If desired, buffering can be achieved with calcium carbonate in the form of marble chips.

It is of paramount importance to place a waterproof label in the collection container before leaving the field site to insure that locality information remains with it. Various waterproof papers are available and can be written on with india ink or pencil. Full locality information—including, for instance, state, county, stream name, road crossing, distance from town or suitable landmark, date, collectors, and field number—should be included on the label; or simply a field number referable to separate field notes with this information can be placed in the container. It is a good idea to keep field notes with complete locality information, plus habitat characteristics such as stream size, water depth, temperature, color, substrate, shore type and others, and to make notations about the fishes collected, such as particular habitat, life colors (which will soon fade in preservation), and so on, and any fishes that may have been released.

Upon returning from the field, after the fishes have been fixed in formalin for 2–4 days, depending on size of specimens, for most uses it is desirable to transfer fishes to alcohol for permanent storage to avoid working with irritating formalin solutions and minimize possible long-term effects of formalin on specimens (decalcification). In silvery fishes, such as minnows and suckers, it may be desirable to leave the specimens in formalin for a couple of weeks until most of the guanine has cleared from the scales such that underlying pigment patterns are no longer obscured. The storage medium of choice for many years has been a solution of 70–75% ethyl alcohol. Specimens have remained well preserved in such solutions for well over a hundred years. More recently, a 40–50% solution of isopropyl alcohol has been used for fish storage. Isopropyl has the advantage of being less expensive and much easier to obtain than ethyl alcohol (which is tightly regulated by law). However, it has been questioned as a long-term storage solution because it is harder to keep up to adequate concentration to prevent specimen softening in the face of evaporation without overconcentrating at times, which causes brittleness and clearing of specimens. Specimens being transferred from formalin to alcohol should be thoroughly rinsed to remove excess formalin and allowed to soak in water or weaker alcohol solutions a few days during transferal.

After collections are processed in the above manner, they may become part of permanent museum collections (usually as sorted lots of individual species) for future systematics research, or they become part of a teaching or short-term research collection of a less permanent nature.

Interested amateurs who want to collect and preserve fishes in order to consult experts about them should follow the basic procedures outlined above only to the extent of formalin preservation and labeling with field data. This will suffice until such time as an ichthyologist can be consulted. If formalin is not available, specimens can be frozen or at least kept on ice until consultation. Amateurs can potentially make valuable contributions to our knowledge of fishes.

Native Fishes in Aquaria

As aquarium fishes, our native species have been largely overlooked in favor of more exotic ones. There are a number of striking and interesting fishes inhabiting our own streams, as is evident from the illustrations in this book. Many kinds of minnows, darters and topminnows (see Quinn, 1991a,b), sunfishes, and other fishes adapt quite easily to life in an aquarium and can make interesting and, in some cases, beautiful pets. Such fishes as the southern redbelly dace, rosyside dace, northern and southern studfishes, golden topminnow, longear sunfish, and tangerine darter make extremely attractive aquarium fishes, though their colors may fluctuate seasonally. A few species, for various reasons, are difficult to maintain. In particular, those fishes that live in very cool, well-oxygenated environments, such as mountain streams, do not do well in aquaria without special modifications. A few fishes, such as some sucker species, have "nervous dispositions" and remain frightened and hyperactive in confinement and usually succumb. Others, such as some topminnows and sunfishes, are easy to maintain as individuals but are aggressive toward other fishes in confinement and may cause injury. Other species simply do not compete well in aquaria. For instance some darters, because of delicate feeding behavior, cannot obtain sufficient food if very many rapid feeders, such as minnows, are present. Such fishes may be kept separately or with a reduced number of competitors. Small catfishes, such as the madtoms, adapt well to aquarium life but are often retiring, only leaving cover at feeding time or in dim light. Trial and error will generally permit the interested aquarist to discover some native species that do quite well either in community or segregated tanks.

Aquaria for native fishes should be well aerated and equipped with a filter. Attempting to duplicate the fishes' natural habitat with the appropriate substrate type (rocks, gravel, sand, vegetation, wood, etc.) can make a more attractive tank and provides cover to those species that prefer it. Plenty of cover can allow fishes that otherwise do not coexist well to sort out specific territories and thus reduce hostilities. Many species adapt well to commercially prepared flake or pellet foods. Others, such as darters, are more finicky but usually will take frozen brine shrimp, chopped earth worms, live meal worms or "black worms"—most of which are available from aquarium shops. Very small species, such as pigmy sunfishes, may require live baby brine shrimp which are commercially available as eggs and can be easily hatched and maintained in an aerated jar of salt water; these are easily extracted for feeding with a food baster.

We recommend that aquarists consider native fishes as additions to their hobby. They will be surprised at some of the fishes easily available within a few minutes or hours of home and will discover the fun of collecting their own pets. As previously discussed under Collection and Preservation of Fishes, a fishing license or collecting permit should be obtained before collecting fishes for aquaria or other purposes. Serious aquarists who set up specialized tanks for certain species may even be able to make significant contributions to our knowledge of certain aspects of the behavior of our native fishes, such as spawning, which are still in many cases poorly known. However, we implore aquarists *not to release fishes in waters other than from where they came*. Many accidental introductions of fishes into nonnative habitats have had detrimental effects on native fishes. Furthermore, such unpublicized introductions may cause misconceptions with regard to native fish distribution for future biologists.

Identification of Fishes

Many users of this book may wish to identify fishes they have encountered in Tennessee's waters. While it is often possible to eventually identify a fish with some accuracy by comparing the specimen with illustrations and range information, this method is subject to error when specimens in question are from areas where similar species occur together. Moreover, for many species, it is extremely important to have definite locality information in order to make accurate distinctions between closely related forms that occur in different drainages. The most reliable way to identify a fish with which one is unfamiliar, short of consulting an expert, is through the use of taxonomic keys and careful comparison with range information, written descriptions, and illustrations.

To facilitate accurate identifications, it is preferable to have several relatively mature representatives of the species in question so that aberrant, potentially misidentifiable, individuals might be recognized. It is also extremely helpful in some cases if life colors of the fish are present or were noted at the time of capture for comparison with color descriptions. On the other hand, in some fishes with silvery guanine in the dermis (e.g., several minnow groups), potentially diagnostic dark pigment patterns do not show up until after being preserved and left in formalin for several weeks.

Use of Taxonomic Keys

Taxonomic keys are designed to allow a person to take a specimen of unknown identity and subject it to successive "tests" for the presence or absence of key identifying characters and, by elimination, eventually deduce the correct identification. While using keys to fishes, it is often necessary to make certain counts or measurements on the specimens to make distinctions between species; methods for these are discussed and illustrated in the following section.

Most taxonomic keys, like the ones presented herein, are "dichotomous," allowing the user to simply choose between two alternatives at each step based on the presence or absence of a particular feature, the number of scales or fin rays, etc., or the range of ratios between body measurements. Each numbered step in the key, consisting of two alternative statements, is termed a "couplet." It is extremely important to consider both statements in each couplet relative to the specimen in hand before proceeding to the next to insure best results from a key. In the following simple example, a fish specimen with 6 lateral dark blotches, 40 lateral-line scales, and 8 anal fin rays from the Tennessee River drainage is "walked through" the couplets to illustrate their use.

Thus we arrive at Species D as the probable correct identification.

As the reader may guess, this is an extremely simple example, and resolving the identity of specimens by use of keys dealing with large numbers of taxa, which vary geographically and with age, is generally not so easily done. Many keys, especially larger ones, will necessarily have several conditions to be met in each couplet, such as a particular scale count range, fin ray count, and pigment attribute; occasionally specimens being keyed will conflict among these. Even in simpler keys, occasional specimens will have conditions that seem ambiguous with regard to a particular couplet. In such cases, the user should retrace steps through the key to be sure an incorrect choice was not previously made. If not, the specimen should be keyed both ways beginning

EXAMPLE KEY

1. Dark lateral blotches 5 or less . . . . *Species A*
   Dark lateral blotches 6 or more 2
   [*thus we go on to couplet 2*]
2. Lateral-line scales 35 or fewer . . . . *Species B*
   Lateral-line scales 38 or more 3
   [*thus we go on to couplet 3*]
3. Anal fin rays 6–7; Conasauga River . . . . *Species C*
   Anal fin rays 8–9; Tennessee River . . . . *Species D*

with the ambiguous couplet. Also, if possible, several specimens of the fish in question should be examined to gain an estimate of variation in critical key characters; this may demonstrate that the majority of specimens would favor a particular choice at the troublesome couplet. In any event, the final distinction between possible identities is made by carefully comparing species names indicated by the key with distributional information, descriptions, illustrations, and in the case of this book, the sections on Similar Sympatric Species, given in the species accounts. Often this will facilitate an easy choice of a name for specimens that were otherwise troublesome in the key. If conflicts cannot be resolved, an expert should be consulted. There is always the possibility of additional species being found in Tennessee or significant range extensions within the state.

Counts and Measurements

When attempting identifications or conducting taxonomic studies on fishes it is often necessary to conduct certain counts and measurements of body parts in order to make choices in a taxonomic key or to compile descriptive or analytical data. Locations for making these counts and measurements are illustrated in Figure 25. By convention, these are made on the left side of the fish when possible.

Counts of body parts related to body segmentation are termed *meristics*. Examples of these include counts of vertebrae, fin rays, and longitudinal scales. Examples of other kinds of counts not related to body segmentation include those of gill rakers, sensory pores of the head, and certain pigment attributes. The following explanations and suggestions apply to those counts and measurements that need clarification beyond the illustrations. Further information on methods for counts and measurements is found in Hubbs and Lagler (1958), and Strauss and Bond (1990).

Scale Counts: Conducting counts of scales can be quite easy or very difficult depending on the characteristics of the species being examined. Some fish have relatively large and firmly attached scales, which make counting very easy. Others have very small scales that may be covered with mucous, or have scales that are very deciduous (easily shed). For fine-scaled species, it is often helpful to dry the area to be counted by blowing air over it. The scales will often become more discernible with drying, especially those of the lateral line. How-

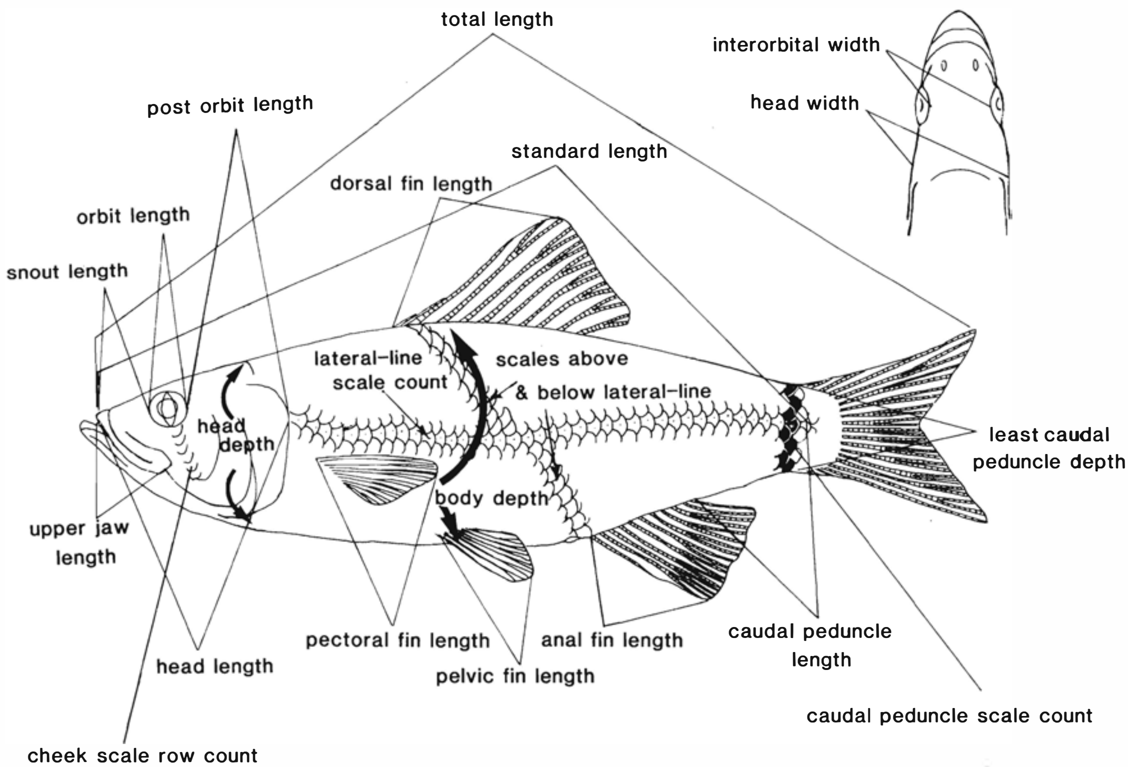


Figure 25. Locations for making counts and measurements on a fish (drawn in part by N. Henn).

ever, in some cases, it may be necessary to lift the posterior edge of each scale individually with a fine needle to assure an accurate count. In species that shed the scales easily, it is possible, with practice, to get an estimate of scale counts by counting the empty scale pockets along with existing scales if not too many are lost, or to count the oblique scale rows persisting above or below the lateral line. Except in larger fishes, a dissecting microscope or other magnification is usually required to facilitate accurate scale counts.

—*Lateral-line scale count.* This count is made from the first pored scale behind the supracleithrum (bone along upper posterior margin of gill opening) to the caudal fin base, as determined by bending the caudal fin to one side and observing where the crease occurs; scales occurring on the base of the fin posterior to the crease are not properly included in the count. In species without a developed lateral line, scales are counted in a longitudinal series over the same approximate course over the midlateral area; such counts are sometimes referred to as "scales in lateral series" or "scale rows along side of body." In species with incomplete lateral lines, the number of pored lateral-line scales and total scales in the line to the base of the caudal fin are usually both noted.

—*Scales above and below the lateral line.* These counts include the scales nearest the base of the first dorsal and anal fin elements (but not on the dorsal or ventral midline) and are made diagonally to, but not including, the lateral-line scale row. The proper position for the count varies with species.

—*Caudal peduncle scale rows.* The count is made around the most slender portion of the caudal peduncle by zigzagging back and forth around an imagined line around this area.

Fin Element Counts: Fins in preserved fishes are not often spread sufficiently to permit easy counts of spines and rays, and it is often necessary to gently spread the fins by gently flexing the body or by lifting these elements, sometimes one by one, with a probe or needle to obtain an accurate count. Magnification is often required to discern these elements with accuracy. In many publications, counts of spines are designated by Roman numerals to distinguish them from soft rays in fin ray count formulas (e.g., "XI,14").

—*Dorsal and anal fin ray counts.* In spiny-rayed fishes, all spines of the dorsal and anal fins are counted, regardless of size. For soft rays of the dorsal and anal fins, the small "rudimentary" rays at the origins of these fins are not included in counts for minnows (Cyprinidae) and suckers (Catostomidae) because they are difficult to discern; thus only the larger *principal rays* (one large unbranched plus several branched) are counted in these groups. In other groups, such as catfishes and topminnows, all anterior rays are usually included in counts. Posteriorly, the last two small branched soft rays, if their bases are closer together than those of more anterior rays, usually share a common basal element and are conventionally counted as one.

—*Caudal fin ray counts.* Caudal fin ray counts may be given as branched rays only, or as principal rays (branched rays + 2, including the 2 large exterior unbranched rays).

—*Paired fin ray counts.* All rays are included in counts of the pectoral and pelvic fin rays, except that the small, thin ray, sometimes found bound tightly to the anterior aspect of the first large ray in these fins, is included in counts for the pectoral fin but not the pelvic.

Vertebral Counts: For systematic studies it is often necessary to collect data on vertebral counts, which can vary between and within species. These counts are often made from radiographs (X rays), but counts are sometimes made from cleared and stained specimens and dried skeletons. The *caudal vertebrae* are those beginning roughly above the origin of the anal fin which have the ventral processes fused to form a haemal spine; vertebrae anterior to these have divergent processes, often have ribs associated with them, and are counted as *precaudal vertebrae.* In fishes that have the anterior vertebrae modified into a Weberian complex (e.g., minnows, suckers, catfishes), the first vertebra and the complex are counted together as four (five in catfishes).

Gill Raker Counts: Gill rakers (Fig. 19) are counted on the first arch. We typically make this count on the right side of the fish since some cutting and tearing may be necessary, and dissecting scope light sources typically make this count easier. Laying the fish on its back and holding the head with one hand, while manipulating the gill flap with the forefinger of the same hand, facilitates counting with a probe held in the other hand. It is sometimes necessary to slit the ventral or dorsal gill cover connection in order to open the gill flap sufficiently to expose the arches. In species with long and numerous rakers, it may be necessary to separate them one-by-one with a needle for counting. All rakers, no matter how small, are counted unless otherwise stated. Counts for the upper and lower limbs of the arch are sometimes noted, separated by a + sign (e.g., 6 + 21); a raker situated at the joint of the upper and lower limbs is included in the count of the lower.

Pharyngeal Tooth Counts: In minnows and suckers the fifth gill arches are modified, being greatly strengthened and bearing inwardly directed teeth (Fig. 20). These teeth may occur roughly in a single row or there may be one or two additional shorter rows. Conventionally, counts are given for both sides, beginning with the shorter row on the left side: thus a specimen with two teeth in the shorter row and four in the longer row on each arch is designated 2,4–4,2; a specimen with only a single row of four teeth on each arch is 4–4. In the majority of species, counts are symmetrical, but some species commonly have more teeth on one arch than the other.

In order to count pharyngeal teeth, it is necessary to carefully dissect the arches from the gill cavity and clean the excess flesh from them. If possible, cutting away the dorsal and ventral connections of the arches with a fine blade is the best way to extract them intact. With practice, however, it is possible to carefully insert, mostly by feel, small forceps behind these connections and gently free the arch without significantly damaging it or surrounding structures.

Branchiostegal Counts: Counts of the branchiostegal bones or rays (Fig. 13) are sometimes important in distinguishing taxa. The anterior rays may be small and, especially in laterally compressed fishes, several of them may be bound tightly together, necessitating the use of a sharp probe to locate each one. Flexing the head relative to the vertebral column to free the gill membranes from the breast often makes the count easier.

Head Pore Counts: Counting of cephalic lateral-line pores (Fig. 26) and locating interruptions in this system often require drying the region with compressed air or repeated blowing by mouth. Air directed from the barrel of a small-mouth medicine dropper inserted into the air supply tube works well for this purpose when light pressure is released.

Body Measurements: Body measurements of fishes consist of distances between anatomical landmarks or extremities (Fig. 25). These measurements can be taken with a simple set of needle-point dividers subsequently compared to a millimeter rule—a slow method—or with calipers, of which there are several kinds available, including vernier, dial, and electronic digital. The

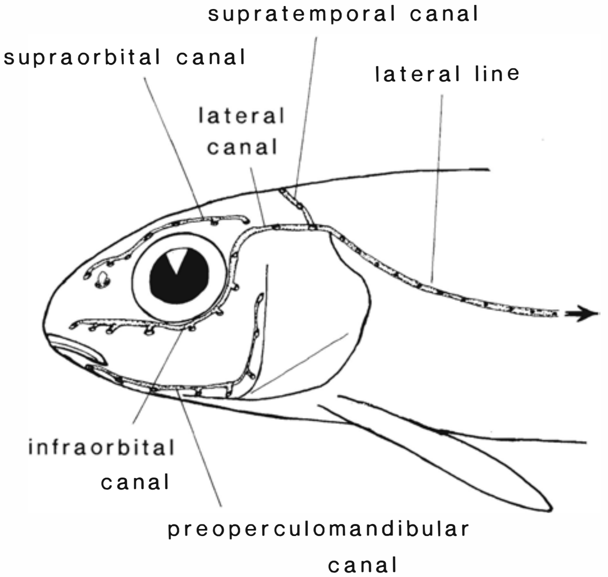


Figure 26. Cephalic lateral-line (external acoustico-lateralis) system of the head region of a fish (minnow) showing locations of canals and pores.

last have the capability of being connected directly to a computer file for easy data entry. Recently, electronic digitizer boards have been used in various ways, with some success, to measure projected or transferred images of fish. All methods are subject to some degree of error due to imprecise placement of measuring devices and specimen distortion. These imperfections can only be accepted and minimized by careful attention to details; needle-point dividers or calipers are essential for placing devices as precisely as possible, and straight, unshrunken specimens should be selected for measuring when possible.

Traditionally, several "extremal" measurements (e.g., maximum body depth, least caudal peduncle depth) have been, and will continue to be, included in descriptive data of fishes; ratios involving these measurements standardly appear in keys. These kinds of measurements can vary considerably in their actual location on the fish, and it may be preferable for more meaningful comparisons, especially when generating data for new studies, to approximate these distances by some related measurement between fixed anatomical landmarks (e.g., for body depth, distance between dorsal fin and pelvic fin origins).

—*Standard length.* Standard length is the measurement most often taken by ichthyologists. It traditionally has been used as the standard of comparing sizes between individuals and often is used as the denominator of proportional body measurements, which are often quoted in "thousandths of standard length." The measurement is taken from the tip of the snout or upper jaw (most anterior of these) to the base of the caudal fin (end of urostylar vertebra or base of hypural plate), as determined by bending the fin to the side and observing the location of the crease at the base of the fin. Standard length is, of course, inapplicable to species without homocercal caudal fins, such as lampreys, ganoid fishes, eels, and cods.

—*Total length*. Measured from the anterior extremity of the head (snout tip or upper jaw, whichever projects farther) to the posterior extremity of the compressed caudal fin (upper or lower lobe). In fisheries work, total length is typically measured from the tip of the lower jaw if it extends farther forward than the snout or upper jaw.

—*Head length*. Head length is measured from the tip of the snout or upper jaw to the most posterior (preferably bony) portion of the opercle.

—*Head depth*. Measurement of head depth is somewhat subjective and usually is measured on an approximate vertical from the occiput or from the occiput to the isthmus (Fig. 25).

—*Head width*. Maximum width of the head is subject to great variation based on the position of the gill covers. If necessary, before measuring, the gill covers should be forced as close to a normal closed position as possible.

Methods for taking other body measurements should be evident from Figure 25.

How to Use the Family and Species Accounts

The orders and families of fishes treated in this book are arranged in phylogenetic sequence, that is, roughly in order from those considered most primitive (the lampreys) through the evolutionarily most derived fishes found in Tennessee (members of Perciformes). The sequence largely follows the classification of Nelson (1984), and group names follow that publication with two exceptions (see Aphredoderidae and Mugilidae). Within families, genera and species are treated in alphabetical order. Undescribed species are treated at the end of the appropriate genus.

If a user of this book wants to locate information on a fish of known identity, or to further identify a fish collected in Tennessee already identified to family, the Table of Contents may be consulted to locate the proper family. If the user wants to identify and find information on a fish of which the identity is unknown or uncertain, the Key to the Families of Tennessee Fishes which follows this section should be consulted to begin the search (see previous section on Use of Taxonomic Keys).

Within the family accounts the reader will find general information on the family, keys to genera and species, and accounts devoted to specific information on each species in the family. General family information pertains to classification, appearances in the fossil record, definitive characters, overall distribution, and general comments on biology, economic importance, and other aspects. In families containing several genera, a key to these is provided, while some smaller families have generic and species keys combined. Again, the reader should consult the previous section on Use of Taxonomic Keys to aid in the proper identification of Tennessee fishes. Keys are provided with page-number references for easy location of taxa.

Once the reader has located the genus in question, in many cases a general generic account will be found in addition to the species accounts that follow. The typical generic account gives the genus name, followed by the name of the ichthyologist who originally described it, information on the systematics and distribution of members of the genus, definitive characters, general biological and other comments, and an etymology giving the derivation of the latinized name of the genus (see explanations on Etymology under the species accounts). The general accounts of larger genera are followed by keys to the species contained within it. We can not overemphasize the care that must be taken when keying members of these larger genera to insure accurate identifications. Possibilities inferred from the key should be thoroughly checked against the descriptions, illustrations, distributional information, and especially the comments on potentially confusing taxa (Similar Sympatric Species) given in the species accounts.

Species accounts are presented for all fishes indigenous to Tennessee plus several introduced species which maintain some degree of permanent residency. The typical species account and the information provided within it are as follows.

Scientific name and common name: For example, *Notemigonus crysoleucas* (Mitchill). Golden shiner. The scientific name is an italicized binomial composed of the name of the genus containing the species and the unique species epithet (see Systematics and Taxonomy of Fishes). This name is followed by the original author who described the species. If the author's name is not enclosed in parentheses, the generic assignment for the species remains unchanged from that of the original description. If the author's name is in parentheses, as in the above example, the species was placed in another genus at the time of its original description (in this case, *Cyprinus* in 1814) and subsequently removed to the genus *Notemigonus* by another author. The common or vernacular name follows that of the author. Both the scientific and common names, with a few exceptions, follow the most recent list of accepted names published by the American Fisheries Society (Robins et al., 1991). In many cases, there are other local or regional vernacular names for fishes, especially those that are commonly encountered by anglers. We have tried to relate the better known of these in the Biology section of the account.

Illustration of Species: Each species is illustrated, usually with a black and white or color photograph or both. In most cases, we have attempted to include illustrations of "average" specimens to be representative of the species, but the user must be aware that many fishes vary in appearance with age and reproductive condition, and the specimen illustrated might differ considerably in appearance from another of the same species. In a few cases, multiple photographs are provided to illustrate dimorphic or otherwise variable species. In the case of minnows or other silvery species, we have selected for black and white photos specimens preserved for sufficient periods in formalin to reveal the underlying dark pigment patterns. For many colorful species, color illustrations are provided, especially to show peak spawning dress. Most were photographed under anesthesia or within minutes after being fixed in formalin solution so that natural coloration is only slightly or not at all faded, though some iridescent qualities are nearly always lost under the latter conditions.

Characters: The characters section provides meristic and other counts (see previous section on Counts and Measurements) plus descriptions of scalation, coloration, other definitive characters, and breeding tubercles if developed (see Anatomy and Function for descriptions of fish morphology). Counts pertain mainly to specimens from Tennessee; specimens from extralimital populations may differ from these. In instances where counts have a considerable range, the initial value or values given are typical of 90% or more of the specimens, followed by the extremes (range) in parentheses. In some cases modal (most commonly occurring) counts are given; in these cases, parenthetical values again represent the known range, but the modal value may occur in fewer than 90% of specimens. Pharyngeal tooth formulas were explained previously under Counts and Measurements. Descriptions of coloration and morphology are brief, deferring to the illustrations, but attempts have been made to describe these in both juveniles and adults and in both sexes where they differ. We have attempted to follow a convention of referring to extensive longitudinal or horizontal body markings as stripes or streaks and vertical markings as bars, or bands (particularly where they encircle the caudal peduncle); markings traversing fins are usually referred to as bands. Breeding tubercle patterns are described to the degree known in all species where they occur and, in some groups in which these have not been adequately described, rigorous accounts are given. Larval fishes, which are as yet poorly known except for a few species, are not described, though references for descriptions of some species are given in the Biology sections, and meristic data given herein may be of some value in their identification.

Biology: In the biological section we present information on a fish's general habitat preferences. (For a discussion and definitions of habitat types and references to stream dimensions—e.g., small river versus large—see the above Habitats and Lifestyles section.) This is followed by a synopsis of available information on reproductive season and habitat, spawning habits, age and growth characteristics, maximum size, feeding habits, relationship to humans, and other miscellaneous information. In discussions of growth or maximum length, lengths given are total length (TL) unless otherwise noted as standard length (SL) or other (see Counts and Measurements). Where applicable, fishing techniques and even a few recipes are given. (Investigative techniques yielding biological information on fishes, and terminology, are discussed in the previous section on Biological Studies of Fishes.) Obviously, economically important fishes have received most of the attention of fisheries biologists. Virtually nothing is known of the biology of many of our smaller fishes, though more and more of these are studied as the years pass. Consequently, the published information available to synthesize is very imbalanced between species. In many cases, we have attempted to supplement meager information with our own observations based on relatively small sample sizes. While bordering on anecdotal, these observations nevertheless provide some preliminary insight into aspects of the biology (e.g., spawning season, growth, diet) of species for which these are otherwise totally unknown.

Distribution and Status: For most species a range map depicting the rivers and larger tributaries of Tennessee is provided for visual reference. A generalized total range is depicted on the inset map of North America. Specific distributional information on Tennessee populations with regard to drainages and, in many cases, physiographic provinces, is provided in the written accounts and summarized in Table 1; more precise information is also provided for overall ranges. The dot distribution maps for Tennessee fishes are based on about 8,000 collections made by ourselves, students and associates at the University of Tennessee and other institutions, as well as some literature records. Most literature records adopted are substantiated by museum specimens we have examined. Those not thus substantiated were used only if they stemmed from an area of known occurrence based on other collections. Questionable records are discussed in the written account. The sources for many of the records, including older collections from the last century, and comprehensive drainage surveys, are cited in the previous section, Ichthyology in the Region of Tennessee. Comments on status refer to relative abundance or rarity of a species within its range, or within Tennessee, and the general outlook for the species's long-term survival in the face of current or expected environmental conditions. In an effort to define terms of relative abundance, given that collecting efforts are in suitable habitat and, in some cases, season, *abundant* fishes will always be taken with minimal effort; *common* species will probably be taken with minimal to moderate effort, *uncommon* species occasionally taken with moderate to heavy effort, and *rare* species may require considerable targeted effort in precisely the right habitat and may not be taken at all at certain times.

Similar Sympatric Species: We feel that it is very useful to alert readers to species occurring or potentially occurring with the particular species being accounted that are similar enough in appearance to possibly be confused with it. Characters given for distinguishing between these species should provide easy resolution of such questions. Some relevant terms to be noted: *sympatric* species are those that occur in the same river system but may or may not occur in the same localities; *syntopic* species definitely occur at the same localities and may be expected to be collected together.

Systematics: The section on systematics is an optional one interjected where necessary for those species whose systematic position or nomenclature has been in question within the past few decades. Here, we discuss relevant literature or provide observations pertinent to these questions. Readers should consult the previous Systematics and Taxonomy section to gain a better understanding of matters discussed and terminology.

Etymology: The derivation of the latinized scientific name is provided for each species and, in the cases of some smaller genera, the generic etymology will also appear in this section. Many names are based on physical attributes or have geographic implications. Others are based on the name of a person, usually as a tribute. Genera are either masculine, feminine, or neuter in gender, and the gender of species names included usually agree, with certain exceptions. Ascertaining gender of genus names in question is complex and best left to competent Latin and Greek scholars. For instance, many names ending in "us" are masculine, and those in "a" feminine, but there are numerous exceptions to these, plus there are several other endings, such as "is," that are variable in gender.

Key to the Families of Tennessee Fishes

Note: In addition to families keyed here, the Atlantic needlefish, family Belonidae, has traversed the Tenn-Tom Waterway and may be expected in the Tennessee River in Tennessee; the extremely elongate body form and toothy, beak-like snout could not be confused with any Tennessee fishes except the gars, family Lepisosteidae. Needlefishes differ from gars (Couplet 5 below) in having a biblobed homocercal caudal fin, tiny cycloid scales, and pectoral fins inserted high on body rather than a rounded heterocercal caudal fin, large ganoid scales, and ventrally positioned pectoral fins as gars do.

1. Paired fins (pectorals and/or pelvics) present; external gill openings single on each side: bony fishes, Class Osteichthyes 2
   Paired fins lacking; 7 gill openings on each side (Fig. 27): *Superclass Agnatha, Family Petromyzontidae, the lampreys* . . . . p. 87

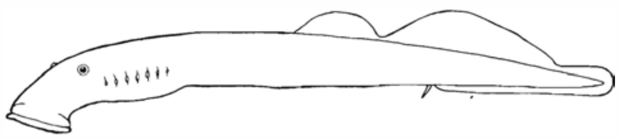


Figure 27. Lamprey.

2. Fleshy base of caudal fin asymmetrical in lateral view (heterocercal or modified heterocercal), with its dorsal portion extending much farther posteriad than its ventral portion (Fig. 28a,b) 3
   Fleshy base of caudal fin symmetrical in lateral view, homocercal (Fig. 28c): modern bony fishes, Subdivision Teleostei 6

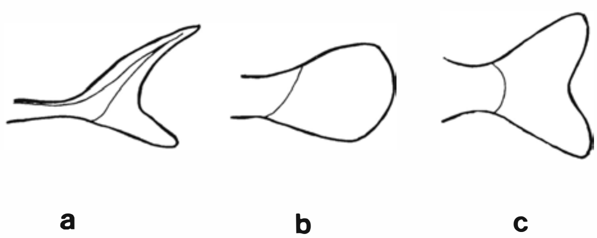


Figure 28. Caudal fin configurations: a) heterocercal; b) modified heterocercal; c) homocercal.

3. Body lacking a complete covering of scales; caudal fin heterocercal (Figs. 29–30): Infraclass Chondrostei 4
   Body completely covered with scales; caudal fin modified heterocercal in adults (Figs. 31–32): Infraclass Neopterygii 5

4. Naked except for small scales on dorsal lobe of caudal fin; snout paddleshaped (Fig. 29): . . . . *Family Polyodontidae, paddlefish* p.104

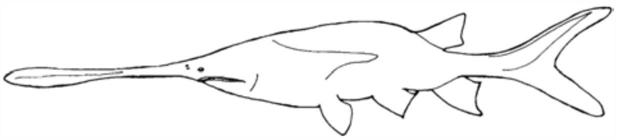


Figure 29. Paddlefish.

Back and sides with 5 rows of bony plates (Fig. 30) . . . . *Family Acipenseridae, sturgeons* p.98

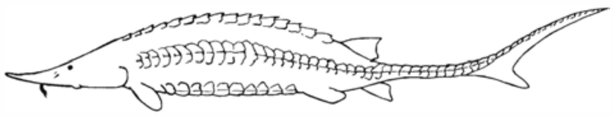


Figure 30. Sturgeon.

5. Scales diamond-shaped, not overlapping, jaws long and beaklike (Fig. 31) . . *Family Lepisosteidae, gars* p.107

Figure 31. Gar.

Scales ovate and overlapping; jaws normal (Fig. 32) . . . . *Family Amiidae, bowfin* p.114

Figure 32. Bowfin.

6. Dorsal fin single—composed of soft rays only, or having three or fewer spiny anterior elements 7
Dorsal fin divided by a distinct notch, or first four or more elements spiny, or both 22
7. Pelvic fins present 8
Pelvic fins absent 21
8. Top of head and/or operculum with some scales 17
Head completely lacking scales 9
9. Adipose fin lacking 10
Adipose fin present 14
10. Anal fin long, with 17 or more elements 11
Anal fin shorter, with 13 or fewer elements 12

11. Ventral margin of abdomen with sharp, saw-toothed edge (Fig. 33) ...... *Family Clupeidae, herrings* p.121

Figure 33. Herring (shad).

Ventral margin of abdomen with sharp, smooth edge (Fig. 34) .... *Family Hiodontidae, mooneyes* p.116

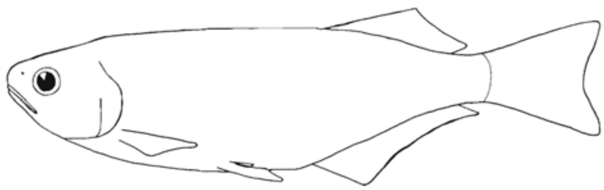


Figure 34. Mooneye.

12. Dorsal fin rays 9 or fewer; mouth usually not fleshy or modified for sucking (Fig. 35) .... *Family Cyprinidae (in part), native minnows* p.129

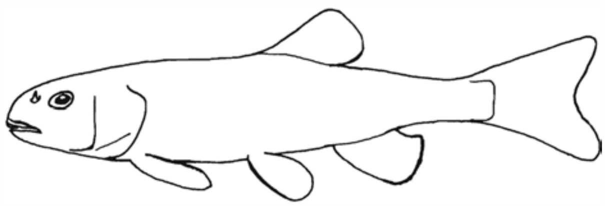


Figure 35. Native minnow.

Dorsal fin rays 10 or more; mouth typically fleshy, ventral, and modified for sucking 13

13. Dorsal and anal fins with first full-length element spiny and conspicuously serrate on posterior surface (Fig. 36) .... *Family Cyprinidae (in part), introduced minnows* p.129

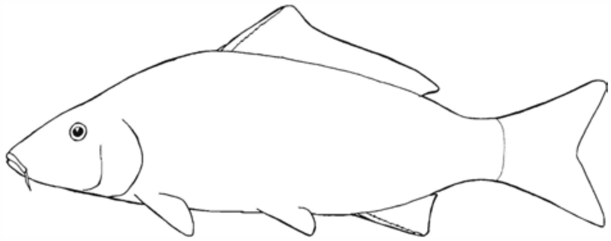


Figure 36. Carp.

Dorsal and anal fins lacking serrated spines (Fig. 37a,b) .... *Family Catostomidae, suckers* p.259

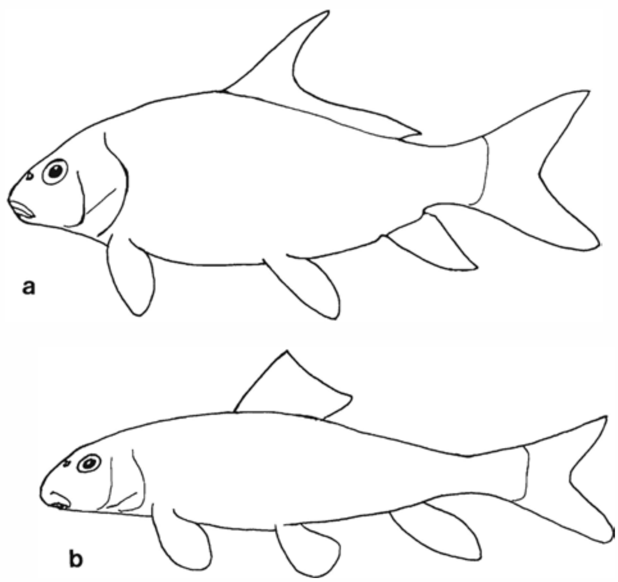


Figure 37. Members of sucker family: a) carpsucker b) redhorse.

14. Barbels lacking; scales present (Figs. 39–41) 15
Barbels conspicuous around mouth; body naked (Fig. 38) .... *Family Ictaluridae, catfishes* p.296

Figure 38. Catfish.

15. Axillary process lacking at base of pelvic fin; scales relatively large, about 40–75 in lateral series 16
Axillary process present at base of pelvic fin (may be small and blunt in *Salvelinus*); scales tiny, with 100 or more in lateral series (Fig. 39) .... *Family Salmonidae, trout* p.343

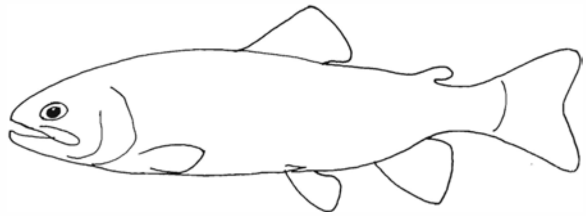


Figure 39. Trout.

16. Dorsal fin origin at about midbody, approximately equidistant between snout and base of caudal fin; scales cycloid, about 62–70 in lateral series; lateral line absent; thusfar occurring only in Mississippi River (Fig. 40) .... *Family Osmeridae, smelt* p.342

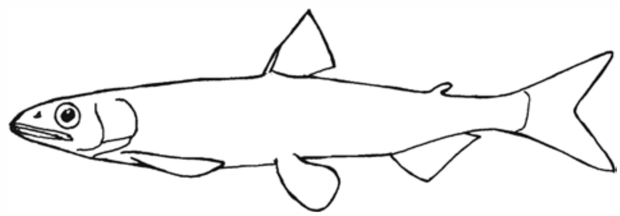


Figure 40. Smelt.

Dorsal fin origin more anterior, much nearer snout than caudal fin base; scales ctenoid, about 40–55 in lateral series; lateral line present; *probably extralimital* (Fig. 41) ..... *Family Percopsidae, troutperch*

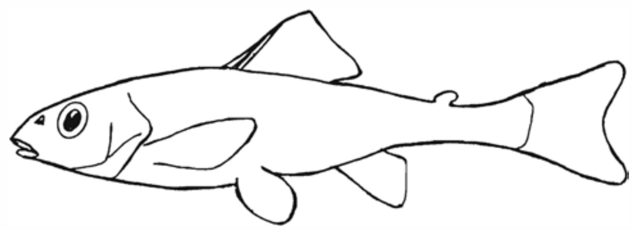


Figure 41. Troutperch.

17. Dorsal fin with three anterior spines; anus under throat (Fig. 42) . *Family Aphredoderidae, pirateperch* p.353

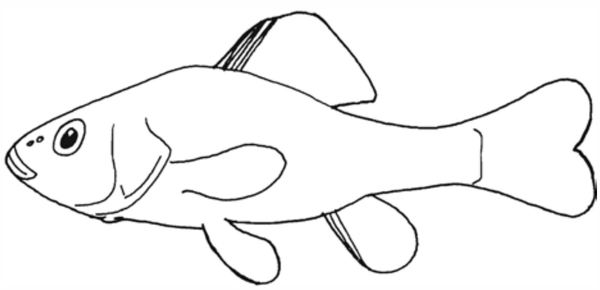


Figure 42. Pirate perch.

Dorsal fin lacking spines; anus immediately anterior to anal fin 18

18. Lateral scale rows more than 100; body very elongate; jaws produced to resemble a duck's beak (Fig. 43) . . . . *Family Esocidae, pike* p.332

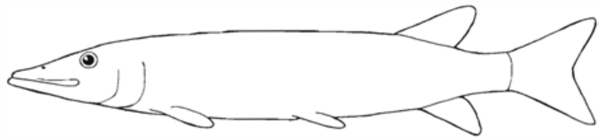


Figure 43. Pike.

Lateral scale rows 50 or fewer; body shape and jaws less elongate 19

19. Origin of anal fin approximately under middle of dorsal fin base (Fig. 44) . . . . *Family Umbridae, mudminnows* p.340

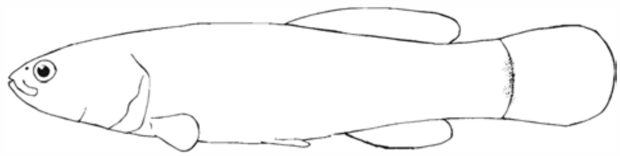


Figure 44. Mudminnow.

Origin of anal fin anterior to or about even with origin of dorsal fin 20

20. Black, triangular suborbital "patch" present; body not marked with horizontal lines; male with anal fin modified into an elongate intromittent organ (Fig. 45a,b) . . . . *Family Poeciliidae, mosquitofish* p.370

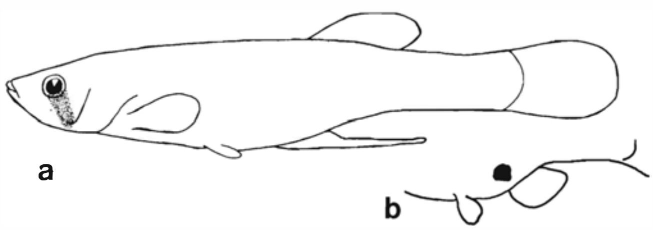


Figure 45. Mosquitofish: a) male, with anal fin modified into gonopodium; b) belly and anal fin configuration and preanal spot of female.

Black suborbital "patch" absent, or if present (*Fundulus dispar*) the body is marked with horizontal lines; anal fin unmodified in both sexes (Fig. 46) . . . . *Family Fundulidae, topminnows* p.360

Figure 46. Topminnow.

21. Dorsal, caudal, and anal fins united (Fig. 47) .... *Family Anguillidae, freshwater eel* p.119

Figure 47. Eel.

Dorsal, caudal, and anal fins separate (Fig. 48) .... *Family Amblyopsidae, cavefishes* p.355

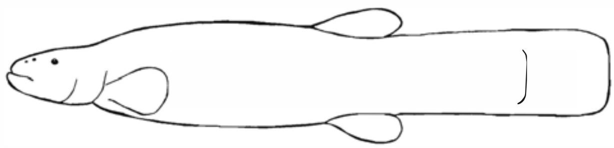


Figure 48. Cavefish.

22. Chin with distinct single median barbel; anal fin and posterior portion of dorsal fin subequal and very long, each with about 60 or more rays (Fig. 49) .... *Family Gadidae, codfishes* p.358

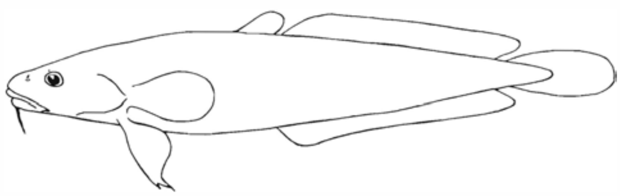


Figure 49. Burbot.

No median barbel on chin; anal fin and/or posterior portion of dorsal fin much shorter, never with more than 35 rays 23

23. Body covered with scales 24

Body naked 30

24. Pectoral fin base extending above lateral midline; spinous dorsal fin inconspicuous, remote from soft dorsal fin, and with 4–5 spines (Figs. 50–51) 25

Pectoral fin base entirely below lateral midline; spinous dorsal fin not as above 26

25. Anal spine single; eye near middle of head; adipose eyelid absent
(Fig. 50) . . . . *Family Atherinidae, silversides* p.375

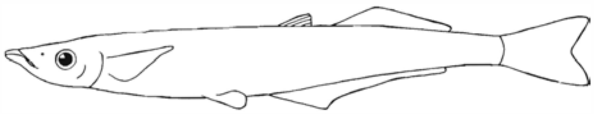


Figure 50. Silverside.

Anal fin with 2 (young) or 3 spines; eye distinctly anterior to middle of head; adipose eyelid present
(Fig. 51) . . . . *Family Mugilidae, mullets* p.379

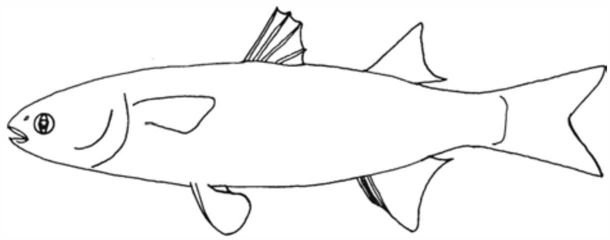


Figure 51. Mullet.

26. Dorsal fin soft rays 24 or more (Fig. 52) . . . . *Family Sciaenidae, freshwater drum* p.602

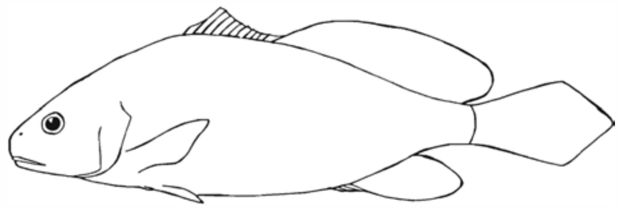


Figure 52. Drum.

Dorsal fin soft rays 15 or fewer 27

27. Total dorsal spines and rays 15 or fewer (IV–V, 9–10); lateral line absent; maximum length less than
45 mm (1.75 in) (Fig. 53) . . . . *Family Elassomatidae, pygmy sunfishes* p.396

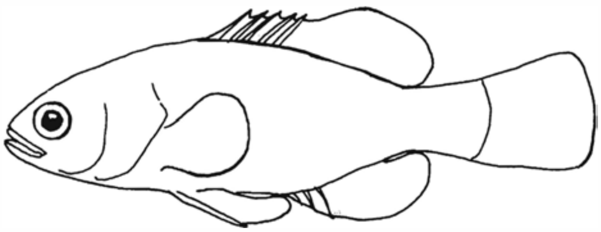


Figure 53. Pygmy sunfish.

Total dorsal spines and rays 16 or more; lateral line may be incomplete, but typically with at least several
pored scales anteriad 28

28. Anal spines one or two; body form "perch-like" or more slender and elongate
(Fig. 54a,b) . . . . *Family Percidae, perches* p.439

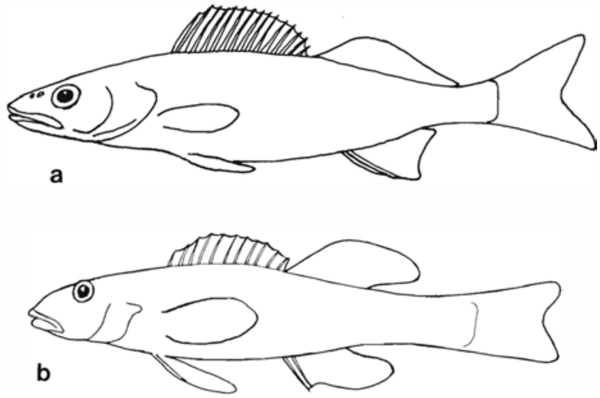


Figure 54. Members of perch family: a) walleye; b) darter.

Anal spines three or more; body form "bass-like" or deeper (Figs. 55–56) 29

29. Dorsal fins separated by a deep notch; two black horizontal lines conspicuous above lateral line; posterior edge of operculum terminating in a sharp spine
(Fig. 55) . . . . *Family Moronidae, temperate basses* p.389

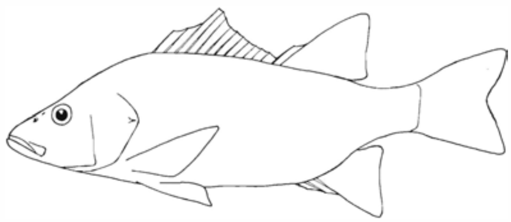


Figure 55. White bass.

Dorsal fins well joined, or if separate (*Micropterus*), horizontal lines are lacking above lateral line; posterior edge of operculum lacking a sharp spine (Fig. 56a,b) . . . *Family Centrarchidae, sunfishes* p.398

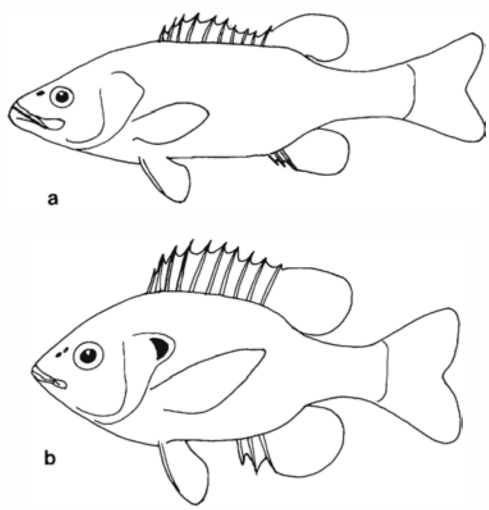


Figure 56. Members of sunfish family: a) bass; b) sunfish.

30. Dorsal spines free, stiff, and not connected by membranes (Fig. 57) . . . . *Family Gasterosteidae, brook stickleback* p.381

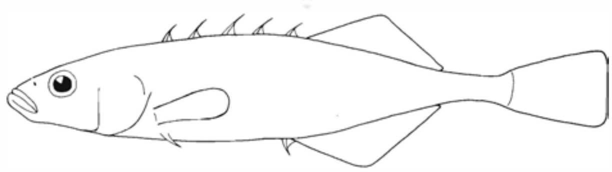


Figure 57. Stickleback.

Dorsal spines soft and connected by membranes (Fig. 58) . . . . *Family Cottidae, sculpins* p.383

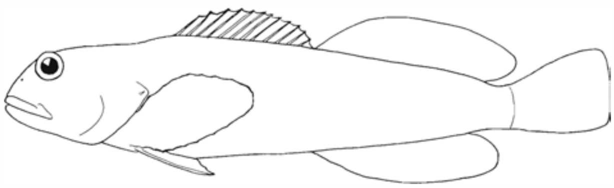


Figure 58. Sculpin.

Accounts of Tennessee Fishes

ORDER PETROMYZONTIFORMES

FAMILY PETROMYZONTIDAE
The Lampreys

Under many classifications, the lampreys (family Petromyzontidae) and marine hagfishes (family Myxinidae) were considered the only living representatives of the class or superclass Agnatha (jawless fishes). Extinct representatives of this group, the ostracoderms, were the first vertebrates to appear in the fossil record, with their skeletons preserved in deposits formed approximately 500 million years ago in the Ordovician Period (Nelson, 1984). Lampreys (order Petromyzontiformes) and hagfishes (Myxiniformes), like the extinct ostracoderms, lack paired fins and jaws, and have a single median nostril. The ostracoderms had well-developed external skeletons of dermal bone, but the lampreys and hagfishes have naked bodies and poorly developed cartilaginous internal skeletons. However, the latter two are not believed closely related and are placed in separate groups (classes or superorders) by some recent authors (e.g., Stensio, 1968; Nelson, 1984). Indeed, hagfishes are considered more primitive than vertebrates by several recent workers (e.g., Maisey, 1986; Pough et al., 1989) and are considered a sister group to, rather than a member of, the Vertebrata. Lampreys are characterized in the following paragraphs; hagfishes are strictly marine creatures which are primarily scavengers, boring inside of carcasses to feed.

Lampreys are primarily northern hemisphere fishes which first appear in the fossil record in the Pennsylvanian period about 280 million years ago (Bardack and Zangerl, 1968, 1971; Janvier and Lund, 1983). Closely related southern-hemisphere forms (three or four species) are variously placed in Petromyzontidae (sensu Potter and Strahan, 1968) or separate families, Geotriidae and Mordaciidae (Hubbs and Potter, 1971; see discussion in Bailey, 1980). Hardisty and Potter (1971–1982) and Hardisty (1979) have compended works on the biology of lampreys and hagfishes. Some species of lampreys live in the ocean and spawn in freshwater streams (anadromous) while others are strictly freshwater. Females are larger than males and lack the long, cylindrical urogenital tube of the males. In all species there is a larval stage, the ammocoetes, that differs from adults in having a hood-shaped structure surrounding the mouth rather than the concave sucking disc (buccal funnel), and in lacking externally apparent eyes. Morphology of ammocoetes was presented in detail by Vladykov (1950); biology was summarized by Potter (1980a). The ammocoetes stage persists for about 3–6 years in Tennessee species, during which time the larvae burrow in silt deposits in rivers and creeks. Food of the larvae includes microorganisms and detritus filtered from water flowing over these deposits. In the so-called "brook lampreys," ammocoetes attain adult proportions and metamorphose in the winter months, persist until the spring spawning period without feeding, and die shortly after spawning. The larger species of *Ichthyomyzon* ("river lampreys") are parasitic as adults and attain greater size after metamorphosis. In Tennessee waters they are often seen attached to larger fishes such as carp, buffalo, catfish, and paddlefish. *Petromyzon marinus*, the sea lamprey, does not occur in Tennessee. It is the species reponsible for decimation of stocks of lake trout and whitefish in the Great Lakes. The sea lamprey was originally anadromous on the East Coast, with several stunted populations landlocked in some eastern lakes. It gained access to the Great Lakes via the Welland Canal (Applegate, 1950). Although the canal was opened in 1829, sea lamprey depradations in the upper Great Lakes did not seriously alter fish populations until about 1940.

Adults of the parasitic species, which attain much larger size than nonparasitic species, attach to the host fish by means of the suction produced by their buccal funnel. They then rasp a hole in the fish with their abrasive tongue and feed on the fluids of the host. The sea lamprey is apparently capable of killing its host directly, or weakening it to the point that it is subject to death from other sources such as fungal infections. Native parasitic lampreys, which are smaller than the sea lamprey and have evolved with our other native fishes, have not been shown to have significant effects on populations of host fishes.

Neotenic development (retention of larval characters into adulthood) has been postulated as the origin for some nonparasitic lamprey species (Zanandrea, 1957; Hubbs and Potter, 1971; Walsh and Burr, 1981), but this hypothesis was challenged (without critical counter-analysis of material) by Vladykov (1985). Hardisty and Potter (1971) and Beamish and Neville (1992) hypothesized that "homogamy" (difficulty in mating between different sized individuals) further enhances separation of these paired species.

Adults move into streams and rivers prior to spawning and congregate on gravel shoal areas. They construct a depression by transporting gravel particles downstream with their buccal funnels. Parasitic forms typically have much higher fecundity (10–20,000+ ova) than nonparasitic species (500–3,000). Adults die shortly after spawning. Eggs deposited in the nests drift into the mound of gravel at the downstream side of the nest. Considerable predation on eggs and small ammocoetes by fishes has been observed for several lamprey species (Potter, 1980a). When the larvae become sufficiently active, they swim up into the current and are passively carried downstream until they are deposited in areas of reduced current. The ammocoetes larvae, occasionally used as bait for bass and walleye, are readily obtained from silt deposits in many of our streams and rivers by using electrofishing equipment or by stirring up the substrate and allowing the dislodged larvae to drift into a seine placed downstream.

Lampreys have received little attention as food fishes in North America, but they are frequently eaten by several Eurasian cultures. Ammocoetes are occasionally used as fish bait.

KEY TO THE TENNESSEE GENERA AND SPECIES

The Tennessee lampreys are similar in general appearance and do not offer large numbers of distinct taxonomic characters. This lack of easily quantifiable external characters has resulted in considerable taxonomic confusion. The genera *Lampetra* and *Ichthyomyzon* are quite distinct, and the difference in dorsal fin structure noted in the key is present in the larvae as well as the adults. Considerable reliance is placed on the number of muscle bands (trunk myomeres) between the last gill cleft and the anus. The first myomere counted (Fig. 12a) is the one with its posterior septum or boundary just behind the posterior gill cleft. The most posterior myomere counted is the one whose anterior ventral extension passes over the anterior dorsal rim of the cloacal opening. These wavy vertical bands of muscle are occasionally difficult to differentiate, and if difficulty is encountered, scraping congealed mucous from the sides of the specimen may be helpful. Myomere counts do not change during metamorphosis, and are useful in guessing at the identity of larvae. For instance, any larva from east Tennessee with separated dorsal fins and 63 or more myomeres is definitely *Lampetra appendix*. Although somewhat variable, the teeth and associated structures surrounding the oral opening of adults (Fig. 12b) are also useful taxonomic characters that are best studied under a dissecting microscope after excess fluids have been removed from the buccal funnel with a jet of compressed air. Vladykov and Follett (1967) provided a detailed terminology of lamprey dentition.

It is sometimes difficult to determine with certainty whether a small adult is a recently transformed specimen of one of the parasitic species or an adult of one of the nonparasitic species. When in doubt, an examination of the visceral cavity can offer positive identification. In the parasitic species, adults have poorly developed gonads until they reach a length of about 175 mm (7 in) TL or longer. The most conspicuous structure in the visceral cavity of an immature adult of one of the parasitic species will be the gut, which is a ventral tube much larger in diameter than the eye, with the musculature arranged in a loose spiral pattern. In adults of the nonparasitic species, the most conspicuous visceral feature is the gonad, which occupies virtually all of the visceral cavity. The gut, if visible, is a fragile, thin tube ventral to the gonad.

1. Dorsal fins separated by a distinct notch that extends to or nearly to the body musculature (Pl. 6–7); teeth few and poorly developed (Fig. 59a): genus *Lampetra* 2

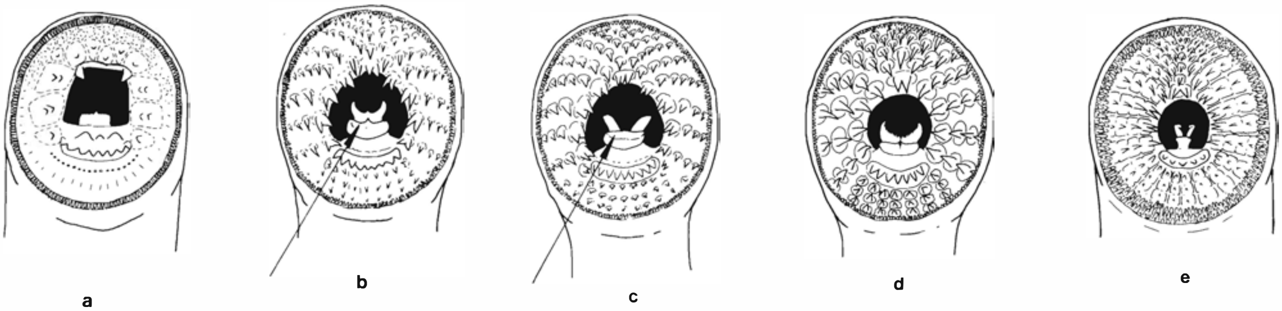


Figure 59. Lamprey buccal funnel morphology: a) *Lampetra*; b) *Ichthyomyzon bdellium*; c) *I. castaneus*; d) *I. unicuspis*; e) *I. gagei*.

Dorsal fins continuous or separated by a shallow notch (Pl. 1–5); teeth numerous and well developed (Fig. 59b–e): genus *Ichthyomyzon* 3

2. Myomeres between last gill cleft and cloaca 63 or more .... *Lampetra appendix* p. 96

Myomeres 61 or fewer .... *L. aepyptera* p. 95

3. Some circumoral teeth bicuspid (Fig. 59b,c); disc length contained more than 12.5 times in total length; widespread 4

All circumoral teeth unicuspid (Fig. 59d); disc length contained 12.5 or fewer times in total length; rare and probably confined to the Mississippi River and lower Tennessee and Cumberland rivers .... *Ichthyomyzon unicuspis* p. 94

4. Teeth well developed on posterior field of disc (Fig. 59b,c); disc length usually contained in total length fewer than 16 times; gut functional and conspicuous at total lengths of 175 mm (7 in) and longer; parasitic 5

Teeth weak on posterior field of disc (Fig. 59e); disc length contained 16 or more times in total length; total length rarely exceeding 150 mm (6 in); gut nonfunctional in adults; nonparasitic species 6

5. Myomeres between last gill cleft and cloaca usually 51–54; buccal funnel large, with disc length usually contained fewer than 14 times in total length .... *I. castaneus* p. 91

Myomeres usually 56–58; buccal funnel smaller, with disc length usually more than 14 times in total length .... *I. bdellium* p. 90

6. Myomeres between last gill cleft and cloaca 55 or more; transverse lingual lamina bilobed and armed with tiny denticles; middle and east Tennessee .... *I. greeleyi* p. 93

Myomeres usually 54 or fewer (49–59); transverse lingual lamina linear, with denticles absent or very weak; Conasauga River and anticipated in lower Tennessee River tributaries .... *I. gagei* p. 92

Genus *Ichthyomyzon* Girard

The River Lampreys

According to Hubbs and Trautman (1937) and Vladykov and Kott (1979), each of our parasitic species of the genus *Ichthyomyzon* has given rise to a non-parasitic or "satellite" species (see family discussion), with *I. bdellium* giving rise to *I. greeleyi*, *I. castaneus* giving rise to *I. gagei*, and *I. unicuspis* giving rise to the more northerly *I. fossor*. We concur with recent treatment of *I. hubbsi* Raney as a junior synonym of *I. greeleyi*, with a discussion included under the account for *I. greeleyi*. The genus is confined to eastern North America.

Etymology: *ichthy* = a fish; *myzon* = sucking.

Ichthyomyzon bdellium Jordan

Ohio lamprey

Characters: Trunk myomeres 53–62, usually 56–58. Dorsal fin not divided. Inner lateral teeth bicuspid; transverse lingual lamina (Fig. 59b) strongly bilobed in anterodorsal view. Color uniformly dark gray to olivaceous above, ventral surface pale, often flushed with yellow.

Biology: The Ohio lamprey lives in somewhat smaller, more upland rivers than does the similar chestnut lamprey, and is less often encountered in reservoirs. It is known to parasitize suckers (Trautman, 1981). An adult female from the lower Hiwassee River was apparently close to spawning condition on 11 April. Rohde and Lanteigne-Courchene (1980) cited two studies indicating a 4-year larval period and a 2-year life span as an adult, with sexual maturity and spawning occurring during the second summer of adult life. The above-mentioned female from the Hiwassee River is apparently one of the largest specimens known, with a total length of 305 mm (12 in).

Distribution and Status: Widespread in the Ohio River basin, including the Cumberland and Tennessee drainages. Fairly common in rivers of east Tennessee.

Similar Sympatric Species: All of our *Ichthyomyzon* are very similar in general appearance. This species is most like *I. castaneus* in shape and tooth development amd most like *I. greeleyi* in myomere counts. In addition to differences in myomere counts and buccal funnel length indicated in the Key, the transverse lingual lamina is more strongly bilobed in anterodorsal view in this species (Fig. 59b) than in the very similar *I. castaneus* (Fig. 59c). Refer to key and introduction to key for useful characters.

Etymology: *bdellium* is presumably from the Greek *bdello* = a leech.

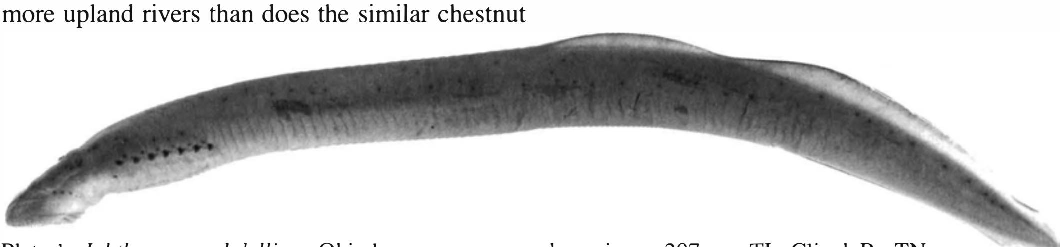
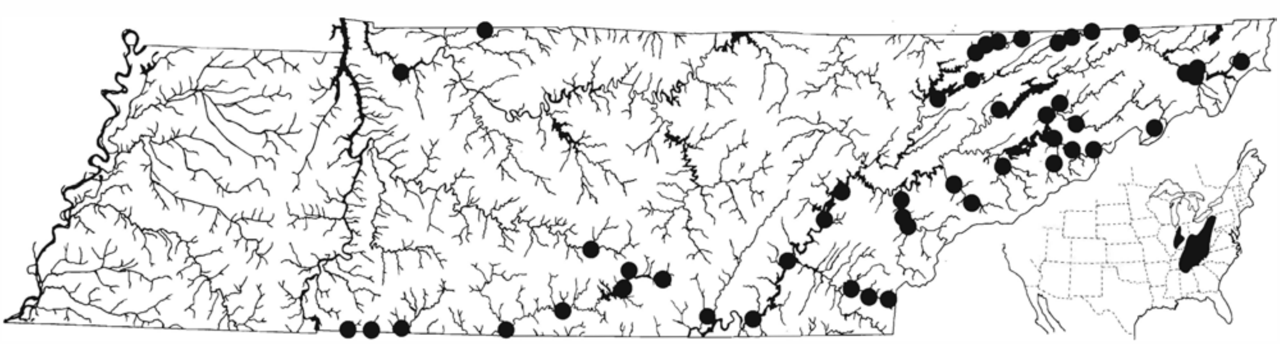


Plate 1. *Ichthyomyzon bdellium*, Ohio lamprey, preserved specimen, 207 mm TL, Clinch R., TN.



Range Map 1. *Ichthyomyzon bdellium*, Ohio lamprey.

Ichthyomyzon castaneus Girard

Chestnut lamprey

Plate 2. *Ichthyomyzon castaneus*, chestnut lamprey, 266 mm TL, Conasauga R., TN.

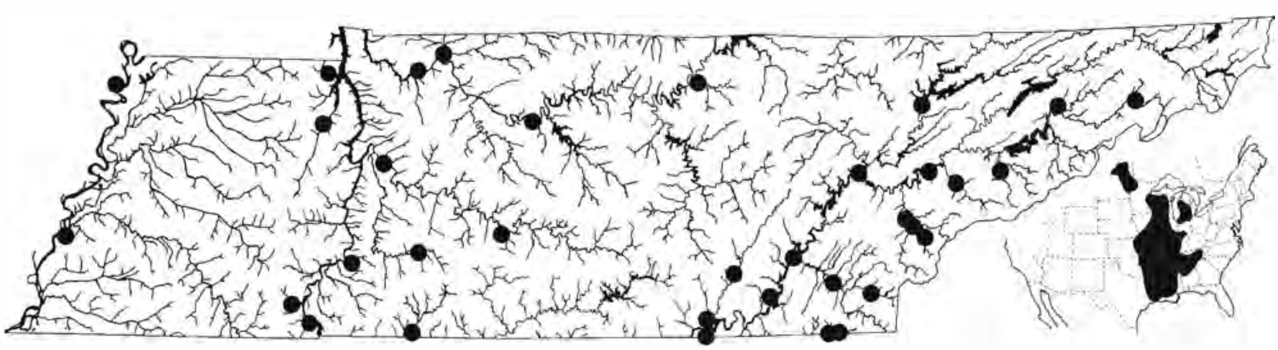
Characters: Trunk myomeres 49–58, usually 51–54. Dorsal fin not divided. Inner lateral teeth (circumorals) bicuspid; transverse lingual lamina weakly bilobed (Fig. 59c). Color usually dark olivaceous or gray dorsally, paler and yellowish ventrally.

Biology: Lampreys found attached to large fishes in large rivers and reservoirs in Tennessee are more likely to be chestnut lampreys than the very similar Ohio lamprey. Adults move into smaller streams to spawn. Spawning in our area is probably in early May; an adult taken from the Little Tennessee River on 23 May was already spent. Scott and Crossman (1973), and Becker (1983), in summarizing life history information for the species, indicated an April through June spawning period in the northern part of its range, transformation to adult in August or September of their final (presumably fifth through seventh) larval year, and sexual maturity during their second adult summer. Spawning, in one observation, was at night and under a log, with eight to ten spawners seen in the area of this single nest. In an additional observation involving a group of about fifty adults, spawning occurred during daylight and apparently through the night in a 1 m long by 0.6 m wide by 5 cm deep depression excavated by the lampreys. When an individual, likely a female, attached to a stone and began quivering, a second individual attached to the head and entwined with the first. Others often attached to the original pair until as many as five were joined. It seemed likely that only one female was involved in these spawning activities. Estimates of fecundity range from about 10,000 to 20,000 ova per female (Beamish and Thomas, 1983). Adults die soon after spawning. Eggs hatch in about 2 weeks, and after an additional week in the nest larvae emerge and drift downstream where they are reported to inhabit firmer substrates and areas of more current than do other ammocoetes. A possible hybrid between this species and *I. unicuspis* was reported from Illinois by Starrett et al. (1960). Maximum total length 345 mm (13.6 in), reported in Starrett et al. (1960). Largest Tennessee specimen recorded, 324 mm (12.75 in), Watts Bar Reservoir, Tenn., 16 Jan. 1979.

Distribution and Status: Central North America in Hudson Bay, Mississippi, and southern Great Lakes basins, and in Gulf Coastal drainages from Mobile Basin to Trinity River drainage of east Texas. Fairly common in all large rivers of Tennessee.

Similar Sympatric Species: See *I. bdellium* account.

Etymology: *castaneus* = a chestnut, referring to the adult coloration.



Range Map 2. *Ichthyomyzon castaneus*, chestnut lamprey.

Ichthyomyzon gagei Hubbs and Trautman

Southern brook lamprey

Plate 3. *Ichthyomyzon gagei*, southern brook lamprey, 128 mm TL, Conasauga R., TN.

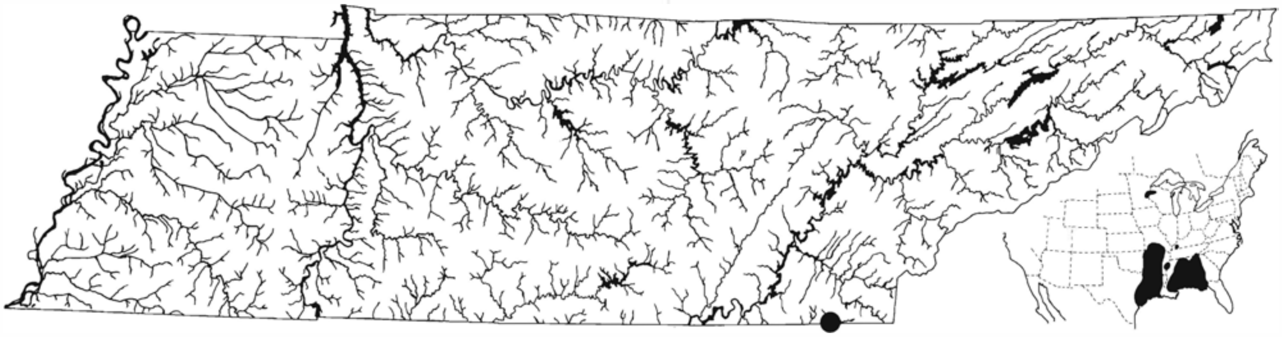
Characters: Trunk myomeres 49–59, usually 52–54. Dorsal fin not divided. Teeth degenerate; inner lateral (circumoral) teeth bicuspid; transverse lingual lamina weakly lobed (Fig. 59e) and lacking denticulations. Color olivaceous, brownish or gray.

Biology: The southern brook lamprey occurs in creeks and small rivers with sand or sand and gravel substrates. Dendy and Scott (1953), Beamish (1982), and Beamish and Thomas (1983, 1984) indicated that spawning in Alabama normally occurs from mid April through early May at water temperatures of 14–24 C. Females produce about 800–2,500 eggs, and both sexes die within 3 weeks after spawning. Larval life span is 3–4 years, with metamorphosis beginning in September and completed by February or March. Moshin and Gallaway (1977) found increased organic content (as opposed to sand and debris), particularly diatoms, in the diet as ammocoetes approach maturity in the spring. Maximum total length 166 mm (6.5 in).

Distribution and Status: Tributaries to lower Mississippi River, and Gulf Coastal drainages from Ochlockonee River of Florida west to San Jacinto River, Texas. A putative disjunct population occurs in the St. Croix River system of Minnesota and Wisconsin (Cochran, 1987). This is one of several species that occurs in Gulf Coastal Plain habitats both east and west of the Mississippi River but has very few populations known from the Mississippi River Embayment physiographic province. The rarity of coarse sand and gravel spawning substrates in portions of the embayment probably limits the success of this lamprey, and it may never be recorded from Mississippi River tributaries in west Tennessee; records are available from the Tennessee River drainage of north Alabama, and it might be expected in the Tennessee portion of that drainage. This lamprey is known in Tennessee only from the Conasauga River, Bradley County, and is treated as a Species of Special Concern in Tennessee (Starnes and Etnier, 1980).

Similar Sympatric Species: Both *I. bdellium* and *I. castaneus* are parasitic species with well-developed teeth (Fig. 59b,c). *Ichthyomyzon greeleyi* also occurs with *I. gagei* in Tennessee River tributaries near the Tennessee-Alabama-Mississippi border. There is some overlap in myomere counts between these two species, but the lack of denticles on the transverse lingual lamina will serve to separate *I. gagei* from *I. greeleyi*.

Etymology: Named in honor of professor S. H. Gage, an early student of lampreys.



Range Map 3. *Ichthyomyzon gagei*, southern brook lamprey.

Ichthyomyzon greeleyi Hubbs and Trautman

Mountain brook lamprey

Characters: Trunk myomeres 53–62, usually 55–58. Dorsal fin not divided. Teeth degenerate; inner lateral teeth bicuspid; transverse lingual lamina bilobed and denticulate. Color olivaceous, brown or gray.

Biology: The mountain brook lamprey is an inhabitant of small upland rivers and creeks. Raney (1939a), Potter and Bailey (1972), Trautman (1981), Beamish and Austin (1985), and our observations all indicated a mid-May to early June spawning period. We observed spawning in Fentress County, Tennessee, on 11 May at water temperature of 13.5 C, where many adults were congregated over nests in gravel substrates in a gentle riffle with clear water and depths of about 30 cm. Potter and Bailey (1972) and Beamish and Austin (1985) estimated a 5–7 year larval life span for upland populations in western North Carolina. Maximum total length 200 mm (7.8 in) reported in Trautman (1981).

Distribution and Status: Upper Ohio River drainage of Pennsylvania, and southern tributaries to the Ohio River south through the Tennessee River. Locally abundant in small to medium upland streams but absent from Coastal Plain areas. Since adults are available for only a short time in early spring, collections of this and other species of nonparasitic lampreys probably underestimate their abundance.

Similar Sympatric Species: See account for *I. gagei*.

Systematics: Trautman (1957) indicated the range of *I. greeleyi* to include the upper Ohio River system of northeastern Kentucky, eastern Ohio, western West Virginia, and western Pennsylvania. Raney (1952) described an additional nonparasitic *Ichthyomyzon*, *I. hubbsi*, from the upper Tennessee River system of western North Carolina and north Georgia. Recent collections of nonparasitic *Ichthyomyzon* geographically intermediate between these widely separated ranges (Rohde and Lanteigne-Courchene, 1980, and our data) cast considerable doubt on the validity of *I. hubbsi* as a species distinct from *I. greeleyi*. The characters listed for *I. hubbsi* by Raney (1952) are essentially the same as those of *I. greeleyi*, and the diagnostic difference from this description, used by Moore (1968), concerning the relative height of the first dorsal fin, is not workable on the basis of specimens we have seen. We concur with most recent treatments in considering *I. hubbsi* as a junior synonym of *I. greeleyi*.

Etymology: Named in honor of Dr. John R. Greeley, discoverer of the species.

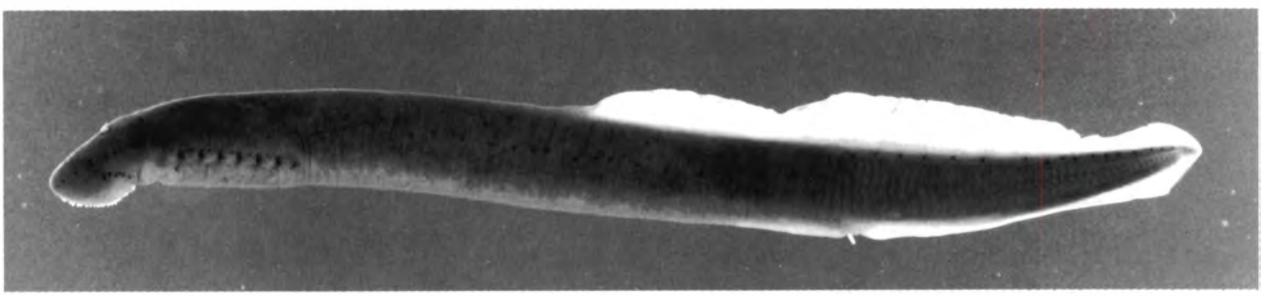
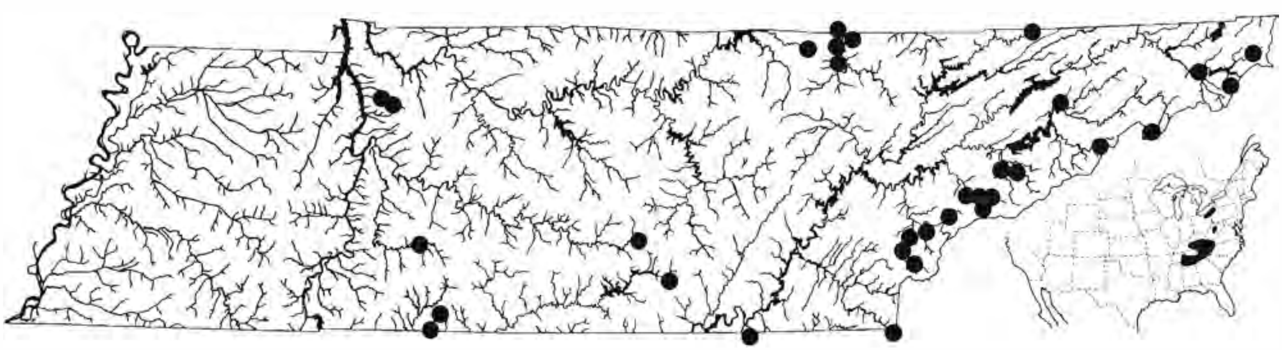


Plate 4. *Ichthyomyzon greeleyi*, mountain brook lamprey, preserved specimen, 135 mm TL, Tennessee R. system, AL.



Range Map 4. *Ichthyomyzon greeleyi*, mountain brook lamprey.

Ichthyomyzon unicuspis Hubbs and Trautman

Silver lamprey

Plate 5. *Ichthyomyzon unicuspis*, silver lamprey, preserved specimen, 195 mm TL, Wabash R., IN.

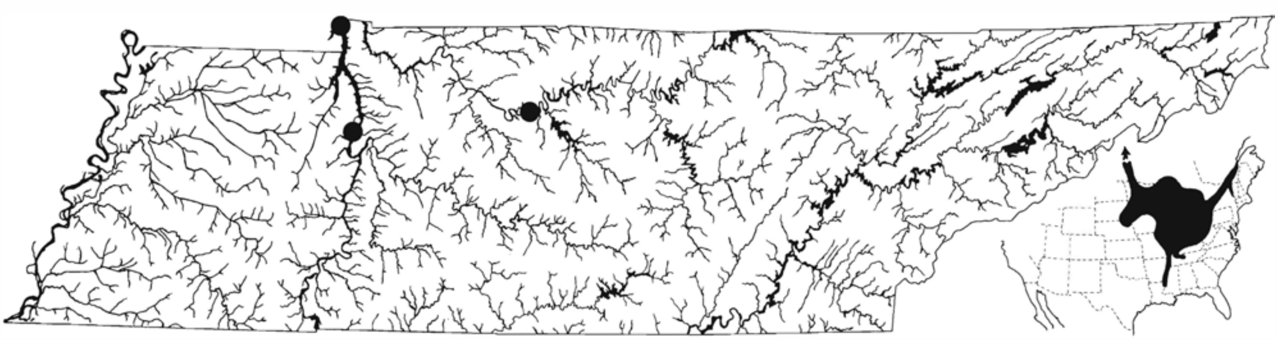
Characters: Trunk myomeres 46–55, usually 49–52. Dorsal fin not divided. Inner lateral (circumoral) teeth unicuspid; transverse lingual lamina bilobed (Fig. 59d). We have one specimen from the lower Wabash River that is typical of *unicuspis* in disc length and myomere count but has a single bicuspid circumoral tooth on each side. Color usually light grayish.

Biology: Scott and Crossman (1973) and Becker (1983) summarized available biological information on the silver lamprey. Spawning occurs from April to June in typical lamprey fashion in medium to large streams, with the male attaching to the head of the female and coiling around her body during the spawning act. An average of 10,800 (Potter, 1980b, cited about 19,000) eggs is produced per female. The ammocoetes stage lasts 4–7 years, with metamorphosis beginning in August. Fully transformed adults emerge from their larval habitats in the spring and are 101–152 mm TL. They parasitize large fishes until the following spring, when spawning occurs, with death following shortly. A possible hybrid between this species and *I. castaneus* was reported from Illinois by Starrett et al. (1960). Maximum total length 395 mm (15.6 in).

Distribution and Status: Mostly recorded from the upper half of the Mississippi River basin, and the Great Lakes and Hudson Bay basins, where it is moderately abundant. A probable reproducing population is documented from an Ohio River tributary in Kentucky (Branson, 1970). In Tennessee the silver lamprey is known from only two specimens, one each from the lower Cumberland and lower Tennessee rivers. It certainly must also occur in the Mississippi River in west Tennessee. It is treated as a Species of Special Concern in Tennessee (Starnes and Etnier, 1980).

Similar Sympatric Species: All other Tennessee *Ichthyomyzon* have one or more bicuspid circumoral teeth. In specimens with one or two bicuspid circumoral teeth (rarely present in *I. unicuspis*), the larger disc of *unicuspis* differentiates it from other *Ichthyomyzon*. The low myomere count, although overlapping with counts for both *I. castaneus* and *I. greeleyi*, is useful in identifying larvae. Larval *Ichthyomyzon* from west Tennessee or the lower Tennessee or Cumberland rivers with 50 or fewer trunk myomeres are likely to be this species.

Etymology: *uni* = single, *cusp* = a pointed projection.



Range Map 5. *Ichthyomyzon unicuspis*, silver lamprey (range in central Canada extends north off inset to Hudson Bay).

Genus *Lampetra* Gray

The Brook Lampreys

The inclusiveness of the genus *Lampetra* has been controversial (Bailey, 1982; Vladykov and Kott, 1982) and interpreted differently by various authors during the past few decades, with the Tennessee species having been included by some workers in the nominal genera *Entosphenus* Gill, *Lethenteron* Creaser and Hubbs, and *Okkelbergia* Creaser and Hubbs. Other workers regard these taxa as subgeneric in rank (summarized in Bailey, 1980). We follow Bailey (1980) in inclusion of all species in the probable monophyletic genus *Lampetra*. In addition to key characters given, *Lampetra* is characterized by the unique possession of a broad supraoral lamina (Fig. 59a) not present in other lamprey groups. Tennessee species are nonparasitic, less than 200 mm (8 in) long, and are late winter to early spring spawners over gravel shoals in small to medium streams.

Etymology: *Lampetra* = a sucker of stones.

Lampetra aepyptera Abbott

Least brook lamprey

Characters: Trunk myomeres 50–61, usually 54–56. Dorsal fin divided by deep notch. Teeth typically absent from posterior field of disc, but if present they are weakly developed. Adults grayish, often mottled on sides; usually with a dark blotch anterior to gill openings (Branson, 1970).

Biology: A number of papers have been written concerning aspects of the life history of the least brook lamprey. The following account is summarized from Seversmith (1953), Brigham (1973), Rohde et al. (1976), Walsh and Burr (1981), and our own observations. Preferred habitats are smaller streams usually with some gravel and sand substrate. Ammocoetes occur in sluggish current areas in silty detrital accumulations. Adults enter riffle areas to spawn. Peak spawning activity occurs at water temperatures of 10–16 C, during March and April.

On 12 March 1989 (9–11 A.M., water temperature 12–14 C, bright sunny day) we observed *L. aepyptera* spawning in a small tributary to the lower Cahaba River in Alabama. Ten to 12 lampreys maintained a pit nest constructed at the head of a riffle in about 20 cm of water with moderate current. Substrates were 0.5–2.0 cm diameter gravel over sand. Spawning and rock moving activity were cyclic with periods of increased rock moving activity alternating with periods of spawning encounters and reduced rock-moving activity. Both sexes appeared to engage in moving rocks by picking them up with the buccal funnel and moving them short distances in varied directions about the pit. Occasionally, two individuals would (by coincidence or not?) "team up" to move a larger rock. In this manner, a small area 3–4 cm in diameter in the center of the nest would be scoured of all loose rocks down to bare sand substrate. One or two lampreys were always alternately lying off to the side "resting" from nesting activity. Spawning cycles were initiated by a female attaching to a rock, usually but not always, in an upstream orientation. Most "successful" encounters occurred when the female anchored to a secure rock on the upstream lip of the nest. After assuming her station, a male would soon attach himself to the top of her head and wrap his caudal region around her in the vicinity of the urogenital area; he was usually quickly joined by two or three other males. The participants then usually quivered and writhed in unison for 2–3 seconds when spawning presumably occurred. The encounter usually was terminated by the female releasing or losing her grip on the anchor rock, whereupon the whole mass drifted downstream until breaking up. Following two to five such encounters, rock moving resumed with rocks being retrieved to cover the bare area (and presumably the eggs) and, simultaneously, clearing a new area just upstream of the

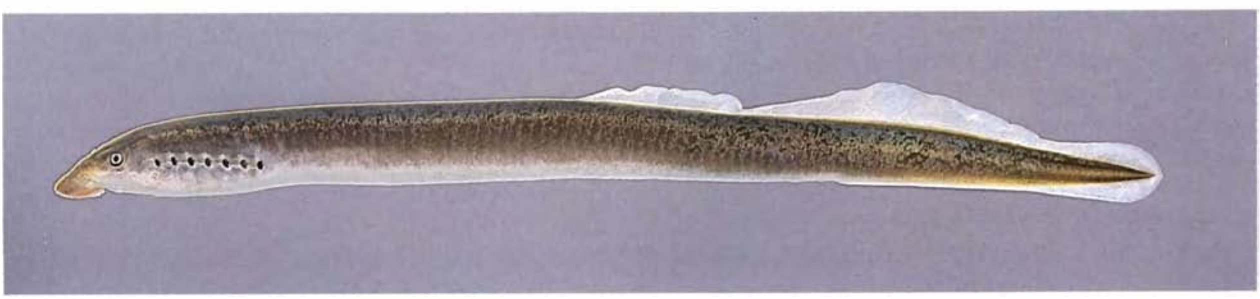
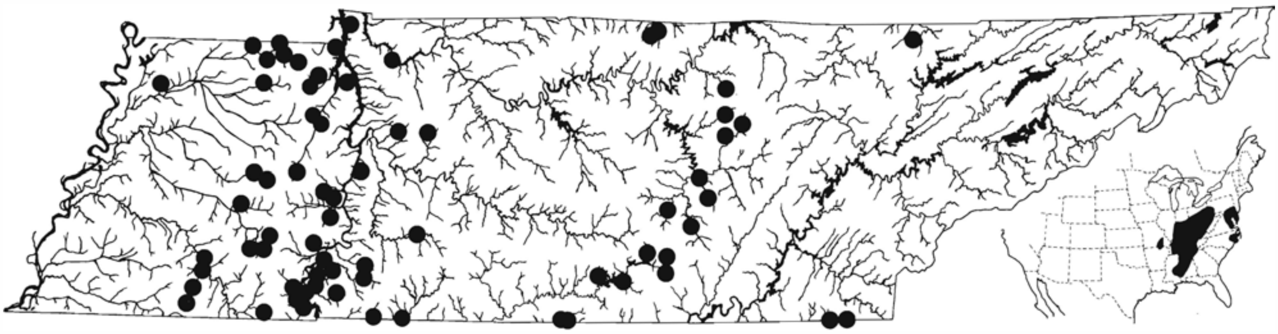


Plate 6. *Lampetra aepyptera*, least brook lamprey, 139 mm TL, Hatchie R. system, TN.



Range Map 6. *Lampetra aepyptera*, least brook lamprey.

first. In this manner, the pit migrated steadily upstream with its center moving 20 cm in 2 hours. Many points of these observations generally agree with those of Rohde et al. (1976) but are not in agreement with those of Brigham (1973) who observed only a pair of lampreys spawning and concluded that *aepyptera* was not a communal spawner.

Females produce from about 600 to 3,000 eggs, and the larval stage is probably 4–6 years, with metamorphosis occurring in autumn. Walsh and Burr (1981) based their study on an Obion River system population that showed evidence of retention of larval form into the breeding season (neoteny), an uncommon developmental phenomenon. However, Vladykov (1985) contended that neoteny had not occurred in these specimens and judged them fully mature, thus making this hypothesis controversial. Maximum total length 180 mm (7 in).

Distribution and Status: Widespread and relatively common in uplands of the Ohio River basin, Ozark systems, and some middle Atlantic Coast drainages. Occurs both above and below fall line in Mobile Basin. Occurrence in west Tennessee is primarily in the firmer-bottomed streams of the higher Coastal Plain above the Mississippi Alluvial Plain. Also common in the gravelly streams of the eastern and western Highland Rim areas; possibly absent from the upper Tennessee drainage, where *L. appendix* is common.

Similar Sympatric Species: Differs from *L. appendix* in having lower trunk myomere counts (61 or fewer), in typically lacking teeth on the posterior portion of the disc, and in the mottled nuptial coloring of the adults.

Systematics: Hubbs and Potter (1971) recognized the genus *Okkelbergia* Creaser and Hubbs for this species but it has been subsequently returned to *Lampetra* (Vladykov and Kott, 1976; Bailey, 1980; Potter, 1980b). We concur with Bailey (1980), Robins et al. (1980), Walsh and Burr (1981), and R. E. Jenkins (in litt.) in treating *Lethenteron meridionale* Vladykov, Kott, and Pharand-Coad (1975) as a junior synonym of *Lampetra aepyptera*. Vladykov and Kott (1979) considered *aepyptera* a "satellite species" of the anadromous parasitic form, *Lampetra ayresi*, of the Pacific Coastal region and the nominal *Lethenteron meridionale* as having a similar relationship to *L. japonica* of the Alaskan region.

Etymology: *aepy* = high, *pteron* = fin or wing.

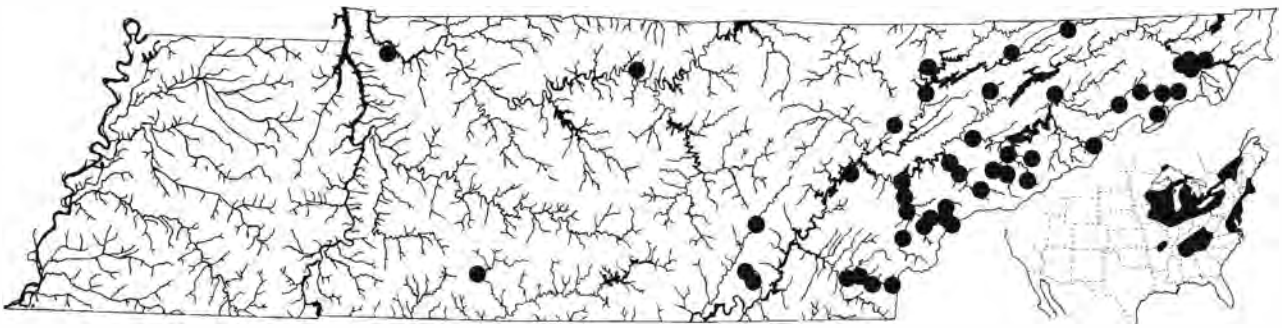
Lampetra appendix DeKay

American brook lamprey

Characters: Trunk myomeres 63–73, usually 66–70. Dorsal fin divided by deep notch. Teeth degenerate but present on posterior field of disc. Pigmentation of adults and ammocoetes uniformly gray above and paler ventrally.

Biology: *Lampetra appendix* is chiefly an inhabitant of upland creeks and small rivers with larval and adult habitats similar to those of *L. aepyptera*, but slightly larger streams are preferred. We observed a spawning aggregation in lower Citico Creek, tributary to the Little Tennessee River, on 5 April. Seagle and Nagel (1982) indicated a March spawning period in northeastern Tennessee. Trautman (1957) found spawning adults in Ohio on 28 April, Rohde et al. (1976) observed spawning from 28 March through 4 April in Delaware, and Scott and Crossman (1973) indicate a May to early June spawning period in southeastern Canada. Females produce from 860 to over 3,000 eggs (average 2,833 in Tennessee specimens), which hatch within a few weeks; the larval stage lasts 5–6 years (Scott and Crossman, 1973; Seagle and Nagel, 1982). In our area, adults often

Plate 7. *Lampetra appendix*, American brook lamprey, 190 mm TL, Little R., TN.



Range Map 7. *Lampetra appendix*, American brook lamprey.

reach total lengths of 200 mm (8 in). Manion and Purvis (1971) reported on unusually large specimens from the upper Great Lakes area that were up to 300 mm (12 in).

Distribution and Status: Widespread in uplands of Mississippi River basin, Great Lakes tributaries, and Atlantic Coast drainages from New England to Roanoke River drainage of Virginia. Fairly common in the uplands of east Tennessee, but not known from elsewhere in the state except for a few collections from middle Tennessee.

Similar Sympatric Species: Differs from all species of *Ichthyomyzon* in lacking well developed teeth and in having a deep cleft separating the dorsal fins. Myomere counts will serve to separate this species from the similar but often strikingly mottled *L. aepyptera*. Larvae are readily identifiable because their myomere count is higher than (63 or more) and non-overlapping with other Tennessee lampreys.

Systematics: This species has been treated under both the genera *Entosphenus* (e.g., Moore, 1968) and *Lethenteron* (e.g., Vladykov and Kott, 1978) within recent decades (see genus introduction). Until recently this species has appeared as *Lampetra lamottei*, with various spellings of the species epithet. Robins et al. (1980) cited Bailey and Rohde (in prep.) in treating *Petromyzon lamottenii* Lesueur as unidentifiable; acceptance of Lesueur's name had been based on the previous belief that only one species of *Lampetra* occurred near the southeastern Missouri type locality where both *aepyptera* and *appendix* are now known to occur. Vladykov and Kott (1982) and Bailey (1982) offered additional comments concerning the appropriate species epithet for the American brook lamprey. Vladykov and Kott (1979) regarded this species as a "satellite" form derived from *Lampetra japonica* of the Alaskan region.

Etymology: DeKay (1842, p. 381–82) does not suggest a derivation for the epithet "*appendix*" in the original description, but his mention of the "slender, thread-like process . . . apparently tubular" arising from the vent suggests the origin of the name.

ORDER ACIPENSERIFORMES

FAMILY ACIPENSERIDAE
The Sturgeons

Sturgeons and the distantly related paddlefish are generally regarded as the most primitive surviving bony fishes. Their extinct relatives (infraclass Chondrostei) date to the Devonian 350 million or so years ago, and *Acipenser* fossils occur in upper Cretaceous strata of western North America (Gardiner, 1984; Cavender, 1986). Patterson (1982) and Lauder and Liem (1983) considered the extinct Chondrosteidae to be the closest relatives of sturgeons, while Nelson (1969a) had paddlefishes as their sister group; Gardiner (1984) considered the extinct *Paleopsephurus* (Cretaceous, Montana), thought by others to be a paddlefish, as the nearest relative to sturgeons with chondrosteids and paddlefishes more distantly related. Relationships of these fishes were further discussed by Schaeffer (1973). In both sturgeons and paddlefishes the posterior vertebrae continue far out into the dorsal lobe of the caudal fin (heterocercal condition), branchiostegal rays are absent or inconspicuous, and the skeleton is primarily cartilage. Sturgeons have a protrusible mouth, toothless in adults, with fleshy lips. The prominent snout has four barbels located about midway between the mouth and the snout tip. The five rows of bony scutes along the body are very sharp in young fish but become smooth with wear in large specimens. They are strictly northern hemisphere fishes, some of which are confined to freshwater while others are anadromous. The genus *Acipenser* is holarctic with five species occurring in North America and about 11 in Eurasia. The genus *Scaphirhynchus* (three species) is confined to central North America. Two additional genera, *Huso* (two species) and *Pseudoscaphirhynchus* (three species), occur in Eurasia. Sturgeons are the largest freshwater fishes, and life spans of larger species may exceed 150 years. *Huso huso*, the beluga, occurring in the Black and Caspian seas and tributaries, ranks as the largest freshwater fish, with weights up to 1,300 kg (2,800 lbs) and lengths of 8 m (26 ft) (Berra, 1981).

Sturgeon flesh is now well accepted as food, but these fishes are better known as a principal source of caviar. Caviar is made from the mature eggs of sturgeon in the following manner. The eggs are separated from the surrounding ovarian membranes by gently working the egg mass through a screen of appropriate mesh. Once separated, the eggs are then mixed with salt, and after excess brine has been poured off, placed in a fine mesh bag. After an additional 8–10 hours of draining, the caviar is ready for consumption. Commercial fishers still take small numbers of *Scaphirhynchus* in the Midwest, and a limited amount of caviar is still produced. With the depletion of sturgeon stocks both here and in Eurasia, paddlefish roe is increasingly used as a substitute in the caviar industry. Sturgeon are being experimented with in aquaculture; the white sturgeon, *Acipenser transmontanus*, of the North American West Coast, is now being commercially produced in limited but growing quantities, and has even entered the aquarium trade. Carlson (1983) provided characters for identifying larvae of the two North American genera.

KEY TO THE TENNESSEE GENERA AND SPECIES

1. Area posterior to anal fin completely covered by bony plates; barbels feathery, with lateral projections: genus *Scaphirhynchus* 2
   Area posterior to anal fin with bony plates on dorsal, lateral, and ventral midlines separated by naked areas; barbels smooth, no lateral projections . . . . *Acipenser fulvescens* p.99
2. Belly typically covered with small bony plates; anal fin rays 23 or fewer; dorsal fin rays 36 or fewer . . . . *Scaphirhynchus platorynchus* p.102
   Belly naked; anal fin rays 24 or more; dorsal fin rays 37 or more . . . . *S. albus* p.101

Genus *Acipenser* Linnaeus

Extremely large fishes characterized by a subconical snout, presence of a spiracle, and smooth barbels. Of the five species of *Acipenser* that occur in North America, the white (*A. transmontanus*) and green (*A. medirostris*) sturgeons are anadromous on the West Coast, and the Atlantic (*A. oxyrinchus)* and shortnose (*A. brevirostrum*) sturgeons are anadromous on the East Coast; the lake sturgeon, *A. fulvescens*, is restricted to fresh water in the central part of the continent. An 1,800-pound white sturgeon was reported from the Frazer River system in British Columbia, and there is a reliable record of a specimen from the same river system that weighed nearly 1,400 pounds (Scott and Crossman, 1973). Gudger (1934) reported a specimen nearly 1,300 lbs from the Columbia River system. A limited sport fishery is supported by the white sturgeon during its upstream migrations in the Pacific Northwest, and a carefully managed winter spearing season is allowed on several Wisconsin and Michigan lakes for the lake sturgeon (*A. fulvescens*). Hermaphroditism has been reported in both *Acipenser* and *Scaphirhynchus* (Atz and Smith, 1976; Carlson et al., 1985).

Acipenser fulvescens Rafinesque

Lake sturgeon

Characters: Dorsal plates 9–17. Lateral plates 29–42. Dorsal fin rays 35–40. Anal fin rays 25–30. Color yellowish brown to gray with small dark blotches sometimes evident.

Plate 8b. *Acipenser fulvescens*, lake sturgeon, small juvenile, 214 mm TL, Wolf R., WI.

Biology: Scott and Crossman (1973) and Becker (1983) included life history information for northern lake sturgeon populations, which we briefly summarize; Cuerrier's (1966) monograph contains much additional detailed information. Preferred habitat is large lakes and rivers, where sturgeon feed primarily on benthic organisms such as crayfishes, mollusks, and insect larvae, especially midges. Adults typically migrate up rivers to spawn, moving as much as 200 km, but some lake populations are nonmigratory and spawn over rocky reefs. Spawning occurs from April through June, at water temperatures of 12–18 C (54–65 F). Groups of males aggregate in shallow water, often with the upper parts of their bodies exposed. When a receptive female joins the group, she is flanked by one or two males. During spawning, eggs are extruded in short bursts lasting about 5 seconds, and fertilized by males whose vibrating caudal fin may be exposed and produce an audible noise. Individual females complete spawning within a 5-hour to slightly over 1-day period. Spent adults typically return to their home lake. Adults do not spawn every year, and the interval between spawning is 4–9 years for females and yearly or in alternate years for males. Extremely large females may produce as many

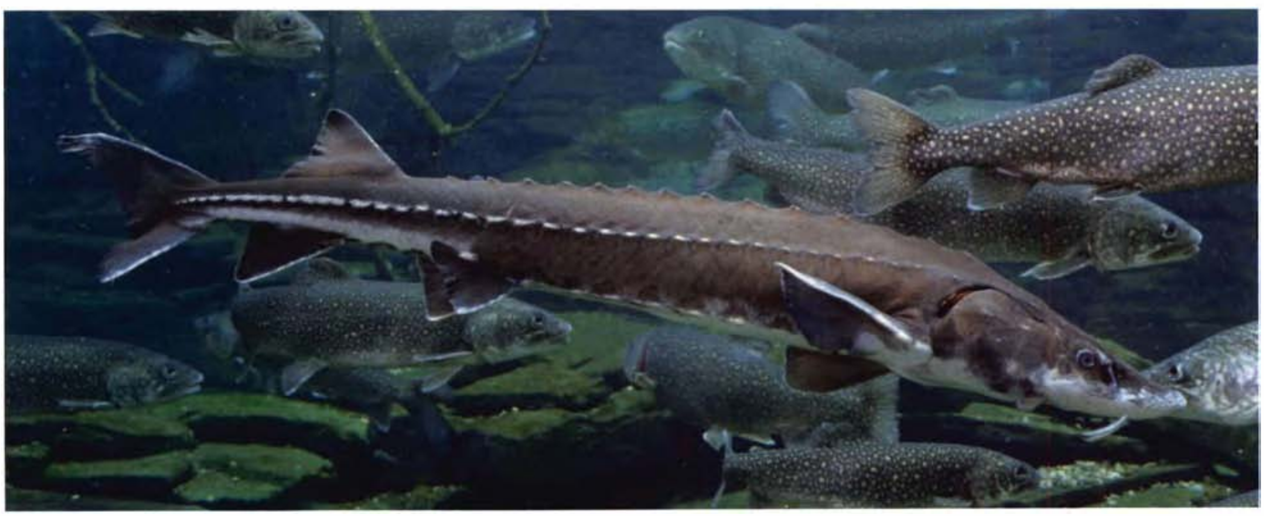
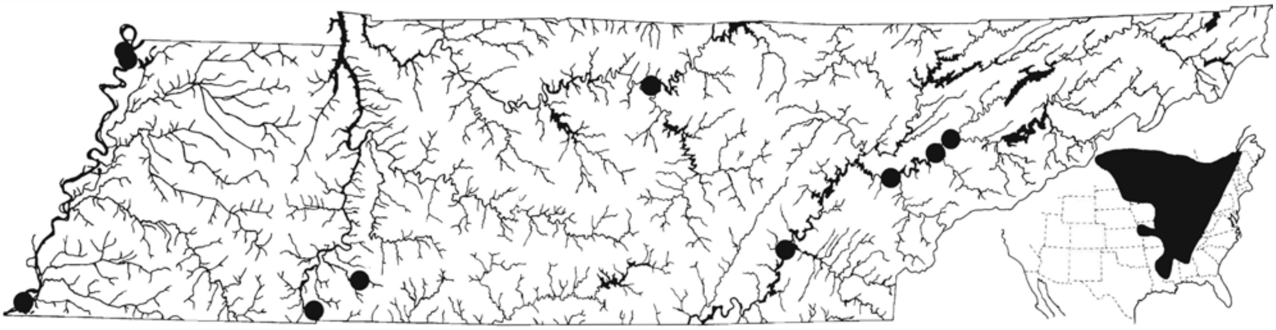


Plate 8a. *Acipenser fulvescens*, lake sturgeon, young adult, 1.1 m TL, Tennessee Aquarium, Chattanooga.



Range Map 8. *Acipenser fulvescens*, lake sturgeon (range in central Canada extends north off inset to Hudson Bay).

as 3 million eggs per spawning, with more typical fecundity ranging 50,000–700,000 eggs. Lake sturgeon grow and mature slowly, with first spawning occurring at about 14–25 years at 90–140 cm (35–55 in) TL for females; males first spawn at 85–114 cm (33–45 in) TL when 12–20 years old. Males and females have similar growth rates, but females have longer life spans and reach much larger sizes. Lake sturgeon live to be much older than other North American freshwater fish, with maximum age estimates of as much as 154 years. Tennessee populations would be expected to spawn earlier and more frequently, reach smaller maximum size, and have a shorter life span than more northerly populations. Although Kirsch and Fordice (1890) reported "a length of nine feet," a Lake Superior specimen taken in 1922 and a 1943 Lake Michigan specimen are the largest for which reliable data are available (Becker, 1983); both weighed 141 kg (310 lb) and were about 2.4 m (8 ft) TL.

Distribution and Status: The lake sturgeon was formerly abundant throughout the upper and middle Mississippi River basin and the Great Lakes and Hudson Bay drainages. It was also reported from the upper Coosa River system by Scott (1951). It has been drastically reduced or eliminated throughout most of this area, and southern populations are justifiably considered as endangered. It may have been uncommon in more southern portions of its range since the Pleistocene, when it was probably displaced southward. Our knowledge of the present and former distribution of lake sturgeon in this area is based primarily on old records and hearsay. Rafinesque (1820) listed the lake sturgeon from the Ohio and Kentucky rivers. Agassiz (1854) listed it from the southern bend of the Tennessee River in Alabama. Trautman (1981) reported lake sturgeon as abundant in the Ohio River until 1915. Kuhne (1939) gave no locality records, but indicated that it was present but uncommon in the upper Tennessee and Cumberland rivers. Brimley (1946) reported a record from the North Carolina portion of the French Broad River near Hot Springs, but the specimens had not been seen by him or other authority. The former abundance of lake sturgeon in the lower Tennessee River is indicated by a 1941 trammel net collection from near Decatur, Alabama, which we recently sorted for cataloging at the University of Michigan Museum of Zoology. The sample contained 58 fish, dominated by smallmouth buffalo (23) and blue catfish (11); six lake sturgeon and three shovelnose sturgeon were included. More recently we have one juvenile from somewhere in Fort Loudon Reservoir, probably from about 1960. Hearsay reports indicate that an occasional lake sturgeon is still taken or seen in Douglas, Fort Loudon, and Watts Bar reservoirs and formerly in the lower Little Tennessee River (now Tellico Reservoir). A sturgeon, presumably a lake sturgeon, was reported from Indian Creek, tributary to the lower Tennessee River in Wayne County, in 1964, and an additional specimen supposedly taken at a later date (pers. comm. J. S. Ramsey). L. G. Allmon of Knoxville (pers. comm.) was rather positive about seeing a small specimen that had been caught by children fishing in the sluice at the bridge above Island Home Airport in Knoxville during April or May 1974. Harned and Hackney (1981) reported on two large adults from the Cumberland River during 1977 and 1978. Warren et al. (1986b) verified three records from the Mississippi River in Kentucky just north of Tennessee, taken between 1968 and 1977. Commercial fisherman Ronnie Capps, Tiptonville, has seen two specimens from the Mississippi River, Lake County, during 1988–1989. Any recent specimens or information concerning this rapidly disappearing species from Tennessee or adjacent states would be greatly appreciated. The lake sturgeon is considered to be a Threatened Species by the AFS Endangered Species Committee (Williams et al., 1989).

Similar Sympatric Species: Members of the genus *Scaphirhynchus* are easily separated from *Acipenser* by referring to the key. A remote future possibility for Tennessee waters, due to completion of the Tenn-Tom Waterway, would be *Acipenser oxyrinchus,* which ascends Gulf of Mexico tributaries to spawn (Vladykov and Greeley, 1963). It has about four small bony plates on the ventral midline behind the anal fin; in *A. fulvescens* there is one large plate in this area.

Etymology: *Acipenser* = Latin for sturgeon; *fulvescens* = yellowish.

Genus *Scaphirhynchus* Heckel
The Shovelnose Sturgeons

These distinctive fishes, often called shovelnose sturgeons or hacklebacks, are confined to large rivers in central North America. They are included in the subfamily Scaphirhynchinae along with members of the genus *Pseudoscaphirhynchus* of the Aral Basin in Eurasia (Nelson, 1984). Members of *Scaphirhynchus* differ from those of *Acipenser* in lacking a spiracle (small opening at dorsal anterior margin of operculum), having feathery rather than smooth rostral barbels, and in having four rather than two papillose lobes on the lower lip, in addition to characters mentioned in the key. The upper caudal lobe is attenuated into a filament, often broken off in adults, which contains a portion of the lateral sensory system and may be important in orienting to current (Weisel, 1978). Systematics of the genus has been treated by Bailey and Cross (1954). In addition to the two species in the Mississippi River drainage, an extremely rare form that occurs in the Mobile Basin, *S. suttkusi,* was recently described by Williams and Clemmer (1991). Biochemical systematics of the two Mississippi drainage species were studied by Phelps and Allendorf (1983), who found no interspecific differences at 37 loci examined, in spite of the morphological distinctness of these species.

Etymology: *Scaphi* = a spade, *rhynchus* = snout.

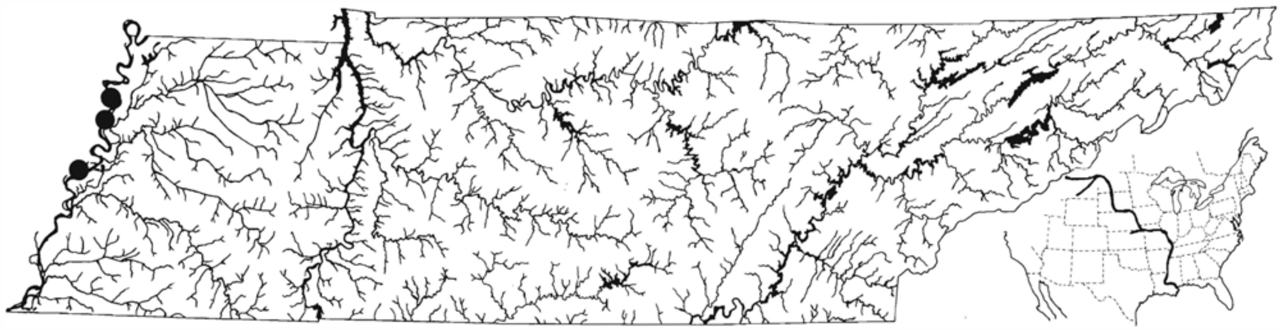
Scaphirhynchus albus (Forbes and Richardson)
Pallid sturgeon

Characters: In addition to characters previously mentioned in the key and generic account, the four rostral barbels do not have their bases in a straight line—the two median barbels are placed farther forward. Color very pale gray to yellowish white.

Biology: Very little is known concerning this rare sturgeon. Habitat preference may be for deeper and swifter waters than those occupied by *S. platorynchus*, and its distribution and morphology suggest it to be more tolerant of turbidity than its congener; however, there is considerable overlap in habitat based on the results of Carlson et al. (1985). Pallid sturgeons were collected both in sluggish areas along sandbars on the insides of bends and behind wing dams frequented by shovelnose sturgeon, and in faster current areas less frequented by the latter. The diet consists of aquatic insect immatures, particularly caddisfly larvae, and small fish (Carlson et al., 1985). Spawning is apparently in midsummer (Forbes and Richardson, 1920), but nothing more is known of reproduction except that pallid sturgeon may frequently hybridize with *S. platorynchus* (Carlson et al., 1985). These workers gave the length of 4–5 year olds as about 50–55 cm (about 20 in) and 12–13 years olds at about 90 cm (35 in). It is considerably larger than its congener, with specimens of 14.3 kg (31.5 lb), 21.4 kg (47 lb), and 31 kg (67 lb) mentioned in Bailey and Cross (1954) and Bailey and Allum (1962).

Distribution and Status: Restricted to the main channels of the Missouri and Mississippi rivers. Pallid sturgeon appear to be most abundant in the prairie region portion of the Missouri River, dwindling in occurrence in the lower Mississippi River. Forbes and Richardson (1905) indicated that only about one in 500 *Scaphirhynchus* from the Mississippi River, Illinois, was *S. albus* but that about 20% of Missouri River specimens were that species. However, Carlson et al. (1985) found them to comprise 2.5% of sturgeons collected in the Mississippi River in Missouri. Ronnie Capps, a commercial fisherman from Tiptonville who is familiar with differences between these two species, estimated that about one of five *Scaphirhynchus* in his recent catches from the Mississippi River in Tennessee were *S. albus*. Warren et al. (1986b) recorded one pallid sturgeon and one probable pallid x shovelnose hybrid from the Kentucky portion of the Mississippi

Plate 9. *Scaphirhynchus albus*, pallid sturgeon, 88 cm TL, Mississippi R., Dyer Co., TN.



Range Map 9. *Scaphirhynchus albus*, pallid sturgeon.

River just north of Tennessee in 1984–1985. We have seen only one specimen (in 1990) from the Tennessee portion of the Mississippi River, but efforts to sample larger fishes and monitor commercial catches from these waters are very limited. Even hearsay records are difficult to obtain, as most area fishers do not distinguish between species of *Scaphirhynchus*. This fish is so infrequently captured that any additional specimens would be valuable. Rangewide, it is apparently decreasing in abundance, and it has been proposed for Endangered status (U.S. Federal Register, 1989). Retention of the head and skin from the belly plus dorsal and anal fins would be sufficient to allow for positive identification.

Similar Sympatric Species: See *S. platorynchus*.

Etymology: *albus* = white.

Scaphirhynchus platorynchus (Rafinesque)

Shovelnose sturgeon

Characters: See key, generic account, and Similar Sympatric Species. Color pale to medium gray or brownish.

Biology: The shovelnose sturgeon inhabits large rivers and is apparently intolerant of impoundments. It occurs in areas with moderate to swift currents over sand and fine gravel substrates. Hurley et al. (1987) found this sturgeon to frequent waters 2–7 m deep with moderate to fast current and to be relatively sedentary much of the time but with occasional long range movements of up to nearly 12 km in one day, primarily during May and July, with some homing behavior indicated. During spring high-water stages, sturgeon usually frequented areas downstream of wingdams or other obstruction and remained near shore, while at summer low levels they remained near midchannel. Food consists primarily of benthic insects, especially burrowing mayflies (*Hexagenia*), caddis larvae of the family Hydropsychidae, midge larvae, plus very small numbers of other invertebrates and fish (Held, 1969; Modde and Schmulbach, 1977; Becker, 1983; Carlson et al., 1985; Raymond Bogardus, pers. comm.). Spawning is reported to occur from April to June (Smith, 1979; Becker, 1983) in large rivers in areas of swift current and coarse substrates (Pflieger, 1975). Additional life history is summarized in Becker (1983). Fecundity averages about 25,000 (10,000–50,000) eggs per female. Sexual maturity occurs at about 635 mm (25 in) fork length at age 5 (males) to 7 (females). In the upper Mississippi basin fork length (FL) at age 1 ranged from 213 to 348 mm. Five late-August specimens in our collection, lower Wabash River, Indiana, are only 102–160 mm FL. Growth increments are about 100 mm per year up to age 4, 20–50 mm from age 5 to 10, and only 10 mm thereafter. However, Carlson et al. (1985) graphed relatively steady growth increments of about 50 mm/yr af-

Plate 10a. *Scaphirhynchus platorynchus*, shovelnose sturgeon adult, Tennessee Aquarium.

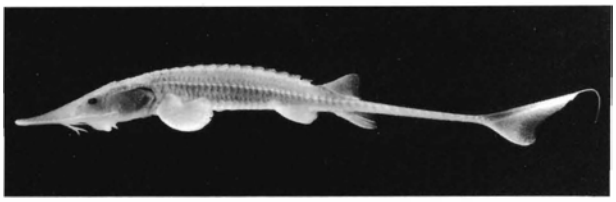


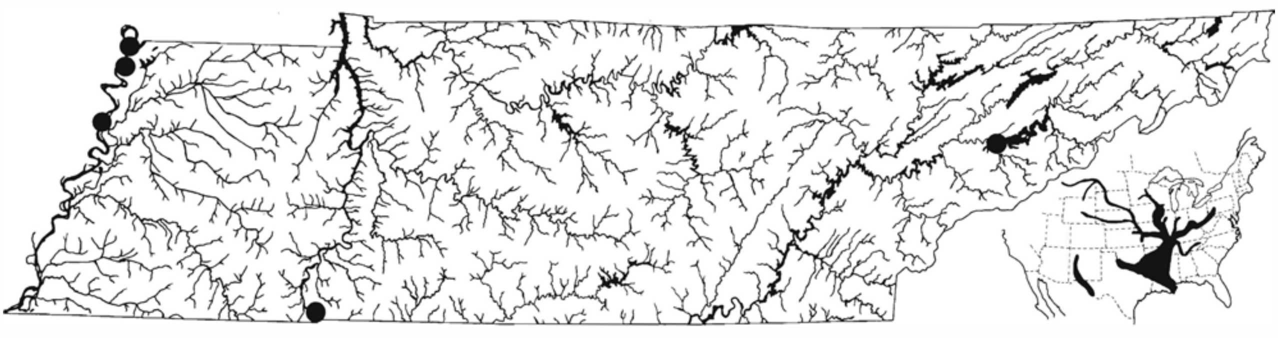
Plate 10b. *Scaphirhynchus platorynchus*, shovelnose sturgeon, preserved juvenile specimen with caudal filament, 226 mm TL, Missouri R., MO.

ter age 6 with 13-year-olds attaining 65 cm FL. Life span probably exceeds 15 years. Maximum size 853 mm (33.5 in) FL (Lee, 1980) and 4.5 kg (10 lb) (Trautman, 1981).

Distribution and Status: Widespread in Mississippi River drainage, and formerly occurred in the Rio Grande drainage. The shovelnose sturgeon occurs throughout the Mississippi River in west Tennessee, and is frequently taken by commercial fishermen, though we have few records substantiated by museum specimens; Warren et al. (1986b) recorded numerous specimens from the Mississippi River in adjacent Kentucky. Although we have no recent records from either the lower Tennessee or Cumberland rivers, it may still occur there sporadically. Bailey and Cross (1954) recorded this species from the main channel of the Tennessee River in Wheeler Reservoir at Wilson Dam, Alabama, and Pfitzer (1954) recorded it from the French Broad River (Douglas Dam tailwater) during 1951 and 1953. It was apparently a common fish in the lower bend of the Tennessee River in 1939 (see comment under *Acipenser fulvescens*).

Similar Sympatric Species: Bailey and Cross (1954) listed nine useful characters, mostly associated with head morphometry, to distinguish between *S. platorhynchus* and *S. albus*. Outer barbel length divided by inner barbel length (1.17–1.48 in *platorhynchus* and 1.64–2.41 in *albus*) allows excellent separation of the two species, and 6 of the remaining 8 ratios had no overlap.

Etymology: *platy* = broad, *rynchus* = snout.



Range Map 10. *Scaphirhynchus platorynchus*, shovelnose sturgeon.

FAMILY POLYODONTIDAE
The Paddlefishes

This family of archaic fishes (see comments under Acipenseridae) consists of but two extant species, *Polyodon spathula* of central North America, and the gigantic *Psephurus gladius* of China (up to 7 m long; Berra, 1981). Fossils of extinct polyodontids date from the late Cretaceous of western North America (Grande, 1980). Patterson (1981) hypothesized that the two extant species are closest relatives, with the extinct genera *Crossopholis* and *Paleopsephurus* as next closest relatives, respectively; Gardiner (1984) allied the latter genus with sturgeons. Most recently, Grande and Bermis (1991) hypothesized relationships as proposed by Patterson (1981) but described a new Paleocene fossil *Polyodon* species as closest relative to the living *P. spathula*. The caudal fin of paddlefishes is heterocercal as in the sturgeons, and the skeleton is largely of cartilage. Scales are nearly lacking. A primitive, spiral valve type intestine, similar to that found in sharks, is present. The function of the long, paddle-shaped snout has received considerable attention. A reasonable theory suggests that, in addition to its probable sensory function, it acts as a stabilizer, keeping the fish swimming on a horizontal plane in spite of drag produced when the lower jaw is extended downward during filter feeding.

Genus *Polyodon* Lacepede

Polyodon spathula (Walbaum)

Paddlefish

Characters: Body naked except for a patch of ganoid scales at base of upper lobe of caudal fin. Gill cover extending back as a long, pointed flap. Color usually medium to pale bluish gray.

Biology: The paddlefish, often called "spoonbill catfish" in Tennessee and elsewhere but not related to catfishes at all, is an inhabitant of large, silty rivers, with populations also occurring in many reservoirs and in the southern Great Lakes. It is apparently more adaptable to impoundments and increased silt deposition than are the sturgeons. Hatchlings lack the distinctive paddle of the adult and retain teeth in the jaws as small juveniles (see Hogue et al., 1976); adults are toothless and rely on their numerous, long gill rakers for straining food organisms, mostly cladocerans and copepods, from the water. Specimens 15–200 mm TL feed principally on the large zooplankter *Daphnia* (Ruelle and Hudson, 1977). In summer, after spawning, adult paddlefish move out of swift current areas to backwaters where plankton is abundant (Southall and Hubert, 1984). Under certain conditions, adults appear to be random filter feeders, ingesting all appropriate sized particles in the filtered water; this is an uncommon feeding strategy in fishes (Rosen and Hales, 1981). Juveniles, and perhaps adults encountering large concentrations of prey such as burrowing mayfly larvae, are more selective. Adult paddlefish make upstream spawning runs, with spawning occurring in swift water over gravel bars and riprap areas in early spring (Purkett, 1961); they also successfully utilize tailwater areas below dams with seasonal success dependent directly on spring flow levels (Pasch et al., 1980). Paddlefish are often seen breaking the water surface during the spawning season. Large females may produce over 500,000 eggs per spawn but may not spawn every year. In Tennessee, peak reproduction is earlier in the Tennessee River than in the Cumberland, with maximum abundance of larvae in April and May, respectively (Wallus, 1986). Growth is rapid, with total lengths at age 1 ranging from 300 to 700 mm; males mature at about 102 cm (40 in) TL (age 7) and females at about 107 cm (42 in) TL at age 9–10 (Becker, 1983). Growth reported for a Cumberland River population by Pasch et al. (1980) exceeds these estimates with age 7 fish averaging 120 cm (47 in) TL, and age 9–10 128 cm (50 in); oldest specimens, at age 14–15, averaged 145 cm (57 in) TL; comparable growth was estimated in a Watts Bar Reservoir population by Alexander et al. (1985). Hageman et al. (1986) estimated that males grew faster than females until age 6, with females growing faster thereafter; males matured at age 5 and females at 8; 12 age groups were identified. Maximum life span is not known but probably exceeds 20 years.

The meat of large paddlefish is excellent, and baked fillets approach the consistency and mildness of chicken. While the meat continues to have a ready market, the recent heavy utilization of paddlefish eggs for caviar has dramatically increased the commercial demand. In Tennessee the caviar fishery occurs in midwinter with large mesh gill and trammel nets used in tailwaters and reservoirs. It is likely that this fishery will have to be carefully regulated in the future to pre-

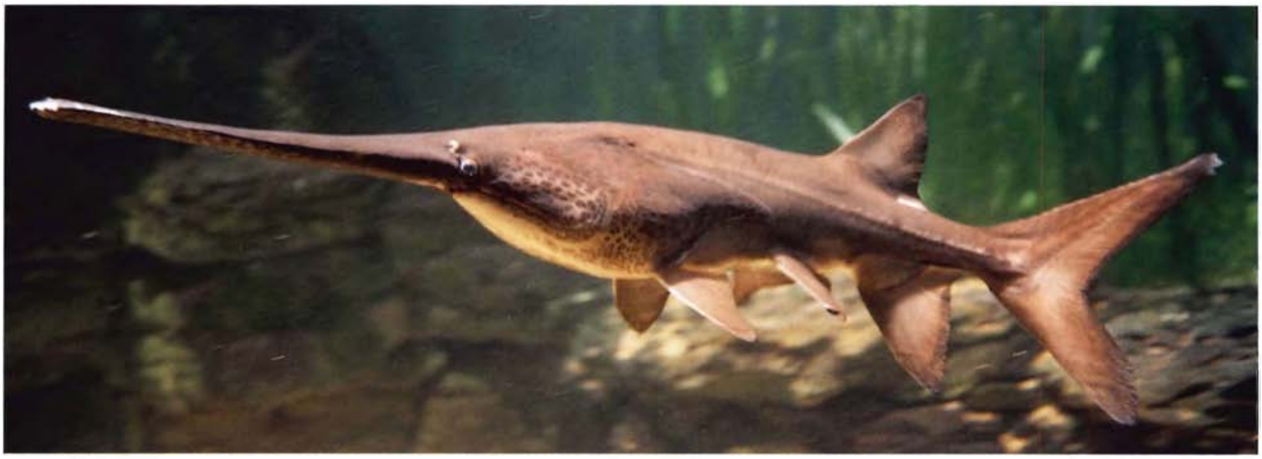
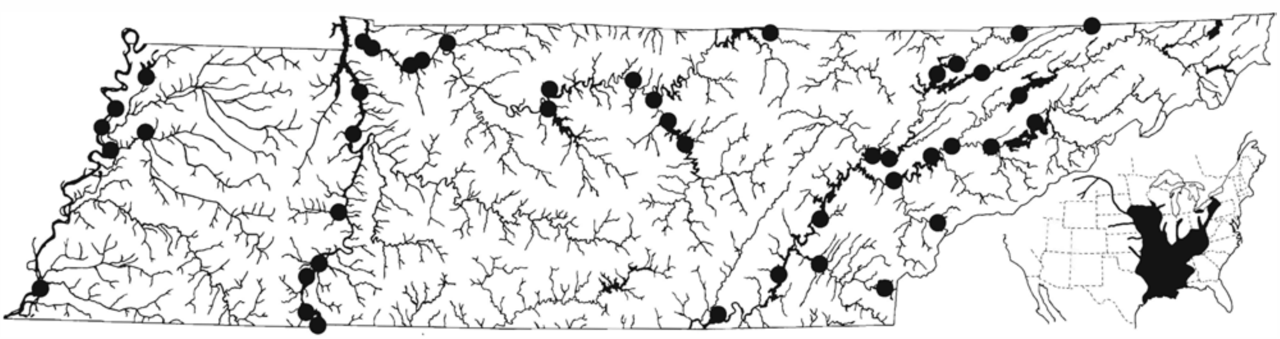


Plate 11. *Polyodon spathula*, paddlefish adult, Shedd Aquarium, Chicago.

vent decimation of our paddlefish stocks. With its large maximum size, rapid growth, low trophic position, excellent flesh, and extremely valuable roe, the paddlefish is receiving considerable attention by fishery biologists as having potential for fish farming. The long bibliography for the species (Graham and Bonislawsky, 1978) and discussion of its status, management, and propagation (Dillard et al., 1986) are indicative of this interest.

Juvenile paddlefish are particularly susceptible to impingement on intake screens associated with cooling water intakes for power plants. Mortality of paddlefish in such areas may be high, but the actual effect on populations is unknown. Pasch et al. (1980) suggested that reduction below current population levels will not occur as the result of existing plants. A sport fishery for paddlefish below dams on the Missouri River involved snagging the fish with large treble hooks, but declining populations are curtailing this fishery. In our area, encounters between anglers and paddlefish are not uncommon, typically accidental, and often decided in favor of the fish. Paddlefish weighing 20–30 kg (44–66 lb) are not uncommon, and Trautman (1981) reported a 184 lb specimen. A 52 kg (114 lb) specimen from Watts Bar tailwater, 20 June 1973, is the largest Tennessee specimen recorded. Tennessee angling record is 53.5 lb, Cherokee Reservoir, Otis Rouse; the world record on hook and line is a 142.5 lb fish from the Missouri River taken in 1973.

Distribution and Status: Mississippi River basin, Gulf Coastal drainages from Mobile Basin to San Jacinto River, Texas, and formerly in Lake Erie. In the recent past it was feared that paddlefish would sharply decline in abundance due to effects of impoundments on Tennessee's large rivers, as has been the case with many big-river fish species. At present it appears that they have taken advantage of these altered environments. Wallus (1986) documented consistent reproduction in the Tennessee and Cumberland rivers in the years 1973–1982. Alexander et al. (1985) hypothesized that the paddlefish population in Watts Bar Reservoir contained an unusually high proportion of young individuals because older fish had been decimated by a gill net fishery that was banned a few years previous. Overfishing could be a future cause for concern if the fishery is not prudently regulated. In more westerly portions of



Range Map 11. *Polyodon spathula*, paddlefish.

the range, such as the Missouri River basin, paddlefish populations have declined, and the species is being considered for federal protection.

Similar Sympatric Species: The only potential confusion is associated with the various common names given this species and the flathead catfish (*Pylodictis olivaris*). It is often difficult to determine if spoonbill cat or shovelbill cat refers to the paddlefish or the flathead catfish; we assume that in most cases these names apply to the former.

Etymology: *Poly* = many, *don* = tooth, referring to the numerous gill rakers; *spathula* = a blade or paddle.

ORDER LEPISOSTEIFORMES

FAMILY LEPISOSTEIDAE
The Gars

The gars constitute a small group of large, primitive predatory fishes with fossils dating to the Cretaceous period 65–100 million years ago and, based on biogeographic implications, may approach 200 million years of age (Wiley, 1976). Earlier workers variously aligned them with bowfins (family Amiidae), the African bichirs or reedfishes (family Polypteridae), or the extinct fossil semionotiform fishes (summarized in Wiley, 1976). But more recent views include gars and their extinct relatives in the separate order Lepisosteiformes (Nelson, 1984), which is considered to comprise the closest relatives to a group consisting of bowfins (Amiiformes) plus the remainder of "higher" bony fishes (teleosts) (Patterson, 1973; Wiley, 1976; Schultz and Wiley, 1984a). Recent gars are restricted to North and Central America and Cuba; Cretaceous to Oligocene fossil forms are known from Eurasia and Africa (Wiley, 1976).

The diamond-shaped ganoid scales that provide a rigid external covering over the entire body of gars are also found, among living fishes, only on bichirs and on the upturned caudal fin base of paddlefish. Gars are unique in several aspects of their skeleton, and are, in addition to a genus of blennies (small, relatively advanced, marine perciform fishes), the only living fishes with a concave posterior and convex anterior vertebral surface (Suttkus, 1963; Wiley, 1976). The highly vascular swim bladder is connected to the esophagus and allows the swim bladder to function as a lung. Gars are often seen taking gulps of air at the surface and can presumably tolerate waters with very little dissolved oxygen. They are also tolerant of estuarine and marine environments, and some species are common in Gulf Coast estuaries. Gars are not highly esteemed as food fishes in this area, but they have a mild flavor and very firm white flesh and are consumed in considerable numbers in portions of Louisiana. They are especially good served as a substitute for lobster (cut into strips, boiled, and dipped in butter). Eggs of all gars are reported to be toxic.

Of the five North American gar species, four occur in Tennessee; the fifth species, *Lepisosteus platyrhincus* DeKay, the Florida gar, is confined to peninsular Florida and adjacent coastal Georgia where it is an important prey species for alligators, ospreys, and bald eagles. The two additional species that comprise the order are *Atractosteus tropicus* Gill from Central America and *A. tristoechus* (Bloch and Schneider) from Cuba; an additional, possibly undescribed form of *Atractosteus* occurs in the Texas coastal region (Wiley, 1976) but recent genetic data suggest that these represent hybrids with *Lepisosteus osseus* (J. K. Gibbons, in litt.).

Gars spawn in late spring, typically over shallow, heavily vegetated areas. Several males accompany the usually larger female. Spawning is random, and the relatively large eggs adhere to vegetation. Gar larvae have an adhesive disk near the tip of the lower jaw with which they adhere to vegetation or other solid objects, hanging vertically, until the yolk sac is absorbed. The suctorial disc is absorbed and the young gars drop off the vegetation and begin to feed actively on microcrustaceans. Juveniles are more distinctly colored than adults, having a broad dark stripe along the side, and the vertebral column continues as a filament above and free from the caudal fin (Fig. 60). Sex ratios are skewed toward males initially, but females live longer and grow to be considerably larger. Gars feed primarily on other fishes, which they catch sidewise in their well-toothed jaws. They catch their prey by lying motionless or slowly stalking prey until the smaller fishes are within reach. They then slash their beak from side to side and, if successful, impale or injure one or more of the intended prey. The prey is usually then maneuvered into position to be swallowed head-first (Branson, 1966). On sunny days, adults are often seen apparently "basking" just beneath the surface.

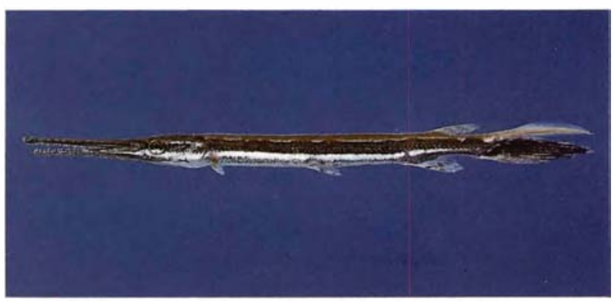


Figure 60. Juvenile gar with caudal filament (*Lepisosteus osseus*, 105 mm TL, Duck R. system, TN).

KEY TO THE TENNESSEE GENERA AND SPECIES

Since gars have a modified heterocercal caudal fin, standard length is not precisely defined, and lateral-line scales are counted all the way to the base of the caudal fin rays in the lateral-line scale row. Predorsal scale rows include the rows composed of smaller scales at the anterior base of the dorsal fin. Gill rakers are knobby projections on the concave surface of the gill arch and are counted on the outer surface of the first functional gill arch. Snout length is measured from the anterior bony rim of the orbit to the tip of the snout. Minimum snout width is measured behind the nares (nostrils) near holes which receive the two large teeth near the tip of the lower jaw. Head length is measured from the tip of the snout to the posterior bony edge of the operculum. Previous keys to North America gars have relied heavily on the presence of enlarged canine teeth on the palatine bones to separate the alligator gar from other species. We find this unworkable, as both the spotted gar and shortnose gar may also have enlarged teeth on the palatines that are as large as the canine teeth on the maxillae on the outer edge of the snout. Snout proportions (Fig. 61) vary considerably with size in gars, but the proportional measurements in the key should accurately separate specimens 50 mm or longer in total length. Simon and Wallus (1989) described early development of gars and provided characters useful for identifying smaller specimens of the four Tennessee species.

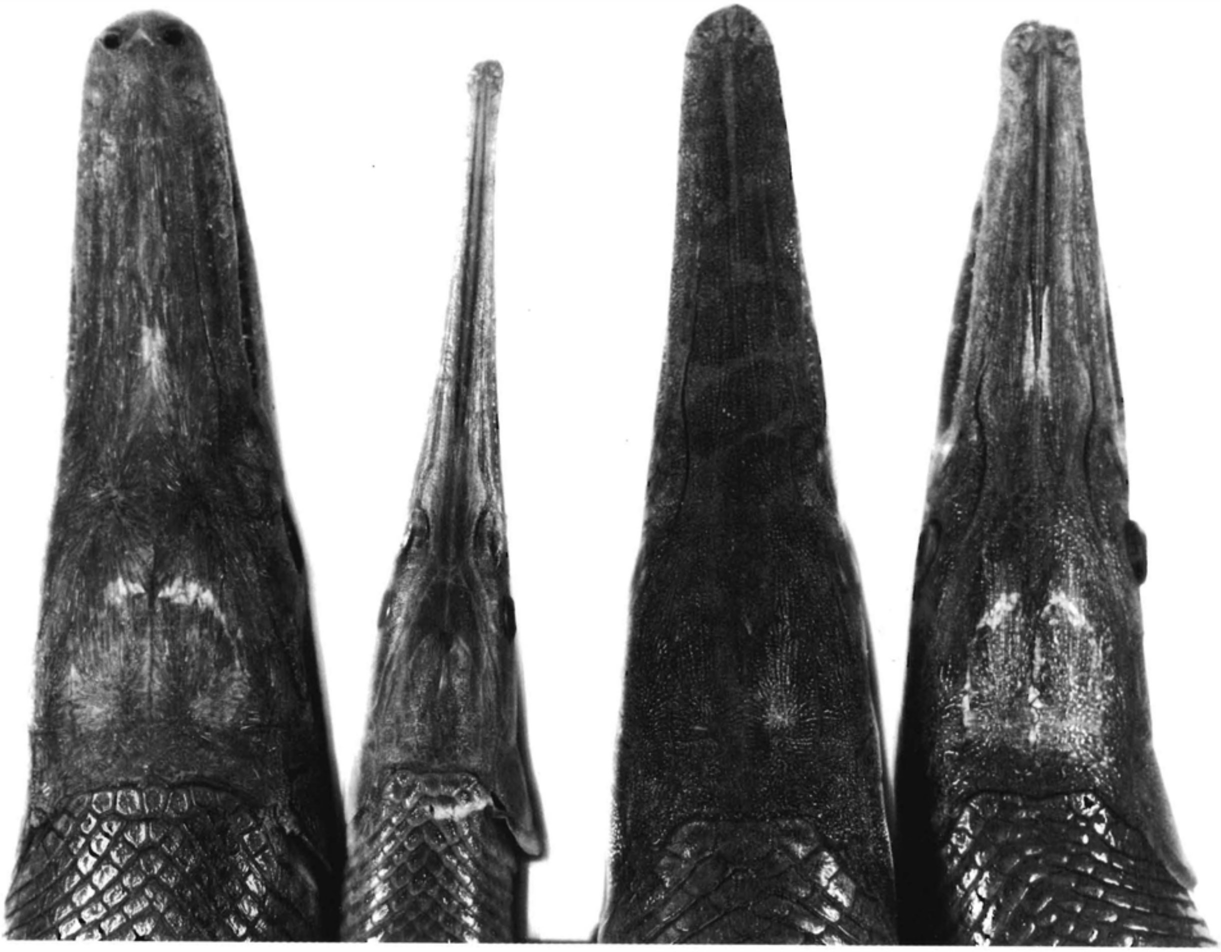


Figure 61. Dorsal view of gar heads, from left, *Atractosteus spatula*, *Lepisosteus osseus*, *L. oculatus*, *L. platostomus*.

1. Gill rakers 30 or fewer; minimum snout width contained 5 or more times in snout length; minimum lower jaw width contained 10 or more times in head length; young lacking a pale middorsal stripe; common species 2

Gill rakers 60 or more; minimum snout width contained 4.5 or fewer times in snout length; minimum lower jaw width contained less than 7.5 times in head length; young with pale middorsal stripe; a rare species confined in our area to west Tennessee . . . . *Atractosteus spatula*

2. Snout long and slender (Fig. 61), its least width contained 13 or more times in snout length . . . . *Lepisosteus osseus* p.112

Least snout width contained 10 or fewer times in snout length 3

3. Snout and sides of lower jaw with irregularly placed dark blotches (Fig. 61); predorsal scale rows usually 50 or fewer (45–54); lateral-line scales 59 or fewer . . . . *L. oculatus* p.111

Snout and sides of lower jaw lacking dark blotches (Fig. 61); predorsal scale rows usually 51 or more (50–55); lateral-line scales 60 or more (59–65) . . . . *L. platostomus* p.113

Genus *Atractosteus* Rafinesque

Atractosteus spatula (Lacepede)

Alligator gar

Characters: Lateral-line scales 58–62, predorsal scale rows 49–54, transverse scale rows (midline just in front of anal fin obliquely forward to dorsal midline) 23. Gill rakers 59–66. Color grayish to dark green dorsally, white ventrally. Median fins spotted. Juveniles have a pale middorsal streak.

Biology: The alligator gar is by far the largest of our gars, and one of our largest freshwater fishes. It inhabits large rivers, backwaters, oxbow lakes, and brackish water estuaries. Until recently, this gar supported an active sport fishery in the White River system in Arkansas, and it continues to be taken by angling and spearing in Louisiana. Little is known concerning its life history, but the April–June spawning season coincides with seasonal flooding of bottomland swamps which may be important spawning habitat, especially considering the concomitant decline of these habitats (caused by leveeing and channelization) and alligator gar populations. Its biology must obviously be quite different from that of other gar species which have persisted throughout these alterations. Simon and Wallus (1989) described early development of a small number of specimens from Lake Texoma, Oklahoma. At 15 mm TL, no yolk sac or suctorial disc on the snout remained evident; at 20–32 mm, fin formation occurred, and scalation occurred by about 65 mm TL. Larvae were collected in late May from a vegetated backwater slough while juveniles (100 mm TL or so) were taken in late July from a shallow embayment in association with plant debris. Adults will presumably attack and eat any potential food item of appropriate size, including blue crabs, turtles, waterfowl or other birds (Hussakov, 1914), and small mammals, and is also believed to scavenge (Suttkus, 1963). Goodyear (1967) reported a diet consisting chiefly of fish (primarily estuarine catfishes and drums), plus scavenged items, such as chicken carcasses, in a Mississippi coastal population. Tales of this fish attacking humans are not uncommon in folklore and popular literature, but according to Suttkus (1963) are without documentation. Maximum size reported (Suttkus, 1963) is a 137 kg (302 lb) specimen, nearly 3 m (9 ft 8 in) long. The world record

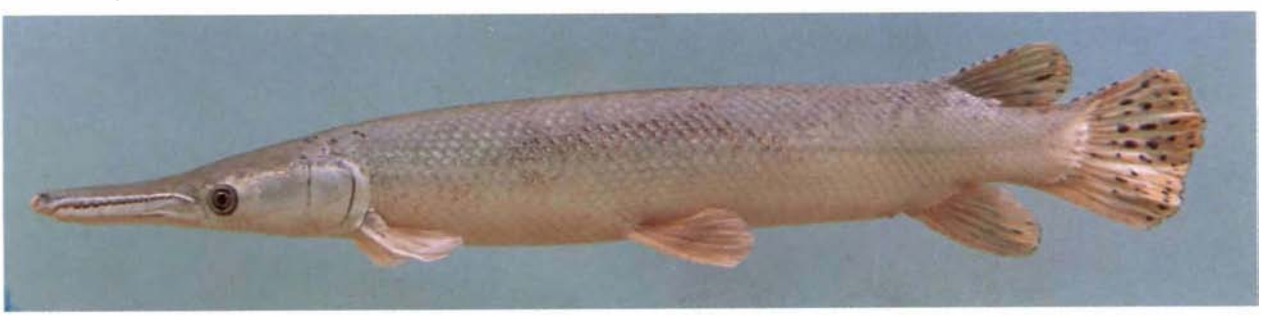


Plate 12. *Atractosteus spatula*, alligator gar, about 1 m TL, specimen from Texas at Tennessee Aquarium, Chattanooga.

Figure 62. Large alligator gar specimen from Moon Lake, MS, just south of Memphis, TN (probably between 1910 and 1930s). Total length estimates based on probable dimensions of boards in photo place this specimen at approximately 3 m or 10 ft. (courtesy of American Museum of Natural History, Negative # 11705).

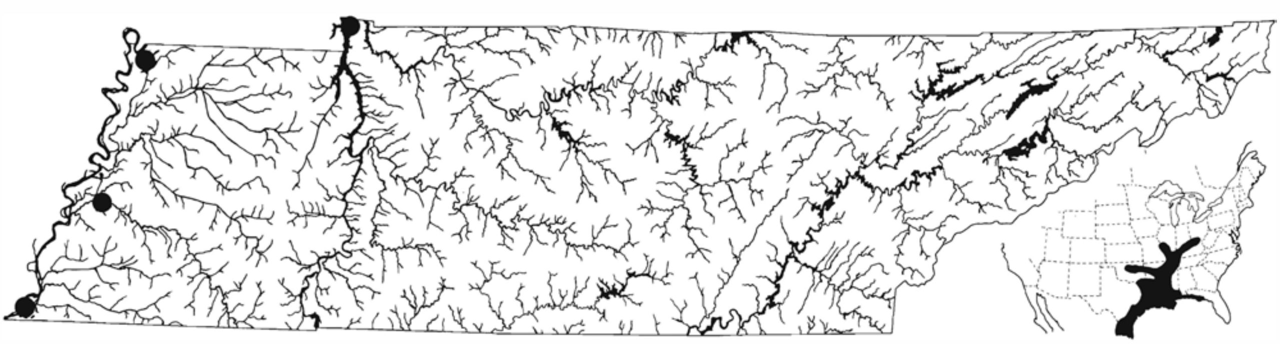
taken by angling weighed 279 lb and was taken in Texas in 1951. The large specimen (Fig. 62) from Moon Lake, Mississippi, just south of Memphis, certainly qualifies as one of the largest ever captured.

Distribution and Status: Former range extended up Mississippi River basin to Illinois, Ohio, and Missouri, and Gulf Coastal rivers from western Florida into Mexico. There are very few recent records of this species from Tennessee, but some commercial fishermen on the Mississippi River profess to catch them occasionally. A potential problem with accepting all of these reports is that there is a tendency to call all large gars "alligator gars." Baker (1937) included a photograph of a specimen from Reelfoot Lake, and Starnes (1973) reported seeing a photograph of a large specimen, supposedly taken from the Hatchie River system. Charles Saylor, TVA, recently mentioned seeing a photograph of two specimens, 30 and 80 lbs, taken from the Cypress Creek area of Kentucky Reservoir, probably during 1976. We have never seen an actual specimen collected from Tennessee waters. Fisheries biologists working in the Reelfoot Lake and Mississippi River areas in recent years have seen no specimens of alligator gar during their surveys or in fishermen's catches (T. Broadbent, pers. comm.) It is likely that the alligator gar has decreased drastically in abundance in the state within the past 50 years, probably in response to river rechannelization and clearing and draining of swamps in the Mississippi River lowlands, and may, in fact, be extirpated. The alligator gar is considered to be in need of management (soon to be upgraded to endangered) in Tennessee (Starnes and Etnier, 1980), endangered in Arkansas (T. Buchanan, 1974), rare in Missouri (Miller, 1972), endangered in Kentucky (Warren et al., 1986), and threatened in Illinois (Simon and Wallus, 1989). Populations may also be declining in some Gulf Coastal areas where it remained common until recent years. Additional valid Tennessee records of this fish would be of extreme interest.

Similar Sympatric Species: Both the shortnose and spotted gar are generally similar in appearance to the alligator gar, but neither is as heavy bodied or has as broad a snout (Fig. 61) as does the alligator gar. Any "short-nosed" gar from west Tennessee that weighs more than 4 kg (9 lb) is very likely this species. Pflieger (1975) recommended comparing the distance from the tip of the snout to the corner of the mouth with length of the remainder of the head; the first of these measurements is smaller in the alligator gar, and longer in our other gars. Very small (Simon and Wallus, 1989) specimens have a pale middorsal streak, while our other gars have a dark middorsal streak as juveniles.

Systematics: We follow Wiley's (1976) elevation, based on several unique characters, of the genus *Atractosteus* from the synonymy of *Lepisosteus*.

Etymology: *Atract* = spindle, *osteus* = bony; *spatula* = a spatula, referring to snout shape.



Range Map 12. *Atractosteus spatula*, alligator gar.

Genus *Lepisosteus* Lacepede

See discussion under Key to Genera for characters.

Etymology: *Lepid* = scale, *osteus* = bony.

Lepisosteus oculatus Winchell

Spotted gar

Characters: Lateral-line scales 53–59, predorsal scale rows 45–54, transverse scale rows 17–20 (18–24). Gill rakers 15–24. Color usually greenish dorsally, white ventrally. Top of snout, sides of jaws, and nape usually with scattered large dark blotches. Median fins spotted. Juveniles with a dark middorsal streak.

Biology: Spotted gars are most abundant in the clear, weed choked waters of backwaters and oxbow lakes, and are apparently less tolerant of silt than is the shortnose gar and less inclined to enter upland rivers than is the longnose. Pflieger (1975) and Echelle and Riggs (1972) summarized results of life history studies in Missouri and Oklahoma, and Simon and Wallus (1989) reported on larval development and ecology based on Tennessee River specimens. Spawning was observed on dead vegetation and algal mats in quiet backwater areas. Small larval specimens, collected in May, retained a yolk sac and suctorial disc on the snout up to about 17 mm TL; fin formation occurred between 17 and 36 mm. Larvae were usually collected near the surface and shore. Young feed for a short time on mosquito larvae and microcrustacea, but rapidly become piscivores, feeding heavily on *Gambusia* and *Fundulus* spp., and then feeding almost exclusively on gizzard shad at larger sizes. Goodyear (1967) reported heavy predation on menhaden and crabs along the Mississippi coast. Spawning in Missouri occurred in April in the swift outflow from a flooded timber stand. At the end of 1 and 3 year's growth, young spotted gar attained lengths of 10 and 20 inches, respectively, with males maturing after 2 years and females maturing after 3 or 4. The oldest fish in this study was estimated to be at least 18 years old. Maximum total length 1.12 m (44 in) (Trautman, 1981).

Distribution and Status: Mississippi River basin and southern Great Lakes, and Gulf Coastal drainages from Apalachicola drainage to Guadalupe River of Texas. Mostly recorded from below the Fall Line in southern portion of its range. Widespread in west Tennessee, and occurring in middle and east Tennessee along the valleys of the larger rivers.

Similar Sympatric Species: Most similar to shortnose gar, and spotted gars from turbid waters may almost completely lack the characteristic spotting pattern (Fig. 61) on top of the snout. Scale counts are necessary for positive identification in these cases, but the spotted gar

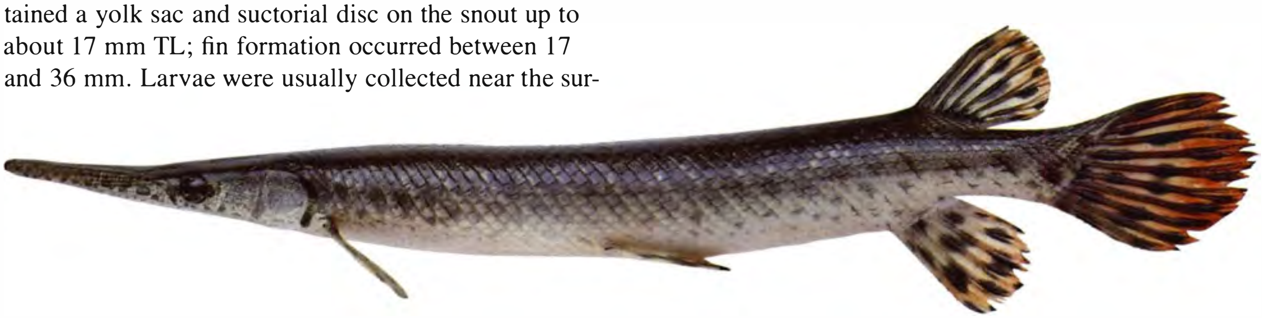
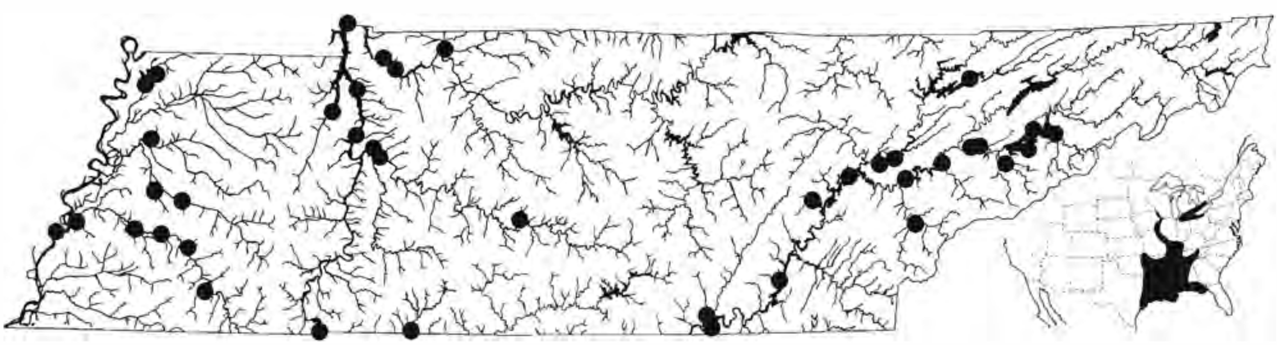


Plate 13. *Lepisosteus oculatus*, spotted gar, 53 cm TL, Kentucky Res., TN.



Range Map 13. *Lepisosteus oculatus*, spotted gar.

usually retains some blotching along the sides of the jaws even when the top of the snout is concolorous. Simon and Wallus (1989) provide characters useful for identifying small specimens.

Etymology: *oculatus* = eyed, referring to the ocellus-like spots on the body.

Lepisosteus osseus (Linnaeus)

Longnose gar

Characters: Lateral-line scales 57–65, predorsal scale rows 47–55, transverse scale rows 17–24. Gill rakers 14–31. Color grayish to olive green dorsally, white ventrally. Median fins spotted. Juveniles with a dark middorsal streak.

Biology: This is the most widespread and familiar of the gars, and it occurs throughout most of Tennessee in rivers and reservoirs, and in swamps and oxbow lakes in west Tennessee. Since it grows to be very large, it is likely that some reports of the alligator gar are based on this species. Longnose gar probably feed most heavily on shad (Netsch, 1964). A Florida population (J. Crumpton, in litt.) fed heavily on gizzard shad and bullheads with minor predation on minnows and sunfishes. Goodyear (1967) reported heavy predation on another member of the herring family, the menhaden, in Mississippi coastal waters. Pearson et al. (1979) found that postlarvae 25–42 mm long fed on larval fish and cladocera. A thorough life history study (Netsch and Witt, 1962) of a Missouri population indicated that spawning occurs from April through June, depending on latitude; in our area peak spawning is in mid-May. Adults may move upstream into rivers and streams to spawn on gravel shoal areas and among rocks (Yeager and Bryant, 1983) and have also been reported to spawn in the weedy shallows of lakes and rivers (Echelle and Riggs, 1972). Goff (1984) noted the frequent occurrence of longnose gar eggs and larvae in smallmouth bass nests, where the male bass guarding the nest provided protection for the young gar in addition to its own young. Females produce about 30,000 (extremes to 77,000) eggs per year. Yeager and Bryant (1983) reported that eggs hatched in 3 days at 26 C and that larvae were 8.8–9.9 mm at hatching. Simon and Wallus (1989) reported on early development of Tennessee River and other specimens: the yolk sac is absorbed at 12 mm TL and the suctorial disc of the snout by 20 mm; fins are formed by 30 mm or so. In the Missouri study, first year's growth was 49.5 cm (19.5 in) for males and 55.8 cm (22.0 in) for females. Females maintain their length advantage throughout life. Sex ratios are initially in favor of males, but their shorter average lifespan (about 11 years) balances and then reverses sex ratios in larger fish; females may live for 22 years. Sexual maturity occurs at age 3 or 4 (males) and at age 6 for females. The largest reported specimen is the current angling world record, 50 lb, 5 oz (22.7 kg) Texas specimen that was just over 6 ft (1.834 m) long. The Tennessee record is a 23 lb fish from Pickwick tailwaters.

Plate 14. *Lepisosteus osseus*, longnose gar, 69 cm TL, Melton Hill Res., TN (snout-tip slightly damaged).

Range Map 14. *Lepisosteus osseus*, longnose gar.

Distribution and Status: Widespread and common throughout much of the United States from the Rio Grande eastward. Occasionally taken in open sea habitat in the Gulf of Mexico (our records). In Tennessee, most abundant in large rivers and reservoirs, but may be expected in small rivers during the spawning season.

Similar Sympatric Species: Specimens larger than 6 inches, with their extremely long snout, are not likely to be confused with other gars. Smaller juveniles of our three *Lepisosteus* have similar bold color patterns, but Suttkus (1963) indicated that, in the longnose, the dark lateral band is scalloped on its dorsal margin (straight in *oculatus*) and the middorsal stripe is cinnamon colored and narrow (broader and darker in *oculatus*). Yeager and Bryant (1983) gave additional characters for young longnose gar, and Simon and Wallus (1989) provided pigment and meristic character differences between young of all four Tennessee gar species.

Etymology: *osseus* = bony.

Lepisosteus platostomus Rafinesque

Shortnose gar

Characters: Lateral-line scales 59–64, predorsal scale rows 50–55, transverse scale rows usually 20–23. Color grayish to pale green dorsally, white ventrally. Median fins spotted. Juveniles with a dark middorsal streak.

Biology: This is our smallest and most silt-tolerant gar. It occurs in pools and overflow areas of large streams, generally avoiding both currents and rooted aquatic vegetation. There is little recent information on its biology. Pflieger (1975) reviewed two earlier papers. Food consists of other fishes, with insects and crayfishes a more important dietary supplement than for other gars. Spawning occurs over vegetation or other submerged objects in quiet, shallow water from May through June where eggs adhere in small gelatinous masses (Potter, 1926). Simon and Wallus (1989) detailed early development of two specimens; the smaller, 26 mm TL, had lost the yolk sac and snout suctorial disc, and fin formation was complete on a 38 mm specimen. Sexual maturity occurs after 3 years, at about 33 cm (15 in). Maximum weight 2.6 kg (5 lb) (Trautman, 1981). Maximum total length about 0.8 m (32 in).

Distribution and Status: Mississippi River basin and western tributaries to Lake Michigan. Tennessee distribution virtually restricted to the Mississippi River lowlands and the larger reaches of the Tennessee and Cumberland rivers. Some of the more upstream reports for this species in the Tennessee River may be based on poorly marked spotted gars, and suspect specimens taken above the Chattanooga area should be carefully examined.

Similar Sympatric Species: See spotted gar.

Etymology: *platy* = flat, *stomus* = mouth.

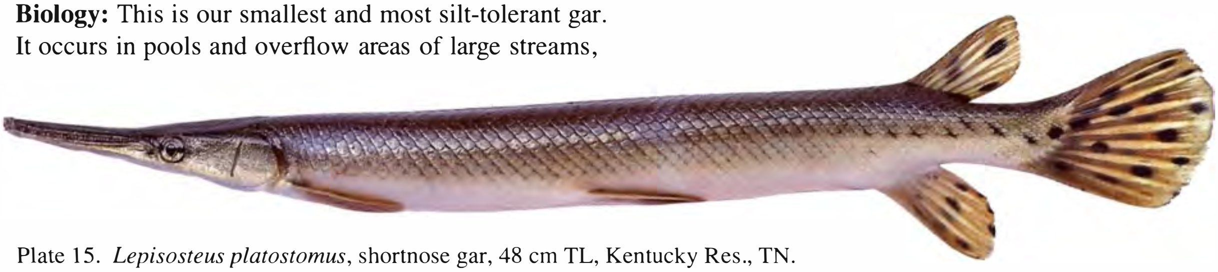
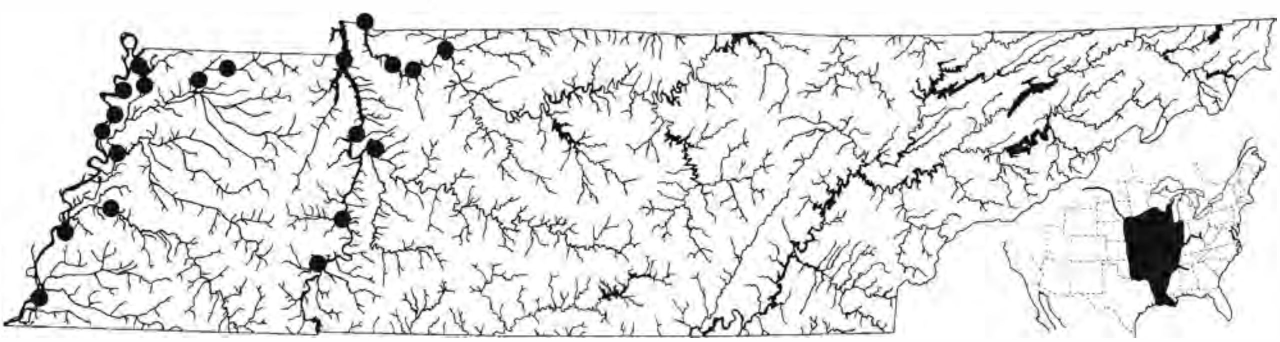


Plate 15. *Lepisosteus platostomus*, shortnose gar, 48 cm TL, Kentucky Res., TN.



Range Map 15. *Lepisosteus platostomus*, shortnose gar.

ORDER AMIIFORMES

FAMILY AMIIDAE
The Bowfin

As is the case with sturgeons, paddlefish, and gars, the bowfin is a modern representative of an ancient group of fishes, the Amiiformes. Relatives (about 10 genera) of the living bowfin were abundant in marine environments in Jurassic and Cretaceous times, approximately 150 million years ago, and a very large (perhaps 2.5 m) form was recently described from early Eocene (about 50 mya) deposits of western Africa (Patterson, 1973; Patterson and Longbottom, 1989). Fossils are known from both freshwater and marine deposits on all continents except Australia. Fishes very similar to, if not identical with, the modern genus *Amia* and with an extensive record in North America, are known from early Cretaceous freshwater deposits, over 100 million years ago, and persist into middle Tertiary times 30 million years or so ago (Grande, 1980; Wilson, 1982; Cavender, 1986). As stated in the discussion of gars, Lepisosteidae, Wiley (1976) regarded Amiidae as the sister group to all "higher" bony fishes (teleosts); Nelson (1969a), however, regarded gars as the closest relatives. *Amia calva*, the only surviving species, retains the modified heterocercal caudal fin structure found in the gars, but the scales are of a more advanced type, somewhat cycloid-like, but with parallel bony ridges. The gular bone, a flat plate on the floor of the mouth between the rami of the lower jaw, is not found in any of our other freshwater fishes, but appears in some marine fishes such as the tarpon and ladyfish (family Elopidae). Within the Amiidae, alternate schemes of relationships of *Amia* to fossil genera were proposed by Schultz and Wiley (1984b) and Bryant (1987), but Patterson and Longbottom (1989) felt that neither was well substantiated.

Amia calva Linnaeus

Bowfin

Characters: Lateral-line scales 64–68. Dorsal fin with 46–50 soft rays. Anal fin rays 9–10. Pectoral fin rays 16–18. Color gray or green dorsally. Adult males have a circular black spot surrounded by a pale orange halo at the upper caudal fin base (shared by juveniles, but typically absent in adult females) and the median fins develop a spectacular blue-green color. Small juveniles up to 60 mm TL are strikingly colored with black and orange (Pl. 16).

Biology: The bowfin, also known as "dogfish," "grinnel," and "mudfish," is a large predator usually associated with shallow, weedy lakes; swamps; and backwater areas. Like the gars, it has a fleshy and vascular swimbladder that is connected to the esophagus, and it is capable of surface respiration. The following account on its biology is summarized from Reighard (1904), Scott and Crossman (1973), and Pflieger (1975). Spawning occurs in the spring, at water temperatures of 16–19 C (April through early June in our area), with the male constructing and guarding a nest excavated in shallow water. Hatchlings appear in about 10 days and have an adhesive organ at the tip of the lower jaw similar in structure and function to that described for gars. Young bowfin are guarded by the male parent, and associate in compact schools until they are about 10 cm long. Early food of juveniles is microcrustacea, with small insects incorporated into the diet in specimens over 40 mm TL or so (Frazer et al., 1989) and a shift to a piscivorous diet at about 10 cm; food of adults is about two-thirds fish (mostly gizzard shad in our area) and one-third crayfishes. Sexual maturity occurs at total lengths of about 18 in (males) and 24 in (females) at ages of about 2–4 years. Moderate sized females (4–5 lb) produce 23,000–64,000 adhesive eggs. Life span in aquaria is reported as up to 30 years but is normally only about 10 years in wild populations. Although sluggish compared to our popular sport fishes, bowfin will occasionally strike an artificial lure. They are used as food in some areas but are generally not esteemed as food fishes, with the flesh being of good flavor but of a soft and gelatinous texture. However, other reports (pers. comm. A. E. Bogan, B. M. Burr) indicate them to be excellent. The largest reported specimen is the current world angling record, a 9.74 kg (21.5 lb) specimen from South Carolina, 1980. The Tennessee angling record weighed 15 lb, 7 oz, and was caught in Reelfoot Lake in 1983 by Charles Aaron.

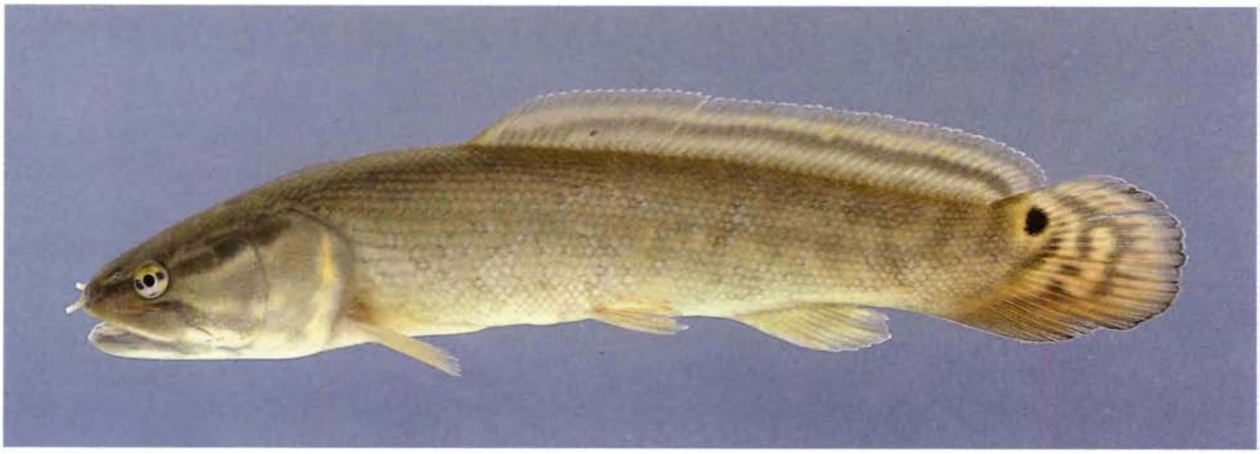


Plate 16a. *Amia calva*, bowfin, young male, 143 mm TL, Mississippi R., TN.

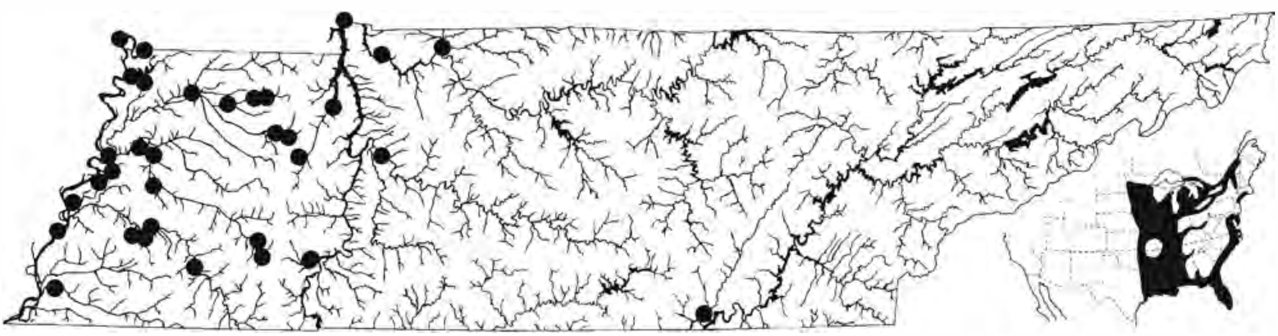
Plate 16b. *Amia calva*, bowfin juvenile, 70 mm TL, Altamaha R. system, GA.

Distribution and Status: Mostly on Coastal Plain of Atlantic drainages from Chesapeake Bay region to Colorado River, Texas. Also widespread in Great Lakes drainage, Mississippi Basin north to Minnesota, and adjacent areas of Hudson Bay drainage of northwestern Minnesota. Common in Mississippi River and tributaries in west Tennessee, but much less common in lower Cumberland River, and lower Tennessee River where it extends upstream into lower Sequatchie River.

Similar Sympatric Species: Juveniles are somewhat similar to the mudminnow (*Umbra limi*) but differ noticeably in having a heterocercal caudal fin and a much longer dorsal fin (46–50 rays vs. 13–15 rays). Also similar in appearance to the burbot (*Lota lota*), which has tiny scales, a median chin barbel, and an anal fin as large as the posterior portion of the divided dorsal fin.

Systematics: Bermingham and Avise (1986) and Avise et al. (1987) analyzed mitochondrial DNA of southern *Amia* populations and discovered evidence for two lineages, comprising, respectively, populations of the Atlantic drainages and Gulf tributaries east of the Escambia River drainage, and those from the Escambia drainage westward.

Etymology: *Amia*, according to Jordan and Evermann (1896) is an ancient name for a fish of uncertain identity, but possibly refers to the Atlantic bonito, *Sarda sarda*; *calva* = smooth.



Range Map 16. *Amia calva*, bowfin.

ORDER OSTEOGLOSSIFORMES

FAMILY HIODONTIDAE
The Mooneyes

The family consists of but two somewhat herring-like fishes, both in the genus *Hiodon*, that are confined to large water bodies in central North America. Greenwood (1973) considered hiodontids and their relatives to be closely related to clupeiform fishes, with these groups together forming the sister group to all other bony fishes above the level of the aforementioned sturgeons, gars, bowfins, lungfishes, and a few other primitive groups. Hiodontids, which date in the fossil record to the Eocene (Wilson, 1978; Grande, 1980), together with the large "bony tongues" of southeast Asia, Australia, Africa, and South America (e.g., arawana, arapaima) of the family Osteoglossidae, and such spectacular aquarium fishes as the African knife fishes (Notopteridae) (hypothesized closest relatives of hiodontids by Nelson, 1969b) and African freshwater butterfly fishes (Pantodontidae), comprise the order Osteoglossiformes (Nelson, 1984). The Old World order Mormyriformes (elephantfishes and gymnarchid eels) of Greenwood et al. (1966) is related (considered more closely related to notopterids than to hiodontids by Patterson, 1973, and Lauder and Liem, 1983) and was considered a suborder of Osteoglossiformes by G. J. Nelson (1968) and Nelson (1984). Hiodontids have adipose eyelids (similar to herrings), an axillary process above the pelvic fin base, cycloid scales, well-developed lateral lines, and prominent teeth on jaws and tongue. They lack an oviduct, and eggs are conveyed through the body cavity prior to spawning.

Etymology: *Hio* = tongue or hyoid, *don* = tooth.

KEY TO THE TENNESSEE SPECIES

1. Keel on venter of abdomen extending forward to breast; dorsal fin origin over or posterior to anal fin origin . . . . *Hiodon alosoides*

   Keel on venter of abdomen extending forward only to pelvic fins; dorsal fin origin anterior to anal fin origin . . . . *H. tergisus* p.117

Hiodon alosoides (Rafinesque)

Goldeye

Plate 17. *Hiodon alosoides*, goldeye, 230 mm SL, Mississippi R., TN.

Characters: Lateral-line scales 57–62. Dorsal fin rays 9–10. Anal fin rays 29–34. Pectoral fin rays 11–12. Branchiostegal rays 8–10. Vertebrae 56–61. Color pale green dorsally, silvery white to slightly brassy on sides; iris of eye often gold.

Biology: The goldeye is an inhabitant of large, turbid rivers. Its biology is summarized in Grosslein and Smith (1959) and Scott and Crossman (1973). Spawning begins in spring when water temperatures reach 10–13 C (50–55 F). Spawning sites are in pools or backwater areas of turbid rivers. Females produce about 6,000–25,000 eggs per season that are semibuoyant—an unusual condition among freshwater fishes. Larvae were described in Hogue et al. (1976). Young feed primarily on microcrustacea, with larger fish having a diet of aquatic insects, small fishes, mollusks, and even frogs and mice. Smoked goldeye, marketed as Winnipeg goldeye, is considered a delicacy in central Canada and often brings a higher per pound return to the commercial fisherman than the highly esteemed walleye. In Canada, lengths of about 18 and 23 cm (7 and 9 in) are reached after the first and second year's growth; growth tapers off after the third year when fish average about 30 cm (12 in). Sexual maturity may occur as early as age 1 for males, or may be delayed until age 10 for females in northern latitudes. Our Mississippi River specimens, all presumably in their first year, are 30, 80, 85–100, and 125–128 mm total length, taken in mid May, mid July, late August, and late October, respectively. Maximum reported size (Trautman, 1981) is 508 mm (20.5 in) total length and 1.4 kg (3 lb, 2 oz).

Distribution and Status: Mississippi River basin, portions of Hudson Bay drainage, and Mackenzie River drainage of Canada. The goldeye was a previous inhabitant of both the upper Tennessee and upper Cumberland rivers (Etnier et al., 1979; Gilbert, 1980), but it has disappeared from these areas following impoundment, and its current Tennessee distribution is virtually restricted to the main channel of the Mississippi River, where it is fairly common. It is more tolerant of turbidity than its congener, *H. tergisus*, and its disappearance following impoundment is not understood; perhaps it is somewhat migratory into southeastern portions of its range.

Similar Sympatric Species: Both mooneye and goldeye differ from the generally similar shad and herring in having the ventral keel smooth (serrate in shad and herring). In addition, the jaws are well armed with sharp teeth, while our shad are toothless, and our herrings are toothless or weakly toothed. Sympatric with the mooneye in west Tennessee, where differences in scale, fin ray, and branchiostegal ray counts, in addition to characters mentioned in the key, should suffice for positive identification of even very small specimens.

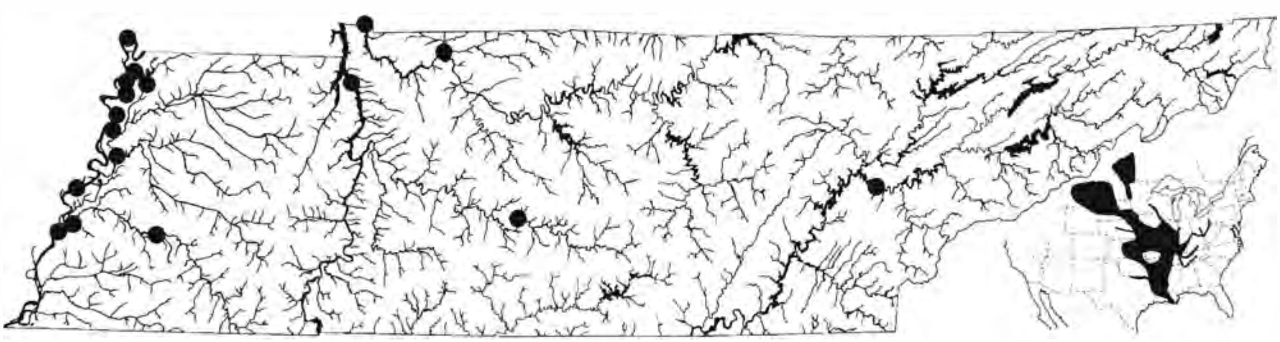
Etymology: *alosoides* = shad-like.

Hiodon tergisus Lesueur

Mooneye

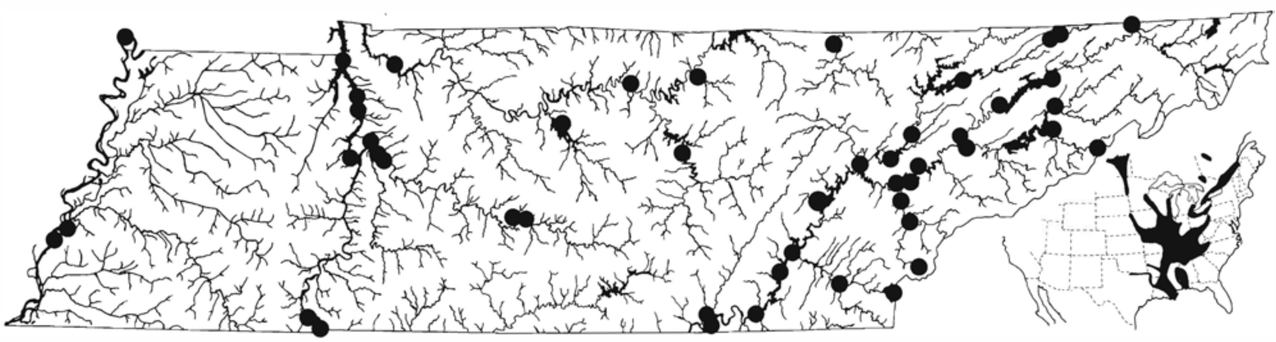
Characters: Lateral-line scales 52–57. Dorsal fin rays 11–12 (10–14). Anal fin rays 26–29. Pectoral fin rays 13–15. Branchiostegal rays 7–9. Vertebrae 53–57. The irregularly placed scales adjacent to the anal fin origin are typical of the species and do not stem from injury. Color pale green or gray dorsally, silvery white on sides and belly.

Biology: The mooneye is a surface-feeding fish of our clearer rivers and large reservoirs. Prior to impoundment, it was an abundant species in the Little Tennessee River, where it was taken frequently on dry flies by trout fishers. Although not used as a food fish, the mooneye offers fair sport and is sufficiently selective to suggest to the dry fly fisher that the pattern he or she is



Range Map 17. *Hiodon alosoides*, goldeye (range extends off inset to extreme northwestern Canada in Mackenzie River drainage).

Plate 18. *Hiodon tergisus,* mooneye, about 225 mm SL, Tennessee R., TN.



Range Map 18. *Hiodon tergisus*, mooneye (range in central Canada extends off inset into central Manitoba and Saskatchewan).

using will take trout if it will take mooneye. The following is condensed from our information and several papers dealing with the biology of the mooneye in the Great Lakes region summarized by Scott and Crossman (1973) and later works by Glenn (1975a, 1975b, 1976, 1978). In Tennessee, spawning occurs in April and May, with adults often making upstream runs into clear rivers. Females produce 10,000–20,000 eggs per year. Larvae were described by Fish (1932) and Hogue et al. (1976). Mooneye feed primarily on surface insects, aquatic insect larvae, and small fishes. Young mooneye are more benthic oriented in feeding behavior, eating chiefly immature aquatic insects. The mooneye is less tolerant of turbidity and less inclined to be active at night than is the goldeye. Growth is rapid, with juveniles reaching up to 200 mm (8 in) during their first growing season. Sexual maturity is reached in from 3 (males) to 5 (females) years, with maximum reported size 445 mm (17.5 in) total length and 1.1 kg (2 lb 7 oz). The Tennessee angling record of 14 oz (.4 kg) is from the Hiwassee River, 1990, Alan Cantrell.

Distribution and Status: Mississippi Basin, Mobile Basin, Great Lakes, and Hudson Bay tributaries. Fairly common in large waters of the Tennessee and Cumberland drainages, but less common than the goldeye in the Mississippi River and its larger tributaries.

Similar Sympatric Species: See goldeye account.

Etymology: *tergisus* = polished.

ORDER ANGUILLIFORMES

FAMILY ANGUILLIDAE

The Freshwater Eels

The family Anguillidae consists of the single genus *Anguilla* Schrank and includes some 15 species (Ege, 1939; D. G. Smith, 1989a), all of which are catadromous (living in fresh water but returning to the sea to spawn). Freshwater eels, which date at least to the Eocene (Cavender, 1986), are similar in appearance to other families of eels, all primarily marine groups, and with them comprise the order Anguilliformes. Eels have very elongate, serpentine bodies, lack pelvic fins (some also lack pectoral fins), and have scales absent or small and embedded. The eel-like form has apparently evolved independently several times, and there are several groups of "eels" (e.g., Synbranchidae of tropical fresh waters) that are not related to true eels and are included in various other orders. The affinities of the true eels with other groups of fishes are not obvious. Greenwood et al. (1966), G. J. Nelson (1973a), and Robins (1989) considered tarpon and bonefish (families Elopidae and Albulidae) to be closely related (same superorder) to eels based on larval similarities and morphological evidence. Robins (1989) allied anguillid eels with the strictly marine families Moringuidae and Heterenchelyidae in a subordinal grouping, Anguilloidei. The European eel, *Anguilla anguilla*, is very similar to the American eel, and this North Atlantic pair, which use overlapping oceanic spawning areas (D. G. Smith, 1968), were thought to represent a single species by some workers (Tucker, 1959; G. Williams et al., 1984). However, based on a growing body of evidence, many recent workers consider them to be separate species (e.g., Tesch, 1977; Comparini and Rodino, 1980; Avise et al., 1986; D. G. Smith, 1989a). Freshwater eels are absent from South Atlantic and eastern Pacific coasts but occur in areas adjacent to the Indian Ocean and in the Pacific Ocean from Australia to Japan. It would appear that anguillids are obligate warm-sea spawners and thus must reproduce in tropically influenced waters with currents suitably directed to return larvae to coastal river mouth areas (D. G. Smith, 1989a), thus limiting their world distribution to regions where this set of circumstances prevails. These eels are important food fishes in some areas, particularly Europe and Japan, where they are considered a delicacy. Along our Atlantic coast, eel is mostly prepared for consumption by smoking.

Anguilla rostrata (Lesueur)

American eel

Characters: Pelvic fins absent; dorsal, caudal, and anal fins continuous. Color yellowish brown; specimens in spawning condition more light gray.

Biology: The American eel is certainly one of our most interesting fishes. Adults migrate from fresh waters of North America to their spawning grounds in the Sargasso Sea, in the northern Caribbean-Bermuda region. This aspect of their life history was not known until well into this century (Schmidt, 1922), and the exact spawning areas, depths, and migratory cues for American and European eels remain poorly understood or unknown (Vladykov, 1964; Tesch, 1977). McCleave et al. (1987) defined broadly overlapping spawning grounds for these species with the European eel spawning more northerly; the mechanism whereby larval stages are sorted to be routed to their eventual correct continental destinations is a complete mystery. Mature American eels migrate to sea in fall and winter, presumably to reach the spawning area. At this time they are called "silver eels" because of coloration, and have increased eye diameter, perhaps to facilitate "sea-going" or mate location. A possible gravid female *Anguilla* has been photographed at the ocean bottom off the Bahama Islands at a depth of over 2000 m (Robins et al., 1979); the implications of this to reproductive behavior are not understood. Female silver eels may contain two million or more eggs (Wenner and Musick, 1974). Adults apparently die after spawning. Eels have a transparent, ribbon-shaped larval form called the "leptocephalus" (described in detail by D. G. Smith, 1989b). In late winter to early spring, larvae become a part of the marine plankton and drift with North Atlantic currents toward both the North American and European shores. Prevailing currents carry most larvae of *A. rostrata* along the Atlantic Coast; thus they are less common in the Mississippi River drainage and other Gulf of Mexico tributaries. The larvae metamorphose into the typi-

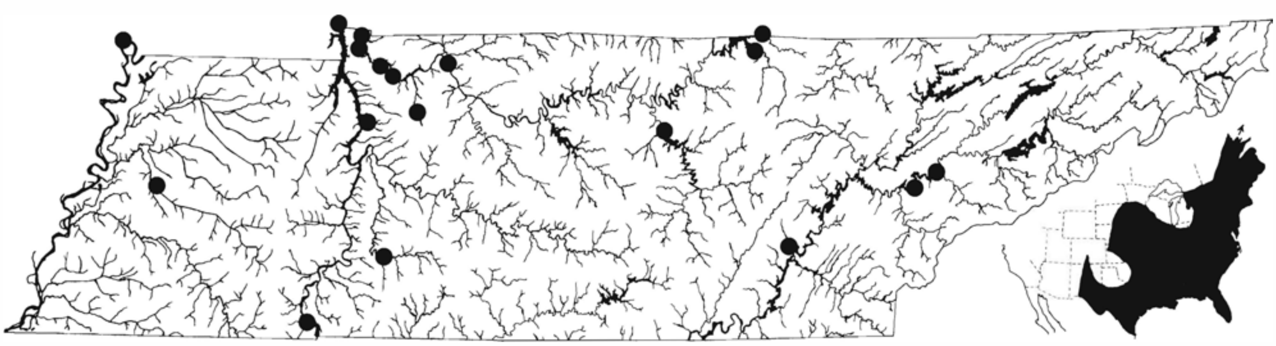
Plate 19. *Anguilla rostrata*, freshwater eel, 234 mm TL, Potomac R. system, VA.

cal adult shape when nearing the coast but continue to be transparent "glass eels" for some time. Juveniles with developing pigment are called "elvers." Male eel larvae may settle out of the currents before females, or it is also possible that those larvae that are transported longer undergo sex-change to females (Helfman et al., 1987). It is not understood what environmental cues trigger winter and spring migration of the elvers into fresh water (Sorensen and Bianchini, 1986). The young female eels migrate upstream from the Atlantic and Gulf coasts, moving as far inland as Minnesota, the upper Ohio River system in Pennsylvania, and east Tennessee, where they normally remain for about 10–20 years before returning to the sea. There is evidence that eels have very strong homing tendencies, as specimens displaced far from their "home" rivers quickly return (Vladykov, 1971). Eels from more northerly latitudes apparently mature at 9–18 years of age while more southern populations mature at 6–9 years (Helfman et al., 1984). Males, which are much smaller than mature females, remain closer to coastal areas, and their freshwater residency is somewhat shorter than that of females. Females grow to about 50 cm (20 in) by age 5, males to about 35 cm (14 in) (Hansen and Eversole, 1984). Females mature at large size (Helfman et al., 1987) and may reach sizes of 1.22 m (4 ft) TL and 7.25 kg (16 lb) (Scott and Crossman, 1973); Trautman (1981) reported a 1.32 m (52 in) specimen, but its weight was only 3.4 kg (7.5 lb). Specimens of *A. anguilla* have lived in captivity for up to 88 years (Scott and Crossman, 1973). Eels are sedentary, nocturnal, predatory fishes that feed on other fishes, crayfishes, and immature insects; near the coasts they feed on small crustaceans, bivalves, and polychaete worms (Wenner and Musick, 1975). They are commonly hooked by anglers near the coasts but are rarely caught in more inland waters.

Distribution and Status: Occurs in all drainages of eastern North America and south to Venezuela and the Caribbean Islands. Eels continue to be fairly common in Atlantic and eastern Gulf coastal areas, but impoundments on most rivers in central North America may have reduced inland eel populations. Occasional eels manage to navigate these barriers, apparently by moving overland on rainy nights (Tesch, 1977) or "locking through" in navigable waterways. Eels are uncommon in Tennessee waters but are still occasionally taken in direct tributaries to the Mississippi River and in the Cumberland and Tennessee rivers as far upstream as Dale Hollow Reservoir and Knoxville, respectively (Wilson and Turner, 1982). The American eel appears on Tennessee's list of Species in Need of Management (Starnes and Etnier, 1980).

Similar Sympatric Species: Lampreys are superficially similar but lack jaws and pectoral fins.

Etymology: *Anguilla* = Latin for eel; *rostrata* = long nose.



Range Map 19. *Anguilla rostrata*, American eel (freshwater range extends off inset through northeastern Canada and Greenland, islands in the Caribbean, and Central and South America south to Brazil).

ORDER CLUPEIFORMES

FAMILY CLUPEIDAE

The Herrings and Shads

The herring-like fishes, order Clupeiformes, comprise a large group (see Nelson, 1984) of primarily anadromous or marine species that are valuable commercial and forage fishes. Their possible interrelationships were addressed by G. J. Nelson (1970a, 1973b) and Grande (1982, 1985); Grande and Nelson (1985) considered these relationships largely unresolved. Included in the order are sardines, herrings, anchovies, menhaden, alewife, pilchard, and shad. With the exception of the anchovies and two small groups not mentioned, the above fishes are all included in the family Clupeidae, which dates to the early Cretaceous, about 120 million years ago (Grande, 1985). Clupeids are extremely abundant in early to mid Eocene deposits (45–55 mya) from western North America (Grande, 1980). Taxonomy of western Atlantic and eastern North American clupeids was treated in detail by Hildebrand (1963—see comments under Berry, 1964) and in part by Miller (1963) with review and some alternate views offered by Berry (1964).

Family characters for clupeids include adipose eyelids, pelvic axillary processes, relatively large, easily shed cycloid scales, and a keeled ventral midline composed of modified scales (scutes). Ventral scute counts are useful taxonomic characters, and are counted from the throat to and including the scute whose point is at or slightly posterior to the anterior pelvic fin insertion (prepelvic count), and from the next posterior scute to the anus (postpelvic count). In general, clupeids are deep-bodied, silvery fishes many of which feed on planktonic organisms, grow rapidly, have short life spans, and typically associate in large schools. Larval herrings are extremely long and slender, and quite different in appearance from adults.

Herrings are certainly among the most valuable commercial fishes in the world, being important food fishes in many countries and serving as a chief source of fish meal for animal feeds. A regionally popular sport fishery exists for the anadromous American shad (*Alosa sapidissima*) along our north Atlantic coastal rivers, where shad flesh and roe are considered delicacies. The five Tennessee clupeid species are little used as food fishes, but both the gizzard and threadfin shads are extremely important in providing the forage base for larger game fishes in our reservoirs. The mooneyes (family Hiodontidae, Pl. 17–18) are very similar in appearance to herrings, but they have well-developed teeth on their jaw bones and a smooth rather than serrate ventral surface of the abdomen.

KEY TO THE TENNESSEE GENERA AND SPECIES

1. Last ray of dorsal fin not elongate; predorsal midline scaled: genus *Alosa* 2
   Last ray of dorsal fin produced as a long filament (Fig. 33); predorsal midline naked: genus *Dorosoma* 4
2. Tip of lower jaw projecting well beyond tip of upper jaw; 24 or fewer gill rakers on lower limb of first arch; widespread and abundant . . . . *Alosa chrysochloris* p.123
   Tip of lower jaw little if any projecting beyond tip of upper jaw; 30 or more gill rakers on lower limb of first arch; restricted and/or rare 3
3. Mouth very oblique; dorsal fin rays usually 13–14 (14–16); introduced in Watauga and Dale Hollow reservoirs . . . . *A. pseudoharengus* p.124
   Mouth nearly horizontal; dorsal fin rays 15–16; rare but perhaps persistent in Mississippi River in west Tennessee . . . . *A. alabamae* p.122
4. Snout bulbous and fleshy, projecting past upper jaw; tip of lower jaw far below level of middle of eye; anal fin rays 29 or more . . . . *Dorosoma cepedianum* p.126
   Snout more pointed and not extending anterior to upper jaw; tip of lower jaw at level of middle of eye; anal fin rays 25 or fewer . . . . *D. petenense* p.127

Genus *Alosa* Linck

Alosa comprises a genus of anadromous fishes of the North Atlantic that are very similar in appearance to the strictly marine herring, *Clupea harengus*. They are predatory species characterized by a relatively large mouth and relatively low gill raker counts. Six species are native to the western North Atlantic and Gulf of Mexico, and other species occur in European waters along the Atlantic and Mediterranean coasts and Caspian Sea, and North Africa. In earlier literature some American species were included in the genus *Pomobolus* Rafinesque. Svetovidov (1964) considered *Pomobolus* a subgenus of *Alosa*, with *A. alabamae* and *A. sapidissima* included in the subgenus *Alosa* and the other four North American species in *Pomobolus*. The commercially most valuable of these species is the American shad (*A. sapidissima*), which is native along our East Coast and has been successfully introduced along the West Coast. Other Atlantic coastal species not treated here are the hickory shad (*A. mediocris*) and blueback herring (*A. aestivalis*). Spring spawning runs up east coast rivers are eagerly anticipated by fishermen. Shad can be taken on light sporting tackle as well as with various nets; the herring and alewife are typically dip-netted or snagged with treble hooks. The alewife has recently invaded the Great Lakes where, in addition to providing forage for recently introduced Pacific salmon (genus *Oncorhynchus*), it quite often creates a serious disposal problem by dying in large numbers and washing up on beaches. It has been recently introduced, apparently successfully, into Watauga and Dale Hollow reservoirs in Tennessee. The two native Tennessee species were originally anadromous or, highly migratory within large rivers, along the Gulf Coast, with *A. chrysochloris* currently (and possibly in preimpoundment days) capable of completing its life cycle in fresh water.

Etymology: *Alosa* is a Saxon name for *Alosa alosa*, the European shad.

Alosa alabamae Jordan and Evermann

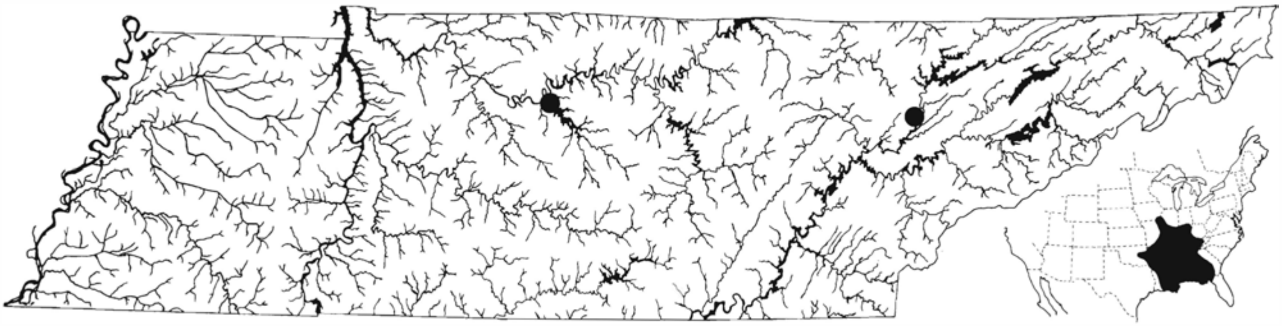
Alabama shad

Characters: Scales in lateral series 55–60. Ventral scutes 19–21 prepelvic, 15–17 postpelvic. Dorsal fin rays 15–16. Anal fin rays 18–20. Jaw teeth weak or absent in adults. Gill rakers usually 30 or more on lower limb of first arch. Tongue teeth present in a single median row. Color bluish gray dorsally with dark streaks along scale rows; silver on sides. Vague dark spot present behind upper operculum. Dark pigment extending along most of length of outer surface of lower jaw.

Plate 20. *Alosa alabamae*, Alabama shad, preserved specimen, 193 mm SL, Choctawhatchee R., AL.

Biology: The Alabama shad is an anadromous species that enters large rivers to spawn. Most available life history information is from Florida rivers (Laurence and Yerger, 1967; Mills, 1972). Adults enter mouths of rivers from January through March, with actual spawning occurring at temperatures of 19–22 C during April, over coarse sand and gravel substrates swept by moderate currents. Adults apparently do not feed during the spawning run. Females produce from 100,000 to about 250,000 eggs per year. Spawning adults are primarily 2 years old, but some 1-year-old fish participate. Adults may live to 3 or 4 years. Juveniles remain in fresh water until late summer or fall, feeding on small invertebrates in flowing water areas. They are about 50–100 mm (2–4 in) long by the time they return to the ocean. The diet probably consists mainly of small fish. Maximum size (Pflieger, 1975) 457 mm (18 in) TL and 1.36 kg (3 lb).

Distribution and Status: Eastern Gulf Coastal drainages from Suwannee River, Florida, to Mississippi River. The Alabama shad was apparently widespread in larger Tennessee rivers in preimpoundment days, with verified records from the Clinch and Stones rivers (Hildebrand, 1963). It has not been able to cope with impoundments, and is presently rare throughout much of its former range in larger rivers tributary to the Gulf of Mexico. Gunning and Suttkus (1990) present data suggesting that it is still declining in the Pearl River system of Louisiana and Mississippi. There are no recent records from Tennessee, but the Alabama shad presumably occurs in the Mississippi River periodically, since recent records are available from that river and its larger tributaries both north and south of Tennessee



Range Map 20. *Alosa alabamae*, Alabama shad (freshwater range).

(Pflieger, 1975; Smith, 1979). Baker (1939) reported this species (as *A. ohioensis*) crossing the spillway into Reelfoot Lake "by the thousands" during May 1937 but the accompanying photo (of *A. chrysochloris*) indicates this record to be of the more common skipjack herring. Charles Saylor, TVA, provided a large adult specimen from the Tennessee River just below Kentucky Dam in Marshall County, Ky., collected in July 1986. It appears on Tennessee's list of rare vertebrates as a species "Deemed in Need of Management" (Starnes and Etnier, 1980). Any records of this species from Tennessee would be of extreme interest.

Similar Sympatric Species: The two species each of *Hiodon* and *Dorosoma* are similar in appearance but can easily be differentiated by referring to characters in the keys. Most like *A. chrysochloris*, from which it differs in having teeth weak or absent from jaws of adults, in having a single median row versus 2–4 rows of teeth on the tongue, and in being deeper bodied, in addition to characters mentioned elsewhere. In a limited number of specimens counted, nine *A. alabamae* had total ventral scutes 36 or more, while in 15 *A. chrysochloris* only one specimen had as many as 36 scutes.

Systematics: Most similar to and probably forming a closely related species pair with *A. sapidissima* of the Atlantic drainages (Berry, 1964). *Alosa ohiensis* Evermann, under which name this species occurred in earlier works, is generally conceded to be a junior synonym of *A. alabamae*.

Etymology: *alabamae* = from Alabama.

Alosa chrysochloris (Rafinesque)

Skipjack herring

Characters: Scales in lateral series 36–50. Ventral scutes 17–19 prepelvic and 14–17 postpelvic. Dorsal fin rays 16–21. Anal fin rays 18–21. Jaw teeth conspicuous in all sizes. Gill rakers on lower limb of first arch 18–24. Tongue teeth in 2–4 rows. Dark pigment on lower jaw restricted to tip. Color gray to intense dark blue dorsally with dark streaks along scale rows. Dull dark spot present behind upper operculum.

Biology: As is the case with the alewife, the skipjack (sometimes called "Tennessee tarpon" and "hickory shad") is able to complete its life cycle in fresh water. With possible exception of Mississippi River populations, Tennessee skipjack are surely landlocked. They occur throughout the state in large rivers and main channel reservoirs. Adults often aggregate in tailwaters and other areas of swift current. At such times they are easily taken on light sporting tackle, with small spoons and spinners the most productive lures. They can offer fast and furious sport, and an excellent way to introduce youthful anglers to the excitement of playing large and active fish on light tackle. Although edible, they are reported to be dry and bony, and are not generally esteemed as food fishes in Tennessee. The rather meager life history information that follows is summarized from accounts in Pflieger (1975), Burgess (1980), and our observations. Spawning occurs in the spring, with adults often making long migrations upstream. Females produce about 100,000 to 300,000 eggs per year, presumably after 2 or 3 years of growth. Juveniles feed on zooplankton, insect larvae, and small fishes. The proportion of fishes in the diet increases with size, and adults are often seen preying on small gizzard and threadfin shad at the surface in local reservoirs. Young reach total lengths of 75–150 mm during their first year, and sexual maturity is at about 30 cm (12 in). The

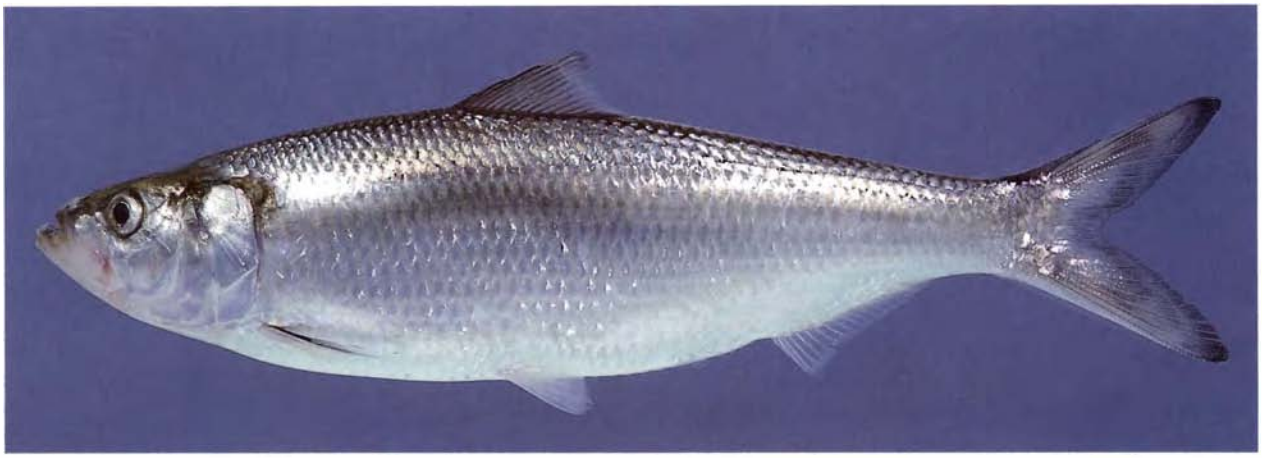


Plate 21. *Alosa chrysochloris*, skipjack herring, 228 mm SL, Tennessee R., TN.

Tennessee angling record, a 1.7 kg (3 lb, 12 oz) fish taken from Watts Bar Reservoir by Paul Goddard in 1982, approximates maximum known size for the species.

Distribution and Status: Gulf Coastal drainages, including much of the Mississippi River basin, from Apalachicola River west to Colorado River, Texas, and occasionally in coastal areas slightly to the east and west of these rivers. Navigational dams have apparently been responsible for its recent disappearance from much of the upper Mississippi River basin. In Tennessee generally common in large rivers and main channel reservoirs, but absent from many storage reservoirs.

Similar Sympatric Species: See *Alosa alabamae*.
Systematics: Forms a closely related species pair with *A. mediocris* of the Atlantic Coast according to Berry (1964).

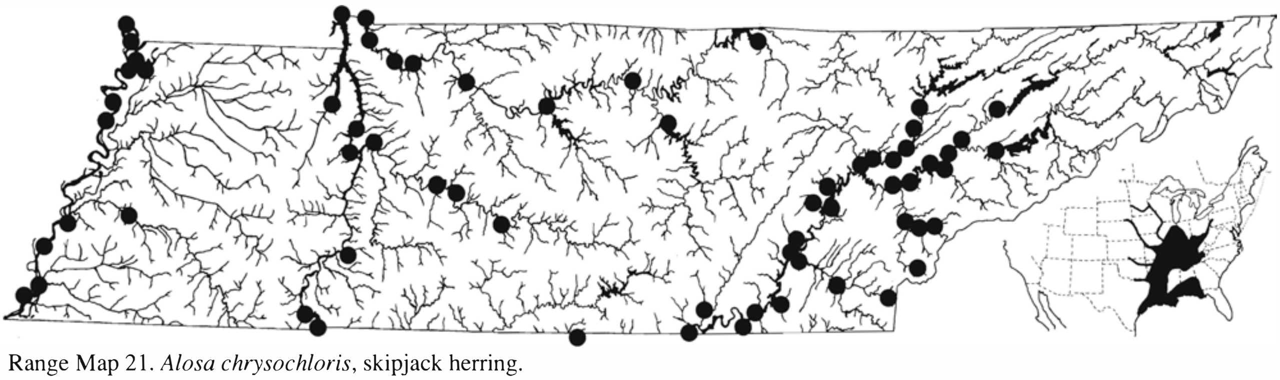
Etymology: *chryso* = gold, *chloris* = green.

Alosa pseudoharengus (Wilson)

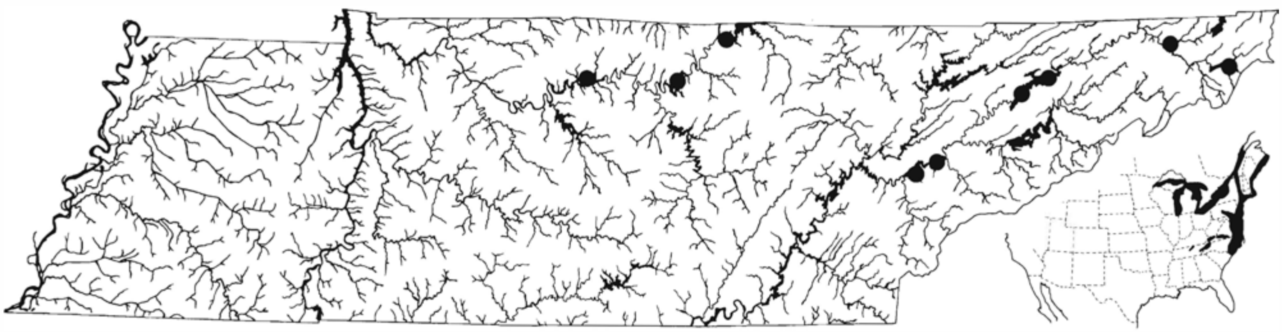
Alewife

Plate 22. *Alosa psuedoharengus*, alewife (preserved 3 days before photo), 225 mm SL, Potomac R., VA.

Characters: Scales in lateral series 42–50. Ventral scutes (17)19–20(21) prepelvic and (12)14–15(17) postpelvic. Dorsal fin rays usually 13–14 (12–16). Anal fin rays 17–18. Jaw teeth weak and inconspicuous. Gill rakers on lower limb of first arch 38 or more in adults (as few as 25 in specimens less than 5 cm according to Menhinick, 1975). Tongue teeth absent. Color greenish



Range Map 21. *Alosa chrysochloris*, skipjack herring.



Range Map 22. *Alosa pseudoharengus*, alewife (native and introduced populations; native range extends off inset to Labrador).

or gray dorsally. Dull dark spot present behind upper operculum.

Biology: The alewife is principally an anadromous species which utilizes lentic (standing) waters of smaller streams and headwater ponds along the middle and northern Atlantic Coast as spawning habitat (Fay et al., 1983; Loesch, 1987). However, it has adapted quite well to landlocked existence in some cooler lakes. The alewife was introduced into Watauga and Dale Hollow reservoirs in 1976 and has apparently become firmly established therein (Strange et al., 1987; L. B. Starnes and P. A. Hackney, in litt.). It was introduced in an effort to provide an adequate forage base in the reservoir, which has water temperatures too cool for maintaining thriving populations of gizzard shad. Alewife are heavily utilized as forage by large predatory species, such as walleye and smallmouth bass, in inland waters where they have become established (Wagner, 1972), and evidence of utilization by walleye, smallmouth bass, crappie, rainbow trout, and ohrid trout was found in Watauga Reservoir (Strange et al., 1987).

Scott and Crossman (1973) and Becker (1983) provided a detailed account of the biology of landlocked populations in the Great Lakes. While other *Alosa* species are piscivorous (fish eaters) as adults, both young and adult alewife predominantly feed on microcrustacea which are strained from the water column by numerous, long gill rakers. Spacing, lengths, and total numbers of gill rakers increase with age to enable adult alewife to continue to feed on zooplankton, although progressively larger prey items must be taken (MacNeill and Brandt, 1990). Adults move from deep waters into shore from April through mid July for spawning, which may occur from June through August but peaks in early July. Spawning may occur during day or night, with landlocked females producing about 10,000–22,000 demersal eggs (up to 100,000 in anadromous females). During spawning, several individuals with their sides in contact swim upward from the bottom in a tight spiral. After considerable splashing at the surface, they return to deeper water. Young reach lengths of 51–75 mm (2–3 in) during their first year's growth. Sexual maturity occurs at age 2 (males) or 3 (females), but occasional age 1 individuals, particularly males, may spawn. In the Watauga Reservoir population, young average 70 mm TL at age 1 and 103 at age 2 (Strange et al., 1987). Life span in landlocked populations is typically 5–6 years. Maximum total length 356 mm (14 in).

Distribution and Status: Native range included East Coast drainages (seasonally) of North America from North Carolina northward, but now introduced and widespread in Great Lakes region and locally elsewhere. Although a remote possibility exists that the alewife was native to Lake Ontario, it is not known from there prior to the 1870s; it has spread throughout the other Great Lakes since the 1930s (Miller, 1956). It remains speculative as to how successful the alewife will be in expanding its range in Tennessee since its 1976 introductions into Watauga and Dale Hollow reservoirs, but it has dispersed downstream in cool tailwaters up to 100 km below these reservoirs (L. B. Starnes and P. A. Hackney, in litt.).

Similar Sympatric Species: Previously, the alewife's restricted Tennessee range made it sympatric in our area with only one other herring-like fish, the gizzard shad. Movement below Dale Hollow Reservoir has brought it in contact with the threadfin shad and skipjack herring, and in the Holston system it is already or will soon occur with both of these species. Alewife are readily separated from both shad based on characters in the key. It differs from the very similar skipjack herring in having fewer dorsal fin rays, a more oblique mouth, a less projecting lower jaw, few if any teeth on jaws and tongue, and many more gill rakers (see Key and Characters for both species).

Etymology: *pseudo* = false, *harengus* = herring.

Genus *Dorosoma* Rafinesque

The Gizzard Shads

Dorosoma, whose species are collectively called gizzard shads, is a North and Central American genus containing three Central American species in addition to the two treated herein (R. R. Miller, 1960, 1963). The vernacular name of the genus stems from the muscular, gizzard-like stomach. They are further characterized by their rather blunt snouts, small mouths, and numerous closely packed gill rakers which may exceed 400 in number. Several related genera, constituting with *Dorosoma* the subfamily Dorosomatinae, occur in the Indo-Australian region (Nelson and Rothman, 1973). Gizzard shad are planktivores, straining fine food items from the water with their numerous gill rakers. They possess a pharyngeal organ which may serve to concentrate and process food for swallowing (Miller, 1964). They are valuable forage fishes, and, although not very hardy, are commonly used live as bait for striped bass, and as dead offerings on trot lines.

Etymology: *Doro* = lanceolate, *soma* = body.

Dorosoma cepedianum (Lesueur)

Gizzard shad

Characters: Scales in lateral series 58–65 (52–70). Ventral scutes 17–20 prepelvic and 10–14 postpelvic. Dorsal fin rays 10–13. Anal fin rays 27–36. Gill raker compliments increase with growth, beginning at near 100 in juveniles and exceeding 400 in adults. Vertebrae 47–49. Color gray or greenish dorsally, silvery below. Large black spot present behind gill cover.

Biology: This familiar forage fish occurs throughout Tennessee in reservoirs and large rivers, with adults often entering mouths of smaller streams. R. R. Miller (1960), Jester and Jensen (1972), and Shelton (1972) have presented detailed treatments on various aspects of gizzard shad biology. Spawning is random, occurs near the surface in shallow water, and involves large aggregations of adults. Females are typically followed and presumably spawned with by several males. In Tennessee, spawning occurs from mid May to mid June. Gizzard and threadfin shad occasionally hybridize (Shelton and Grinstead, 1973). Average size females produce about 300,000 eggs per year. Eggs are about 0.75 mm in diameter, are adhesive, and hatch in 2 or 3 days. Fry feed primarily on copepods and cladocerans, with adults eating large amounts of phytoplankton in addition to zooplankton. Maturity is generally reached in the second year, with 3 or 4 years the normal life span. Maximum size 52 cm (20.5 in) total length, 1.6 kg (3.5 lb).

Since gizzard shad are primary consumers (plant feeders), extremely large populations can be maintained. Although there has been some interest in the commercial use of the species as a source of fish meal, oil, and food for pets and fur bearers, there is little if

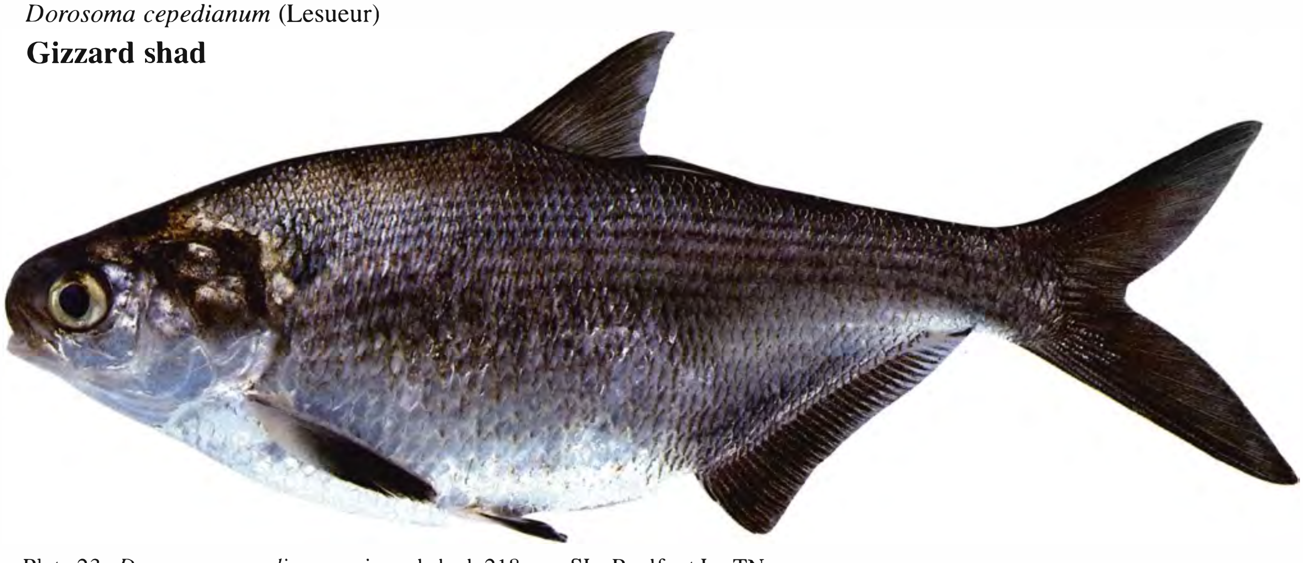
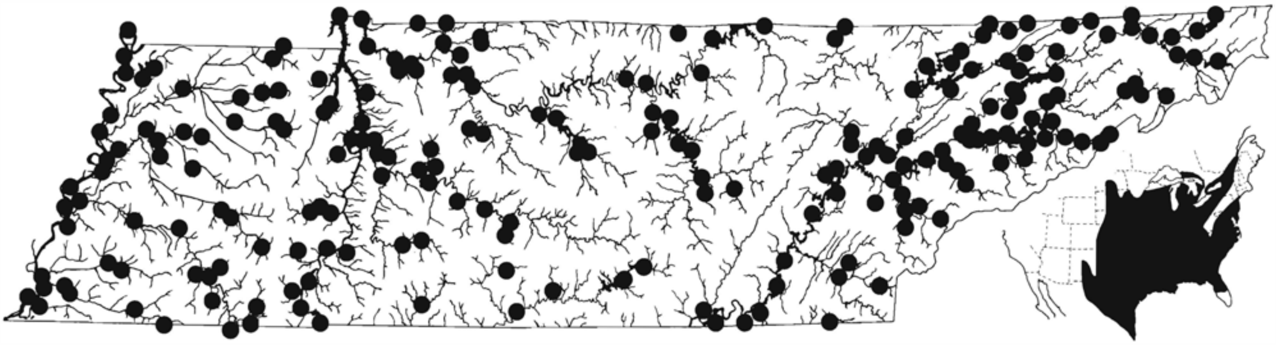


Plate 23. *Dorosoma cepedianum*, gizzard shad, 218 mm SL, Reelfoot L., TN.



Range Map 23. *Dorosoma cepedianum*, gizzard shad.

any commercial utilization at present. Their value as a forage species for more popular food and game fishes has been well publicized, but is conjectural among fishery biologists. A major problem involves their rapid growth and relatively large maximum size. Within their first year they commonly reach lengths of 10–18 cm (4–7 in) and rapidly become too large to be preyed upon by all but the largest predators. Although not directly competitive with more popular fishes, gizzard shad are extremely successful in reservoirs and often comprise 40–80% of all fish by weight. At such densities their sheer numbers may reduce carrying capacity for other species. Furthermore, it is not unlikely that bass (*Micropterus* sp.) have an actual preference for crayfishes and spiny-rayed fishes as food items. The striped bass (*Morone saxatilis*) and muskellunge (*Esox masquinongy*) have been introduced into several of our reservoirs as potential predators on adult gizzard shad, and it would appear that the striped bass can provide considerable pressure on gizzard shad populations. Muskellunge are likely to be less effective, since they can not be maintained in high densities, tend not to be open water feeders, and prey heavily on sunfish and crappies. Although gizzard shad are better able to withstand low winter temperatures than is the threadfin, large winter die-offs are not uncommon. When these occur, dead and dying shad are eaten by crows, turkey vultures, bald eagles, and waterfowl.

Distribution and Status: Native range presumably included all eastern and central drainages in North America except those in New England and southern Florida. Widely introduced elsewhere. Abundant in large waters throughout Tennessee.

Similar Sympatric Species: Both the mooneye and goldeye (*Hiodon tergisus* and *H. alosoides*) and our three species of *Alosa* are superficially similar, but all of these species lack the elongate posterior dorsal fin ray. In *Hiodon*, the keel (knife-edged ventral margin of the abdomen) is smooth rather than serrate as in the herrings. The threadfin shad is very similar to the gizzard shad, but these species are easily separable by referring to characters listed in the key and in both species accounts. Hybrids are not uncommon, and these can usually be detected by noting the intermediate snout shape and intermediacy of the many non-overlapping meristic features. Useful field characters include the lack of yellow fin color in the gizzard shad (all fins except the dorsal yellow in life in the threadfin) and the snout shape.

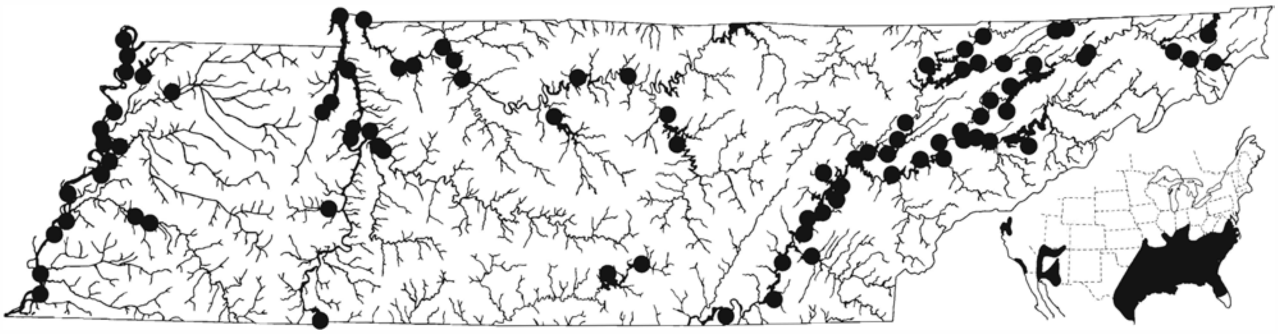
Etymology: Named after Lacepede, the French ichthyologist.

Dorosoma petenense (Guenther)

Threadfin shad

Plate 24. *Dorosoma petenense*, threadfin shad, 76 mm SL, Mississippi R., TN.

Characters: Scales in lateral series 40–43 (40–50). Ventral scutes 15–18 prepelvic and 10–12 postpelvic. Dorsal fin rays 14–15. Anal fin rays 20–25 (17–27). The number of gill rakers (300 to 440 in specimens 66–180 mm SL) increases with size. Vertebrae 40–45. Color gray or green dorsally, silver below. Large black spot present behind gill cover. All fins except dorsal yellowish.



Range Map 24. *Dorosoma petenense*, threadfin shad (native and introduced populations; native range extends south off inset to Guatemala and Belize).

Biology: Like the gizzard shad, threadfin shad are reservoir and big-river species found throughout the state. Because of their smaller size they are considered to be a more valuable forage species than gizzard shad. They are less tolerant of cold water than is the gizzard shad, and populations in our cooler storage reservoirs can be extirpated or drastically depleted during severe winters. Based on studies performed on threadfin from the Clinch River, Tennessee, sublethal effects, such as feeding cessation, can begin at 10 C (50 F) and inactivity at 6–7 C (47 F); death occurs at 4–5 C (39 F) (Griffith, 1978). In other studies cold-induced mortality occured at temperatures as high as 12 C (55 F) (McLean et al., 1982). Its biology is generally similar to that of the gizzard shad (Shelton, 1972; Pflieger, 1975). Spawning is initiated in the spring when water temperatures reach 21 C (70 F) and may extend well into the summer. P. W. Smith (1979) indicated the presence of both a spring and fall spawning peak. Spawning occurs along shorelines and is typically a group activity. The eggs are adhesive and are deposited above the substrate on boulders, logs, or debris. Spawning time is restricted to a few hours just after sunrise. McLean et al. (1982) suggested that darkness is the cue that causes release of eggs from their ovarian membranes and noted that mature adults collected immediately before or after the brief spawning period were not ripe (would not release eggs or milt when abdominal pressure was applied). They further suggested that the spawning synchrony resulting from this behavior is important in avoiding predation and in rapidly rebuilding populations where winter die-offs have been severe. Threadfin and gizzard shad occasionally hybridize (Shelton and Grinstead, 1973). Food of both young and adult threadfin is about half phytoplankton and half zooplankton. Young reach lengths of about 53 mm (2.1 in) after one year's growth and may spawn during their second summer. Life span is only about 2 or 3 years, with occasional females surviving 4 years. Maximum total length 216 mm (8.5 in).

Distribution and Status: Since threadfin shad have been widely introduced as forage fish, their original distribution is uncertain. They were certainly native to the Tennessee and Mississippi rivers, and possibly occurred in the lower Cumberland and Ohio rivers as well (Minckley and Krumholz, 1960). Present distribution includes the Gulf Coast from Florida to Texas and extends up the Mississippi River lowlands to Arkansas, Oklahoma, Missouri, southern Illinois and Indiana, Kentucky, and Tennessee, and south to Central America. Populations are also established in reservoirs along the Atlantic Coast and in western United States.

Similar Sympatric Species: See gizzard shad account.

Etymology: Named after the type locality, Lake Peten, Yucatan.

ORDER CYPRINIFORMES

FAMILY CYPRINIDAE

The Minnows

Cyprinids constitute the type family for an extremely large order of freshwater fishes, the Cypriniformes. In addition to the minnows and suckers (Catostomidae), the order includes the old world loaches (Cobitidae, Homalopteridae), and algae eaters (Gyrinocheilidae), many of which are popular with tropical fish fanciers. The orders Cypriniformes, Characiformes (African and South American tetras, piranhas, etc.), Gonorynchiformes (two marine families and two African freshwater groups), and Siluriformes (various catfish families) are included in the superorder Ostariophysi (Fink and Fink, 1981). In all ostariophysans the anterior vertebrae are modified and are known as the Weberian ossicles, which function in transmitting vibrations (sound) to auditory receptors in the brain. In cypriniforms, four anterior vertebrae contribute to the Weberian apparatus.

The family Cyprinidae occurs in Africa, Eurasia, and North America. It contains some 1,500 or more species, with nearly 300 North American species, of which about 80 occur in Tennessee waters. Except for a doubtful Cretaceous fossil from western Tennessee (Lundberg, 1975a), the earliest known fossil cyprinids in North America are from Oligocene deposits, 30–35 million years ago (Gilbert, 1976; Cavender, 1986). Based on this somewhat limited fossil evidence, our native cyprinids may be of recent origin when compared with the Eurasian species (Novicek and Marshall, 1976), but lack of knowledge concerning extralimital relationships of North American cyprinids (Patterson, 1981) and the lack of a fossil record in eastern North America hampers understanding of their biogeographic history. Evidence advanced by Howes (1984) suggests that North American minnows indeed are of polyphyletic origin relative to Eurasian groups. Mayden (1989) has hypothesized, though, that a sizable number of mostly eastern North American genera constitute a monophyletic assemblage. If Eurasian cyprinids do in fact have a longer history than North American minnows, then their dispersal to North America was presumably at various times over the past 50 million years during emergent periods of the Beringia connective between Siberia and Alaska in the north Pacific. It is also possible that some ancestral forms shared an earlier trans–North Atlantic distribution. Under current classifications, ties of our cyprinid fauna with that of Eurasia have been virtually severed at the genus level, with a single genus, *Phoxinus*, as provisionally recognized, shared by the two continents.

The term "minnow" generally evokes an image of a small fish in the minds of the average person, but many species are quite large, such as the familiar carp, and such fishes as the Colorado squawfish (genus *Ptychocheilus*) which formerly attained weights up to 36 kg (80 lbs), and the Asian bighead carp, now introduced to North American waters, which can reach 41 kg (90 lbs) or more and lengths of well over a meter. Cyprinids are characterized by having 19 principal caudal fin rays, and all native species have 9 or fewer dorsal fin rays (usually 7–8), while the somewhat similar members of the sucker family have 18 principal caudal fin rays and 10 or more dorsal fin rays. Scales are cycloid, easily shed in some groups. In Tennessee, cyprinids occur in all waters that are inhabited by fish except subterranean environments, with the largest numbers of species occurring in medium-sized, fairly warm, unpolluted rivers. All native Tennessee species are small, most seldom exceeding 130 mm (5 in) total length. They have evolved to occupy virtually all aquatic habitats, and the various species feed on detritus, algae, aquatic and terrestrial insects, microcrustacea, Asiatic clams, and small fishes. Many of the Eurasian species are detritivores or herbivores. There are no teeth associated with the jaws, but the posterior gill arch has a number of bony protuberances directed up and back into the throat (see Anatomy and Function section). These structures, the pharyngeal teeth (Fig. 63), are quite consistent in shape and number within a species. They function in holding, tearing, and grinding ingested food items, working against a horny pad in the roof of the pharynx, on the ventral surface of the basioccipital bone. In virtually all native minnows the pharyngeal teeth vary from slender, hooked structures to more robust but still pointed processes. In carp, the teeth are similar in shape to human molars. Over the minnow's lifetime, pharyngeal teeth are periodically

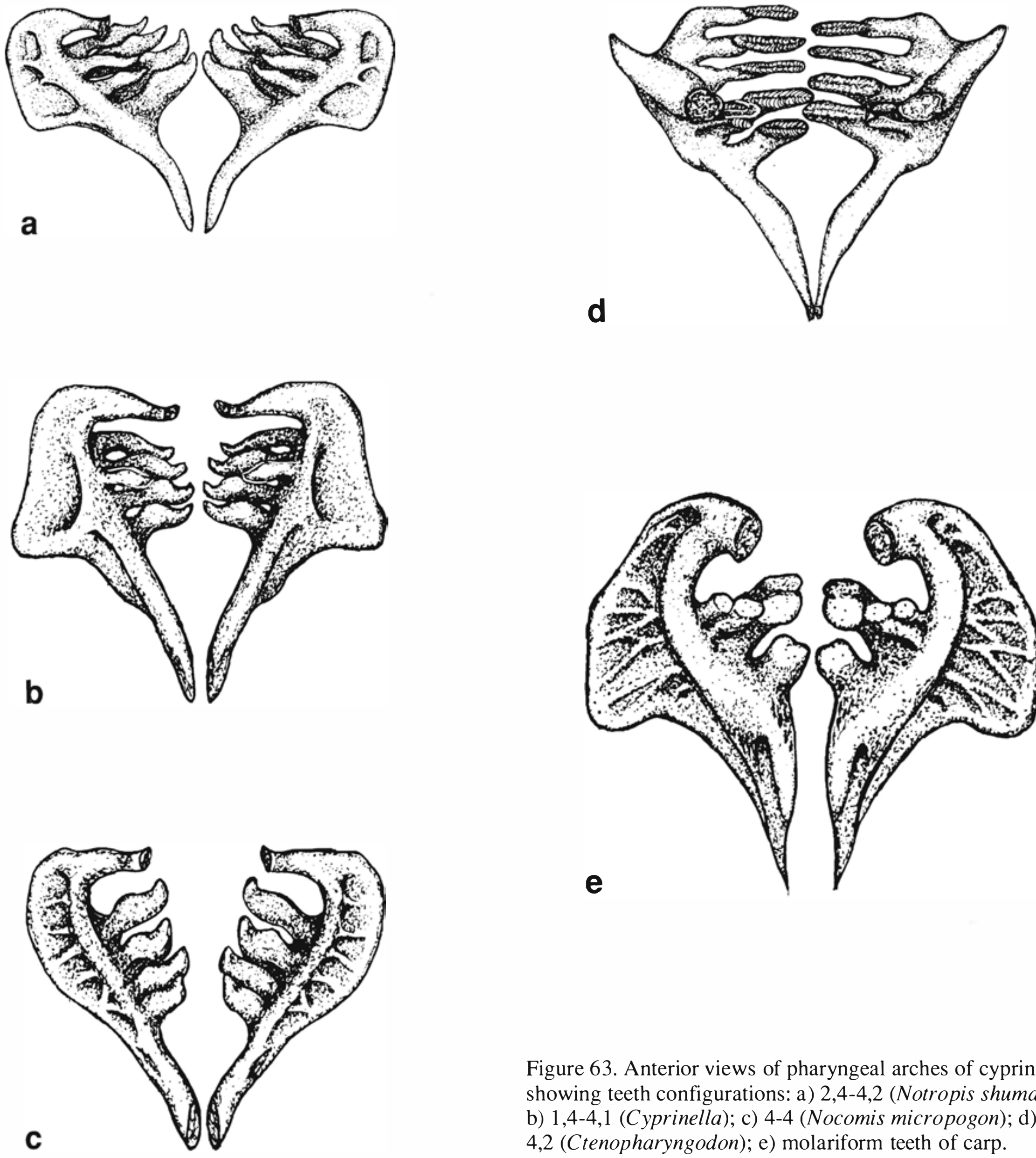


Figure 63. Anterior views of pharyngeal arches of cyprinids showing teeth configurations: a) 2,4-4,2 (*Notropis shumardi*); b) 1,4-4,1 (*Cyprinella*); c) 4-4 (*Nocomis micropogon*); d) 2,5-4,2 (*Ctenopharyngodon*); e) molariform teeth of carp.

supplanted by replacement teeth which develop in tissue adjacent to the arch and ankylose (become joined by bone) to the attachment site (see Evans and Duebler, 1955; Cooper, 1981). Males (and occasionally females) of many species develop nuptial tubercles and red and yellow breeding colors during the spring or early summer spawning season. Spawning is typically random, but several species hollow out well-defined nests in gravel substrates or utilize the nests of other species.

KEY TO THE GENERA OF TENNESSEE CYPRINIDAE

As is typical with dichotomous keys to most difficult groups of animals, ability to use the key accurately is closely related to the user's familiarity with the group of animals; this is nowhere more true than with minnows. Many of the characters used in the key are difficult to describe or illustrate, and until these characters are seen in actual specimens, the user will be forced into making sometimes difficult decisions as to the presence or absence of a structure, or whether or not a structure is "conspicuous." The ability to accurately count anal fin rays is absolutely essential to successful use of the cyprinid key. Since modal number of anal fin rays is a frequently used character, decisions based on single specimens may lead to difficulties.

1. Dorsal fin rays 13 or more; dorsal and anal fins with a serrated anterior spine 2
   Dorsal fin rays 9 or fewer; dorsal and anal fins lacking serrated spines 3
2. Barbels present on upper jaw (Fig. 64a) . . . . *Cyprinus carpio* p.161

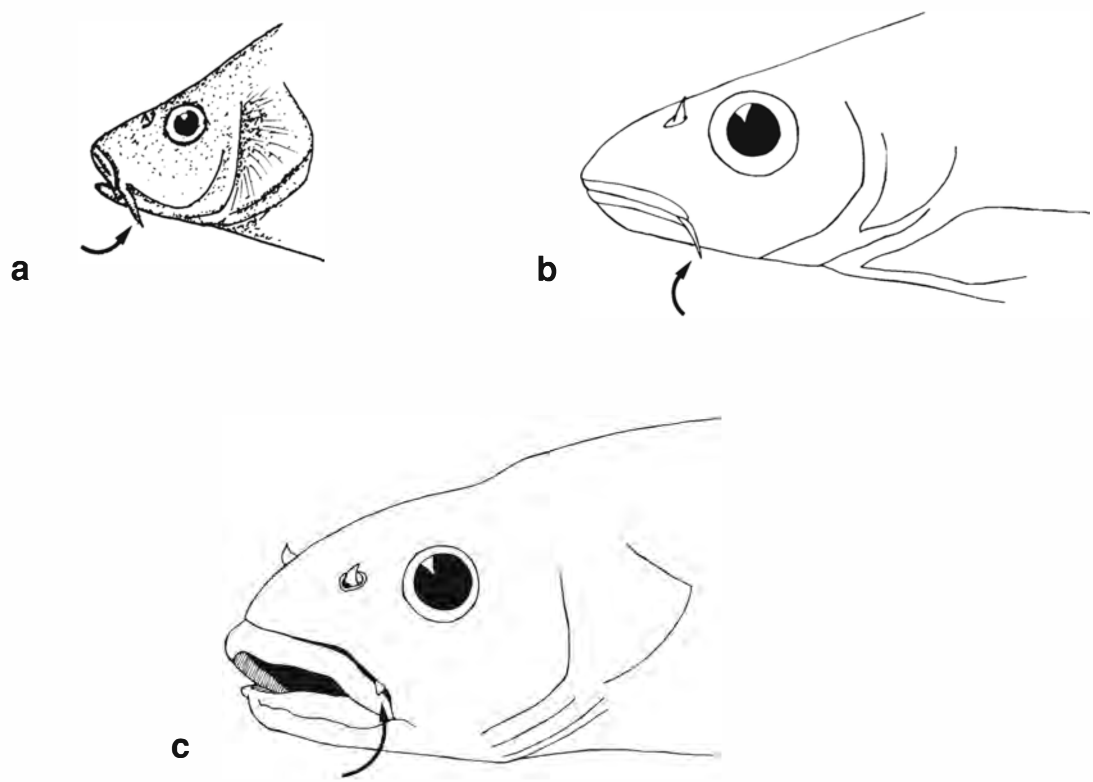


Figure 64. Barbels of cyprinids: a) carp; b) chub (*Erimystax*); c) creek chub (*Semotilus*).

   Barbels lacking . . . . *Carassius auratus* p.141

3. Premaxillae nonprotractile, attached to the snout by a smooth continuation of the skin overlying the snout (Fig. 65a) .... *Rhinichthys* p.254
Premaxillae protractile, separated from the snout by a groove that is continuous along the entire posterior margin of the upper jaw (Fig. 65b) 4

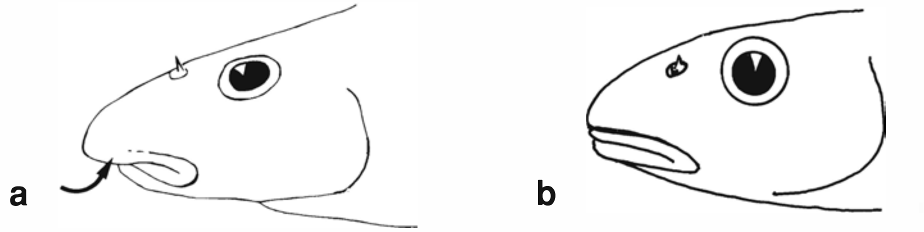


Figure 65. Cyprinid premaxillaries: a) nonprotractile (arrow points to frenum); b) protractile.

4. Lower jaw with a dorsal, horizontal shelf of cartilage (Fig. 66) that projects anteriad of the tip of the lower jaw .... *Campostoma anomalum* p.139

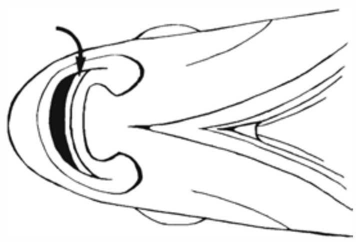


Figure 66. Cartilaginous shelf on lower jaw of *Campostoma*.

Lower jaw lacking a horizontal shelf of cartilage 5

5. Distance from origin of anal fin to caudal fin base equal to distance from anal fin origin to pelvic fin insertion (Fig. 67a) .... *Ctenopharyngodon idella* p.144
Distance from origin of anal fin to caudal fin base 1.5 to 2 times distance from anal fin origin to pelvic fin insertion (Fig. 67b) 6

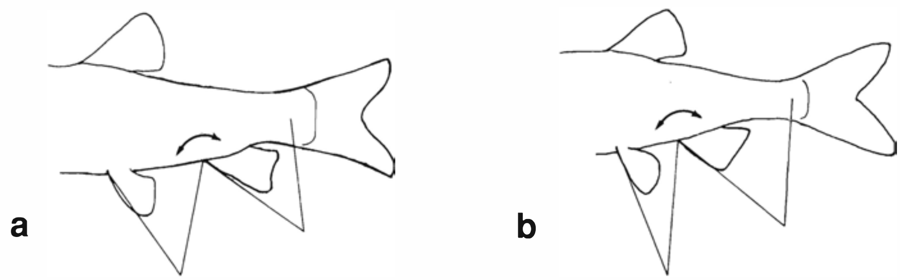


Figure 67. Relative anal fin positions of minnows: a) *Ctenopharyngodon*; b) native minnow.

6. Fleshy barbel (Fig. 64b) present at posterior tip of maxilla (a barbel also occurs in this position in nuptial male *Pimephales notatus*, which have three horizontal rows of large tubercles on the snout; and near this position in groove between maxilla and eye in *Semotilus*, Fig. 64c) 7
Barbel absent from posterior tip of the maxilla, or if present in this position (nuptial male *Pimephales notatus*) the snout bears three horizontal rows of large tubercles 12

7. Diameter of orbit much less than distance from posterior rim of orbit to posterodorsal attachment of operculum (Fig. 68a); caudal fin orange or red in life; lateral-line scales fewer than 45 . . . *Nocomis* p.196

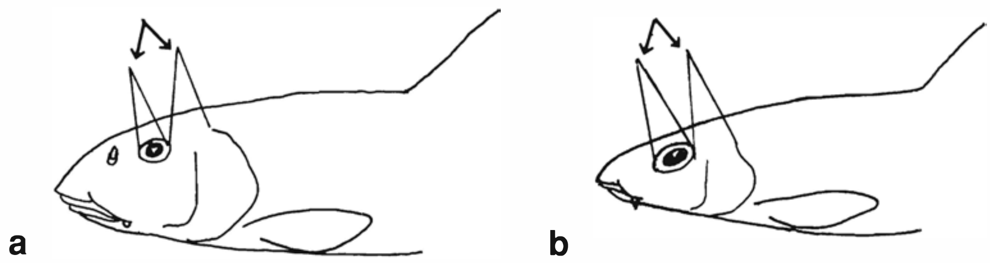


Figure 68. Relative eye sizes of minnows: a) *Nocomis*; b) *Erimystax*.

Diameter of orbit subequal to above mentioned postorbital head length (Fig. 68b), or if not so, lateral-line scales 48 or more; caudal fin never orange or red 8

8. Modal number of anal fin rays 7 . . . . *Erimystax* p.164

Modal number of anal fin rays 8 9

9. Lateral-line scales 49 or fewer (rarely 50); widespread 10

Lateral-line scales 51 or more (rarely 50); rare and localized species 11

10. Dark midlateral stripe prominent; lower lobe of caudal fin concolorous . . . . *Hybopsis* (in part) p.174

Dark midlateral stripe faint; lower lobe of caudal fin usually dark with white ventral border . . . . *Macrhybopsis* p.192

11. Dorsal and anal fins pointed, with tip of anterior ray extending past tips of posterior rays when fin is depressed; restricted to main channel of Mississippi River . . . . *Platygobio gracilis* p.253

Dorsal and anal fins rounded, with tip of anterior ray not reaching tips of posterior rays when fin is depressed; rare in east and middle Tennessee . . . . *Cyprinella monacha* p.153

12. Modal number of anal fin rays 12 or more; belly with a sharp keel between the pelvic base and the anus (Fig. 69) 13

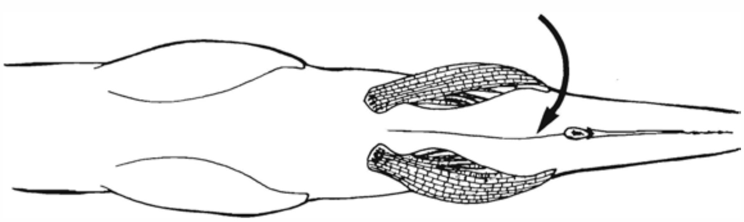


Figure 69. Keel on belly of *Notemigonus crysoleucas*.

Modal number of anal fin rays 11 or fewer (rarely 12 in *Lythrurus fumeus* and *L. umbratilis*); belly rounded posterior to pelvic fins 14

13. Lateral scale rows 55 or fewer, scales visible without magnification even in small (3-in) specimens . . . . *Notemigonus crysoleucas,* p.199

Lateral scale rows 85 or more, scales visible without magnification only in specimens 6 inches or longer . . . . *Hypophthalmichthys,* p.178

14. Dorsal fin rays 9; first 4 and last 3 dorsal fin rays outlined with melanophores, rays 5 and 6 lack pigment (Fig. 70); mouth small and nearly vertical (Pl. 92) . . . . *Opsopoeodus emiliae* p.237

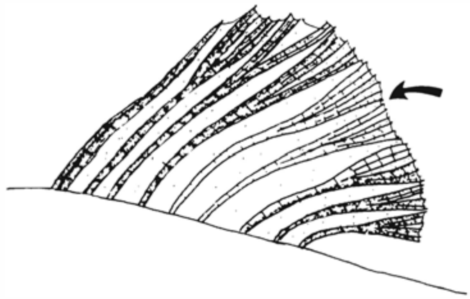


Figure 70. Dorsal fin pigmentation of *Opsopoeodus emiliae*.

Dorsal fin rays 7 or 8; all dorsal fin rays lined with dark pigment, or plain, except for *Notropis* sp., the "sawfin shiner", which has dark pigment on anterior 4–5 rays only; mouth variable but never tiny and nearly vertical 15

15. Snout projecting well beyond tip of upper jaw; predorsal scale rows 20 or more; mouth fleshy and sucker-like (Fig. 71) . . . . *Phenacobius* p.239

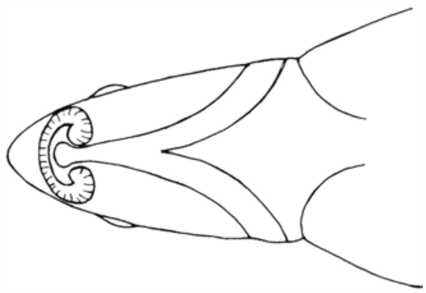


Figure 71. Sucker-like mouth of *Phenacobius*.

Tip of upper jaw at anterior end of head, or if slightly subterminal, there are fewer than 18 predorsal scale rows; mouth not sucker-like 16

16. Scales in lateral series 66 or more, these scales scarcely visible without magnification in specimens 50 mm (2 in) TL or smaller . . . . *Phoxinus* p.243

Scales in lateral series 60 or fewer, these scales visible without magnification, at least on the caudal peduncle, in specimens longer than 50 mm (2 in) 17

17. Lateral line incomplete, with only 10–20 pored scales; dorsal fin origin distinctly posterior to pelvic fin origin (Fig. 72a) . . . . *Hemitremia flammea* p.168

Lateral line complete, or if incomplete (occasional *Pimephales promelas*) the dorsal fin origin is directly over that of the pelvic fin (Fig. 72b) 18

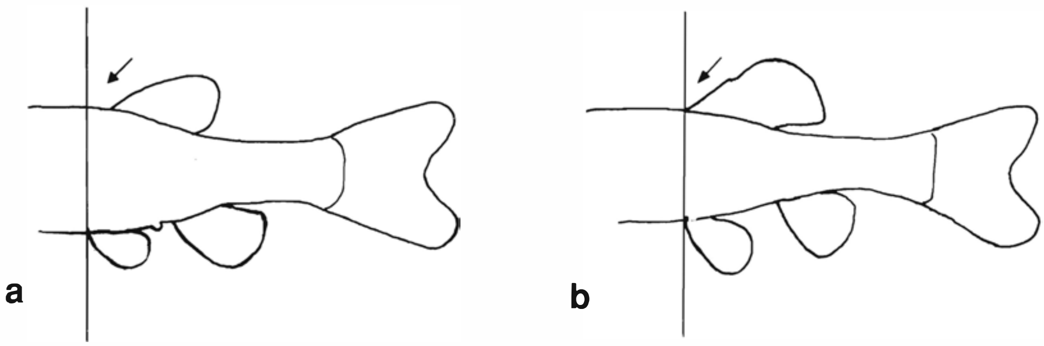


Figure 72. Relative dorsal fin positions of minnows: a) *Hemitremia*; b) *Pimephales*.

18. Mouth very large, with jaw length measured from anterior tip of premaxilla back to jaw angle greater than post-orbital head length (Fig. 73); lateral-line scales usually 43 or more; anal fin rays modally 9; sides with randomly scattered dark scales; lower jaw lacking tubercles . *Clinostomus funduloides* p.142

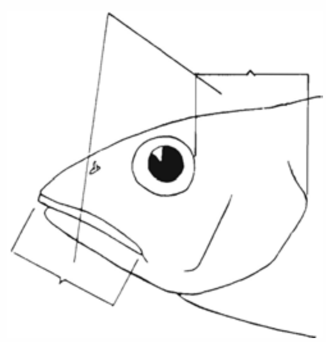


Figure 73. Comparison of jaw and postorbital lengths in *Clinostomus*.

Jaw length less than post-orbital head length (about equal in *Luxilus coccogenis*, which has 42 or fewer lateral-line scales and lower jaw tubercles persistent on juveniles and adults of both sexes throughout the year; and in genus *Lythrurus* whose 4 Tennessee species have modally 10 or more anal fin rays) . . . 19

19. Lateral scale rows 50 or more; a tiny, flat, triangular barbel usually present near posterior tip of jaw in groove between upper jaw and snout (Fig. 64c) . . . . *Semotilus atromaculatus* p.257

Lateral scale rows 48 or fewer; barbel never present except at posterior tip of lower jaw in nuptial male *Pimephales notatus* 20

20. Infraorbital and preoperculomandibular canals excessively developed, forming visible cavities in the bones below the eyes (Fig. 74); mouth subterminal and horizontal; predorsal scale rows 14 or fewer; rare in upper Cumberland drainage in Tennessee, but widespread north and south of Tennessee . . . . *Ericymba buccata* p.163

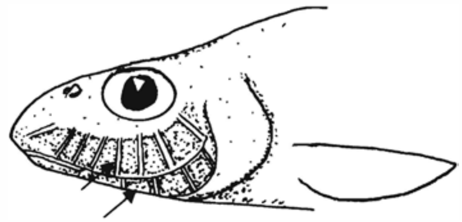


Figure 74. Cavernous infraorbital and preoperculomandibular canals of *Ericymba.*

Head canals not excessively developed; mouth usually oblique or predorsal scale rows 16 or more (except in *Hybopsis amnis* which has a black midlateral stripe of uniform intensity, and *Notropis ammophilus* which has only 7 anal fin rays) 21

21. Predorsal scale rows 19 or more and anal fin rays 7 . . . . *Pimephales* p.248

Predorsal scale rows 18 or fewer, or 8 or more anal fin rays 22

22. Groove starting posterior to angle of jaw continues forward onto snout (this groove present in addition to the groove separating the upper jaw from the snout), the linear extent of this groove on the snout at least twice as long as the fleshy width of the upper jaw (Fig. 75a); intestine in ventral view coiled like a spring; peritoneum black; tip of depressed dorsal fin does not reach to middle of anal fin base; anal fin rays 8 . . . . *Hybognathus* p.169

Groove mentioned above absent from snout, or if present (Fig. 75b) it is not distinctly longer than the fleshy width of the upper jaw, the tip of the depressed dorsal fin extends well past the middle of the anal fin base, or anal fin rays are 9 or more; intestine with a single S-shaped loop; peritoneum usually silvery 23

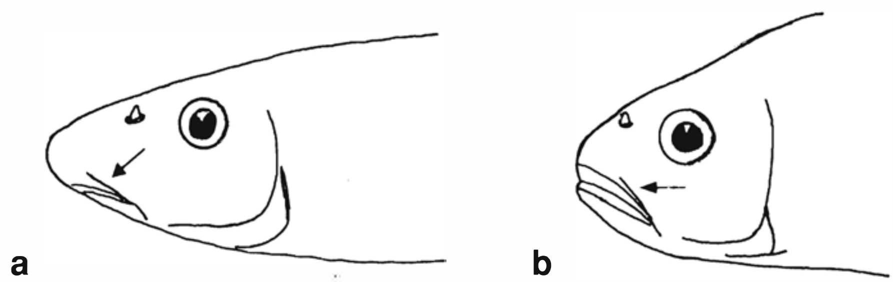


Figure 75. Lachrymal grooves of minnows: a) *Hybognathus*; b) *Luxilus*.

23. Predorsal scales much smaller than those on hind portion of body, with 21 or more predorsal scale rows; anal fin rays modally 10 or 11, occasionally 12; origin of dorsal fin far behind origin of pelvic fins (Fig. 76) . . . . *Lythrurus* p.186

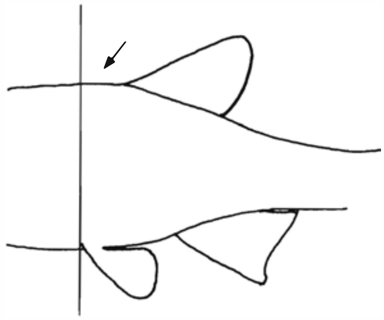


Figure 76. Dorsal fin position in *Lythrurus umbratilis*.

Predorsal scales similar in size to those on hind portion of body, with 20 or fewer predorsal scale rows; mode of anal fin rays often 9 or fewer; dorsal fin origin often directly over origin of pelvic fins or nearly so . . 24

24. Posterior membranes of dorsal fin with dark pigment (Fig. 77a); pigment pattern of dorsolateral scales (typically diamond-shaped) continues without interruption through lateral stripe to or below lateral line on anterior half of body; anal fin rays modally 8 or 9; pharyngeal teeth 1,4–4,1 (male *Notropis spectrunculus,* p. 226, may key here) . . . . *Cyprinella* (in part) p.146

Posterior membranes of dorsal fin lacking dark pigment (rays may be bordered by dark pigment) (Fig. 77b); pigment pattern of dorsolateral scales interrupted by lateral stripe on anterior half of body (except in *Luxilus coccogenis* and *Notropis rubricroceus*, both of which have a prominent black bar behind the operculum), and usually not diamond-shaped; anal fin rays variable; pharyngeal teeth usually 2,4-4,2 or 4-4 25

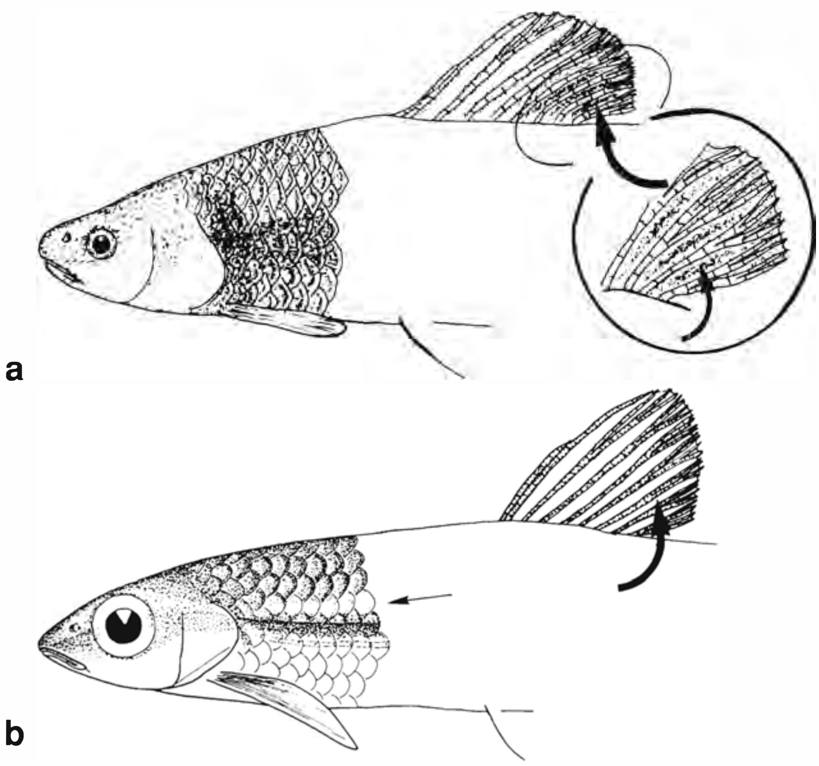


Figure 77. Pigmentation patterns of dorsal fins and anterior body scales in minnows: a) *Cyprinella*; b) *Notropis*.

25. Exposed portion of anterior lateral-line scales more than twice as deep as wide (Fig. 78a); anal fin rays modally 9; pharyngeal teeth 2,4-4,2; pectoral fin tubercles (present only on nuptial males) with 2–6 points per tubercle (Fig. 79); breast completely scaled . . . . *Luxilus* p.181

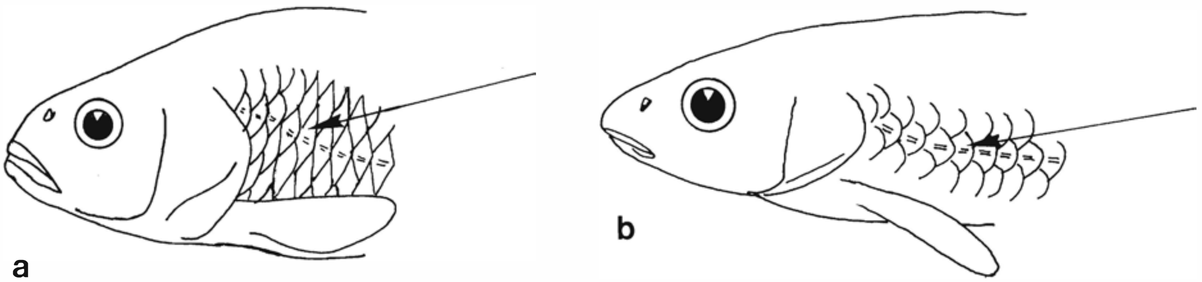


Figure 78. Shapes of anterior lateral-line scales in minnows: a) *Luxilus chrysocephalus*; b) *Notropis* spp.

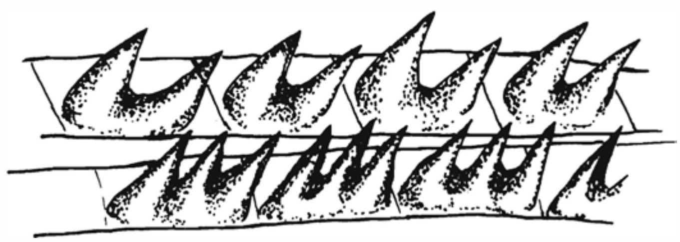


Figure 79. Pectoral fin tubercles of *Luxilus* showing multiple cusps per tubercle base.

Exposed portion of anterior lateral-line scales (Fig. 78b) less than or about twice as deep as wide (except in *Notropis volucellus* group, which have only 8 anal fin rays); anal fin rays and pharyngeal teeth variable; pectoral fin tubercles of nuptial males with a single point per tubercle; breast variable 26

26. Mouth horizontal and distinctly subterminal (Fig. 80); predorsal scale rows 13–15; anal fin rays modally 8; dorsal and anal fins sharply pointed, with tips of depressed anterior rays extending far beyond tips of posterior rays; midlateral stripe of nearly uniform width and intensity extends from snout through eye and to caudal fin base; pharyngeal teeth 1,4-4,1 . . . . *Hybopsis amnis* p.176

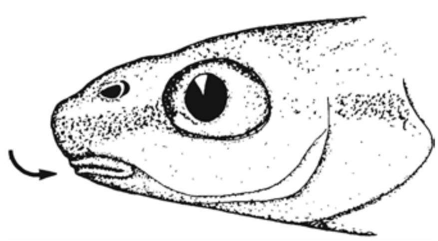


Figure 80. Subterminal, horizontal mouth of *Hybopsis amnis*.

Lacking the above combination of characters . . . . *Notropis* p.201

Genus *Campostoma* Agassiz
The Stonerollers

Until recently, the distinctive genus *Campostoma* was treated as containing but two species, *C. anomalum* ranging throughout much of central and eastern North America, and *C. ornatum* of Mexico and southern Arizona and Texas. The large scale stoneroller, *C. oligolepis* Hubbs and Greene, has recently been shown to be distinct from *C. anomalum* (see Pflieger, 1971; Burr and Smith, 1976), and occurs in cooler waters from Wisconsin and southeastern Minnesota south through northcentral Illinois, eastern Iowa, and the Ozark region of Missouri and Arkansas. Ozarkian and Midwest *C. oligolepis* differ consistently from *C. anomalum*, and the two species often occur sympatrically with no evidence of mixed mating. In addition to having lower scale counts (especially lateral-line scales and body circumferential scales), *C. oligolepis* differs from *C. anomalum* in that tuberculate males of the former lack inter-nasal tubercles, have only 10–22 cephalic tubercles, and lack a dark band in the anal fin (Burr and Smith, 1976; Burr and Cashner, 1983). An electrophoretic analysis (Buth and Burr, 1978) generally confirmed the validity of *anomalum* and *oligolepis* as distinct species.

This conception ended when Burr and Cashner (1983), in describing a new species from the upper Apalachicola drainage, adjacent Mobile Basin, and Tennessee River headwater streams in Georgia, indicated that much of the lower Tennessee River and virtually all of the Mobile Basin were inhabited by a form of *Campostoma* meristically indistinguishable from *C. anomalum* but having the above-mentioned *C. oligolepis* characters in tuberculate males.

The newly described species, *C. pauciradii*, differs in having only 11–17 gill rakers on the first arch (19 or more in both *anomalum* and *oligolepis*), and in having iridescent bluegreen dorsal, anal, and pelvic fins in nuptial males. A search through our holdings indicates that we do not have specimens of *C. pauciradii* from either the upper Coosa, Hiwassee, or Little Tennessee river systems in Tennessee, or from the upper Coosa and upper Etowah river systems of north Georgia. The marked difference in gill raker counts leaves little question concerning the validity of this new taxon, despite its unusual but believable distribution. It may eventually appear in some of our more montane Hiwassee River tributaries. We will certainly be looking for it.

We question the identification of lower Tennessee River *Campostoma* as *oligolepis*. Data from nuptial males in our collection suggest to us that, at least in the Ohio River basin, including the Tennessee and the Cumberland rivers, there is a trend toward decreased cephalic tuberculation and anal fin pigmentation at lower elevations in the nominal subspecies of that area, *C. a. anomalum*.

There has been a tendency among ichthyologists to ignore stonerollers as boringly common, ubiquitous, not very handsome, and of little taxonomic interest. We plead guilty, salute the authors of these recent papers for revitalizing interest in stoneroller systematics, and eagerly await additional interpretations of this complex problem.

Cavender and Coburn (1985) hypothesized closest affinities between *Campostoma* and the primarily Mexican genus *Dionda* Girard; Mayden (1989) agreed and hypothesized *Nocomis* as the sister group to these two genera.

Campostoma anomalum (Rafinesque)
Central stoneroller

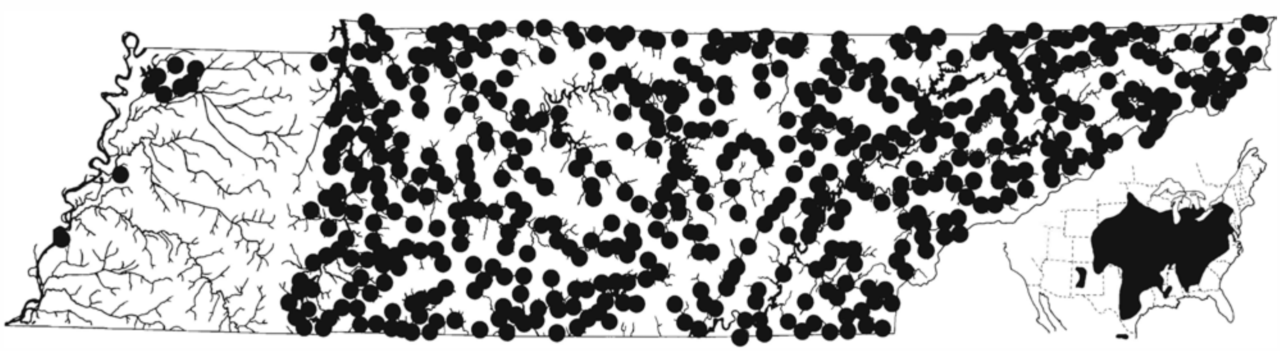
Plate 25a. *Campostoma anomalum*, central stoneroller, 69 mm SL, Conasauga R. system, TN.

Plate 25b. *Campostoma anomalum*, central stoneroller, breeding male, 190 mm SL, Little Tennessee R. system, NC.

Characters: Two recognized subspecies occur in Tennessee, with *C. a. anomalum* widespread in east and middle Tennessee, and *C. a. pullum* (Agassiz) in several localities immediately adjacent to the Mississippi River in west Tennessee. Data for *C. a. pullum* is given in parentheses where differing from that for *C. a. anomalum*. Lateral-line scales 46–51 (47–55), body circumferential scales 35–42 (38–47). Anal fin rays 7. Pectoral fin rays 15–16 (16–18). Gill rakers 21–27 (24–33), length of longest rakers 1.5–2 times their basal width. Pharyngeal teeth 4-4 to 1,4-4,1 (4-4). Breast scaled. Most specimens have the sides randomly marked with some scales that are darker than the background color of the fish (not to be confused with the discrete, spherical black dots caused by certain fluke metacercariae). Nuptial males have an orange band in the dorsal fin and black bands in the dorsal, and often anal, pelvic, and pectoral fins. During peak tuberculation, males have blunt, cornified enlargements on breast scales and large, erect tubercles on about half of the dorsal and lateral body scales, one tubercle per scale. Even larger tubercles occur on top and upper sides of the head, extending anteriad to the nostrils. Branchiostegal rays and lower free edges of opercular bones with rows of blunt tubercles. An ovate, callus-like concretion occurs on each side of the snout, just anterior to the lachrymal groove. Pectoral fin with uniserial tubercles on dorsal surface of rays 2–5. Dorsal fin with tubercles best developed on leading edge, progressively weaker posteriad. Caudal fin with a few small tubercles on dorsal edge, near base of fin.

Biology: The stoneroller is the most widespread and abundant stream-dwelling fish in east and middle Tennessee. It occurs in flowing water habitats ranging from very small streams to large rivers. Adult males may reach lengths of about 30 cm and are commonly sought by anglers in the mountainous areas of east Tennessee. Because of their conspicuous head tubercles, nuptial males are locally known as "hornyheads," as are several other species (e.g., *Nocomis*) of cyprinids which reach large size and are highly tuberculate during the breeding season. Stonerollers are also very popular bait minnows, and the demand generated by both "hornyhead" anglers and bait dealers has resulted in some management problems in upper east Tennessee (Beets, 1979). Life history information is abstracted from Miller (1962) and Burkhead (1980). Spawning occurs from early April to mid June in Tennessee. Males excavate pits in gravel substrates, and females periodically move into the pits to spawn with the resident male or males. Males defend the pit in which they are located, but they may change pits. The clean gravel associated with these and similar nests of other minnows and sunfishes is apparently attractive to smaller species of minnows as potential spawning substrate (Starnes and Starnes, 1981), and it is not unusual to find aggregations of two or three species spawning over the same nest. This is certainly a primary reason for the rather common occurrence of hybrids among nest-building cyprinids. Hybrid combinations are known involving *Campostoma* with species of *Clinostomus*, *Luxilus*, *Nocomis*, *Notropis*, and *Phoxinus* (Schwartz, 1981, and our data). Peak spawning occurs at water temperatures of 12–14 C. Females produce from 200 to 2,500 eggs per year at sizes of 65–130 mm SL. Young feed on rotifers and microcrustacea, but subadults and adults feed on detritus, filamentous algae, diatoms, and occasionally on small aquatic insects. Anglers catch them on earthworms, indicating that they are opportunistic, at least during the spawning run. Growth is rapid, with young reaching lengths of about 35–65 mm SL after 1 year and 75–110 mm SL after 2 years. Sexual maturity is often achieved at the end of 1 year, and life span is about 4 years. Maximum total length 287 mm (11.3 in) reported by Lennon and Parker (1960). The Tennessee angling record of .277 kg (9.76 oz) was caught in the Hiwassee River, 1 May 1983, by Roy King.

Distribution and Status: Widespread and abundant in most upland waters of the eastern United States but mostly restricted to the Blue Ridge in Atlantic Coastal drainages. Stonerollers occur in all physiographic prov-



Range Map 25. *Campostoma anomalum*, central stoneroller (populations in central New Mexico are introduced).

inces of Tennessee, but on the Coastal Plain they are restricted to isolated higher-gradient, gravel-bottom streams draining the bluffs along the eastern edge of the Mississippi Floodplain. They are absent (apparently naturally) from some streams in the Cumberland Plateau (perhaps due to lack of gravel) and have probably been extirpated from several others by surface mining activities as they seem intolerant of heavy siltation.

Similar Sympatric Species: Juveniles are somewhat similar to *Rhinichthys atratulus*, *Semotilus atromaculatus*, and *Nocomis micropogon*. These species all have a pale peritoneum. In *Campostoma* the black peritoneum is visible through the body wall of preserved specimens. The lower jaw structure of stonerollers is so distinctive that a glance will allow easy identification of subadults and adults.

Etymology: *Campo* = curved, *stoma* = mouth; *anomalum* = extraordinary; *pullum* is probably derived from the Latin *pullus*, the young of an animal, reflecting Agassiz's (1854) belief that this represented the smallest species in the genus *Chondrostoma*, a Eurasian genus with a similar lower jaw structure.

Genus *Carassius* Nilsson
The Goldfishes

Carassius is a Eurasian genus that includes the well known goldfish and the crucian carp, *C. carassius*. Both are deep-bodied, coarse-scaled fishes that have been extensively cultured as aquarium pets, food fishes, and bait minnows. Although crucian carp have been sporadically introduced into North American waters, they apparently have not become established.

Carassius auratus (Linnaeus)
Goldfish

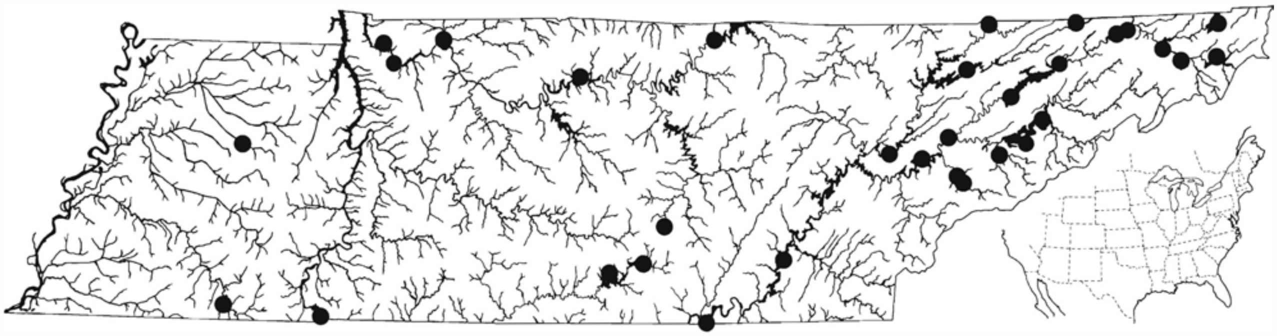
Characters: Lateral-line scales 25–31. Dorsal fin with a long, serrated spine (preceded by several rudiments) and 15–18 soft rays. Anal fin with a serrated anterior spine and 5–6 soft rays. Pectoral fin rays 15–17. Pelvic fin rays 8–9. Gill rakers 37–43. Pharyngeal teeth 4-4 and not molariform. Vertebrae 28–29. Breast scaled. Color of wild types is olivaceous, but escaped or re-

Plate 26. *Carassius auratus*, goldfish, 170 mm SL, Douglas Res., TN.

leased cultured varieties of brassy gold, orange, or blotched orange, black, and white may be encountered in Tennessee waters. Nuptial males develop fine tubercles on the opercles, nape, and pectoral fins.

Biology: The goldfish was imported from Asia primarily as an aquarium fish. Readers are doubtless familiar with the many aquarium varieties of goldfishes that have been developed over the centuries, including many color morphs and the bizarre "tripletail" and "balloon-eyed" varieties. In most parts of the country the number of family pets and bait-bucket remnants released into natural waters has been sufficient to establish local populations. Goldfish are now present throughout the larger rivers of the entire Mississippi River basin, with the most successful populations occurring in small, heavily vegetated ponds. Wild specimens are typically olive brown, but occasional indications of the genetic heterogeneity of aquarium stocks are seen in wild populations. The young are valuable bait fishes in areas where their use is permitted and are sold as "Baltimore minnows" in Tennessee.

Like carp, goldfish are omnivores that spawn in early spring over submerged vegetation. Several males typically accompany a single spawning female which may extrude several thousand eggs at each spawning. In Europe, gynogenetic populations (see Reproduction and Early Development section) consisting entirely of females are known which are dependent on sperm of males of other minnows, such as carp, to stimulate cell division in the ova, but incorporate no genetic information from those males (Muus and Dahlstrom, 1971). Eggs hatch within 2–10 days, depending on temperature (Mansueti and Hardy, 1967). In the wild, goldfish attain a total length of 70–90 mm at age 1, 125–135 at age 2, and about 170 mm at age 3 (Becker, 1983). Goldfish feed on a variety of aquatic insects, detritus, and vegetation. They are occasionally taken by anglers fishing for bluegill with wet flies or worms. Techniques



Range Map 26. *Carassius auratus*, goldfish (to be anticipated throughout North America north to southern Canada).

for goldfish propagation in the bait industry are elaborated in Prather et al. (1953). Douglas (1974) reported sizes up to 500 mm TL and 2.3 kg (20 in, 5 lb).

Distribution and Status: Native to Eurasia but widely introduced and established throughout North America north to southern Canada. Scattered wild populations presumably occur throughout the larger portions of the Cumberland and Tennessee rivers and in the Mississippi River. They appear to be particularly common in Douglas Reservoir in east Tennessee but are uncommon or not established in our other storage reservoirs.

Similar Sympatric Species: The presence of serrated anterior spines in the dorsal and anal fins distinguishes goldfish from the morphologically similar members of the sucker family, and the absence of barbels separates goldfish from carp. Goldfish and carp occasionally hybridize, and hybrids typically have characters intermediate between those of the adults. In addition to barbels, carp and goldfish differ in lateral-line scales (35–38 in carp, 26–30 in goldfish), gill rakers on first arch (21–27 in carp, 37–43 in goldfish), and pharyngeal teeth (five molariform in three rows in carp, four flattened and in single row in goldfish).

Etymology: *Carassius* = Latinized version of karass, the common name for these fishes in Eurasia; *auratus* = gilded.

Genus *Clinostomus* Girard
Redside Daces

The genus *Clinostomus* consists of two closely related eastern North American species but has sometimes been treated as being congeneric with western species referred to the genera *Gila* or *Richardsonius*. Affinities with these western species seem definite (Cavender and Coburn, 1986), but most modern workers treat *Clinostomus* as a distinct genus. In addition to *C. funduloides* the more northerly redside dace, *C. elongatus* (Kirtland), occurs in northeastern North America west to Minnesota, south to Kentucky, and north to southern Canada.

Clinostomus funduloides Girard

Rosyside dace

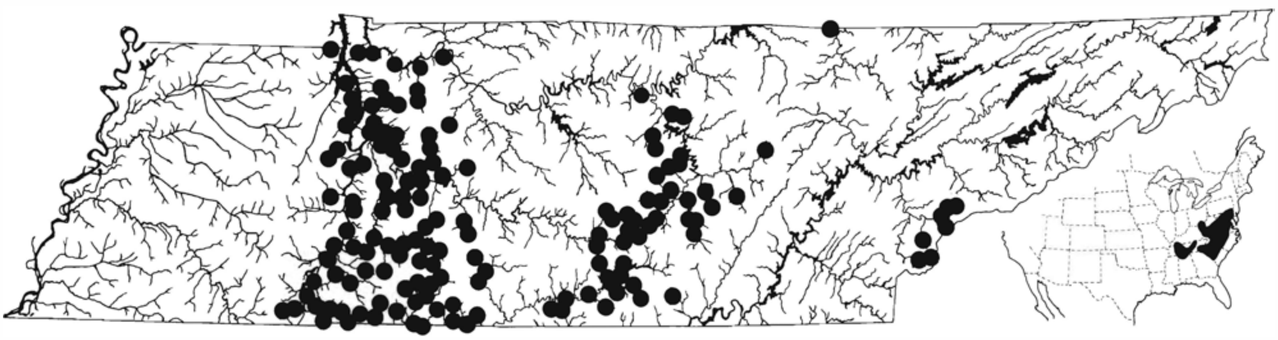
Characters: Lateral-line scales usually 43–47 (42–52) in middle Tennessee, 50–58 in Little Tennessee and Hiwassee rivers. Anal fin rays 9 (8–10). Pectoral fin rays 14–16. Pelvic fin rays 8. Gill rakers 4–8, length of longest rakers 0.5–1.0 times their basal width. Pharyngeal teeth 2,5-4,2. Breast scaled. Both males and females have broad red stripe along sides that intensifies in males during the breeding season. The Little Tennessee subspecies, in addition to having smaller scales, is more melanistic and has a shorter jaw with a less-pointed snout (jaw length about equal to post-orbital head length). In both subspecies, tubercles of males are as follows. Large tubercles on top of the head are interspersed with small, granular ones, these smaller tubercles also present on cheeks, opercles, and branchiostegal areas. No tubercles on lower jaw. Body scales have one to four large tubercles per scale that become less prominent ventrad and are virtually absent from the belly. Two patches of large, multicusped tubercles occur on anteriolateral portions of the breast and are separated by a median hiatus. One tubercle occurs on each segment of dorsal, anal, pectoral, and pelvic fin rays, with these tubercles only on the dorsal surface of the paired fins. Females may develop smaller tubercles on the head and on body scales.

Plate 27a. *Clinostomus funduloides*, rosyside dace, 59 mm SL, Cumberland R. system, TN.

Plate 27b. *Clinostomus funduloides*, rosyside dace, breeding male, 66 mm SL, Tennessee R. system, AL.

Biology: The rosyside dace is an active minnow that occurs in pool areas of clear, cool, rocky streams. The only tuberculate males in our collection are from mid May (middle Tennessee) and late May and early June (east Tennessee), indicating a brief breeding season. We observed brightly colored and highly tuberculate males and gravid females engaged in apparent spawning behavior in Big Richland Creek, Humphreys County, on 16 May, along with several extremely colorful *Notropis leuciodus*; both were spawning over the clean gravel of stoneroller nests in water only about 5 cm deep. Water temperature was 15.5 C (67 F). Because of its habit of spawning over gravel nests of other species, hybrids involving the rosyside dace are to be expected, and several are listed (for *C. f. funduloides*) in Schwartz (1981). In a Maryland population (*C. f. funduloides*), R. Davis (1972) reported fecundity estimates of about 290 ova in age 1 females to about 560 in age 3. Size ranges of specimens in our collection indicate that young are of 30–45 mm TL at age 1, are not sexually mature until after 2 years of growth, and probably have a maximum life span of 4 years. R. Davis (1972) reported age 1 dace average 60 mm TL; age 2, 73 mm, and 3, 85 mm, with a very few fish surviving into a fourth year; all specimens over 60 mm were sexually mature. The rosyside dace feeds largely on adult terrestrial and aquatic insects taken at the surface with some feeding on benthic insects in cooler months (Breder and Crawford, 1922; Flemer and Woolcott, 1966). The extremely large mouth is likely an adaptation allowing exploitation of the wide size range of this food resource. Hill and Grossman (1987) hypothesized that rosyside dace spend much of their life in a home range extending over only 10–15 m of stream. Maximum total length 115 mm (4.5 in).

Distribution and Status: The nominate subspecies occurs in Atlantic Coastal drainages from the Delaware River south through the Savannah River and in portions of the upper Ohio River drainage. Two additional subspecies are recognized, and both occur in Tennessee. The Highland Rim region of the central portion of the state, Tennessee and Cumberland river drainages, is occupied by *C. f. estor* (Jordan and Brayton), and an undescribed subspecies (possibly representing a valid species) occurs in upland tributaries of the Little Tennessee River and adjacent Savannah River headwaters; specimens from the Hiwassee River system were believed to represent intergrades between these two forms (Deubler, 1955). *Clinostomus f. estor* is abundant in cool to cold Highland Rim streams and extends northward into a few Highland Rim tributaries in Kentucky (L. Miller, 1978). Its fidelity to that physiographic province is sufficient to allow approximate location of the Nashville Basin (where it is absent) and the Highland Rim on the accompanying distribution map. The undescribed upland form is common in portions of the Little Tennessee River system of North Carolina and



Range Map 27. *Clinostomus funduloides*, rosyside dace.

barely invades that system in Tennessee, where it is uncommon and of spotty occurrence.

Similar Sympatric Species: Large-jawed shiners, especially *Luxilus chrysocephalus* and *coccogenis*, are rather similar in appearance as juveniles, but they have fewer than 40 lateral-line scales and lack a red midlateral band. In *L. coccogenis* the lower jaw bears conspicuous tubercles even in juveniles. Randomly placed dark lateral scales are characteristic of *C. funduloides* but also occur in *L. chrysocephalus*. Juveniles of these two species can be difficult to separate without magnification.

Systematics: See comments under Characters as well as Distribution and Status regarding subspecies recognized by Deubler (1955). Lachner and Deubler (1960) pointed out that the two syntypes of *Clinostomus vandoisulus* (Valenciennes) are actually of the Eurasian genus *Leuciscus* with erroneous locality information. This necessitated the name change to *C. funduloides* Girard, the oldest available name for the species.

Etymology: *Clino* = inclined, *stomus* = mouth; *funduloides* = *Fundulus*-like.

Genus *Ctenopharyngodon* Steindachner

Ctenopharyngodon is a montypic East Asian genus (see characters below) containing the widely introduced grass carp. It is superficially similar to members of the Asian genus *Hypophthalmichthys*, with three species, two of which have also been introduced to North America. Though formerly thought closely related, these fishes have been placed in separate subfamilial lineages by Howes (1981) with *Ctenopharyngodon* included in the Squaliobarbinae along with Eurasian genera *Mylopharyngodon* and *Squaliobarbus*.

Ctenopharyngodon idella (Valenciennes)

Grass carp

Characters: Lateral-line scales 34–37. Dorsal fin rays 8. Anal fin rays 9. Pectoral fin rays 18–20. Pelvic fin rays 8. Gill rakers 15–16. Pharyngeal teeth 2,5-4,2 (Fig. 63c), the teeth with elongate, corrugated grinding surfaces. Breast scaled. Color olivaceous to silvery white.

Biology: The grass carp, or white amur, was brought into this country in the 1960s as a potential food fish and control agent for aquatic vegetation. It is an extremely important cultured food fish in China. It grows to a large size (45 kg in Eurasia) and is reported to be an excellent food fish (but so was the common carp prior to introduction). Cottrell (1976) reported it to be less preferred than channel catfish but as acceptable as largemouth bass or bluegill in taste tests in Tennessee. In Missouri, commercial fishermen indicated it to be a good food fish, but some indicated it to be no better or worse than carp (Pflieger, 1978a). It is omnivorous in its feeding habits with a voracious appetite, and large individuals are known to consume many pounds of aquatic vegetation in a single day. Studies indicate that in specimens over 60 mm TL, aquatic macrophytes dominate the diet with minor utilization of filamentous algae and benthic invertebrates (Colle et al., 1978). Digestive efficiency is apparently very low with digestion confined to those plant cells that are ruptured by the pharyngeal teeth (Hickling, 1966). Thus great quantities of plants must be consumed. Very young fry probably feed on microcrustaceans and other small organisms. Grass carp randomly spawn in large rivers, apparently in response to rising water levels, in areas of strong current at temperatures of about 18–19 C (64–66 F) (Stanley, et al., 1978). Fecundity is extremely high with large females having a million or more ova. The eggs must remain suspended in current until hatching 2 days or so later, so long reaches of flowing river are required for reproduction. Larvae reside in quiet vegetated areas. Juveniles apparently migrate great distances, facilitating fast dispersal. Growth is rapid with sizes of up to 5 kg (11 lb) attainable in less than 2 years (C. Smith, 1985). By age 7 a length of 75–80 cm TL and weight of 7.5 kg is reached and by age 11 up to 110 cm TL and 15 kg (Berg, 1949).

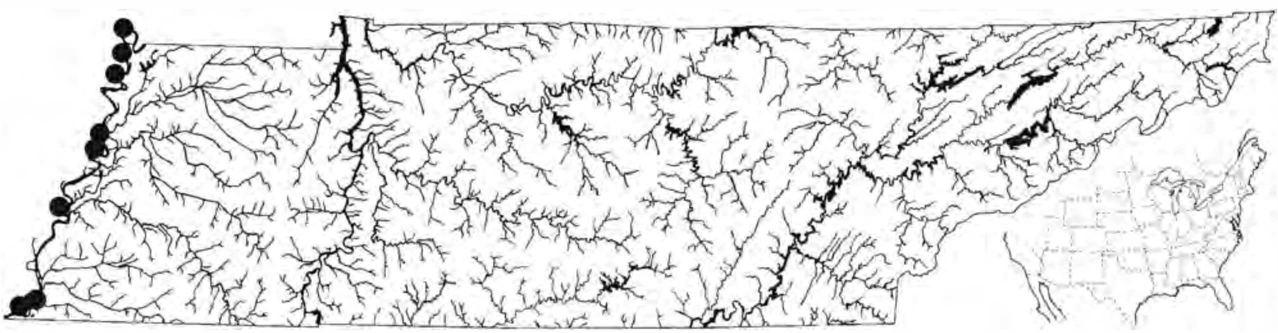
The grass carp is apparently reluctant to bite on lures or even natural bait (Cottrell, 1976), but when hooked is reported to be a powerful fighter. The impact of this species on native fishes and aquatic habitats could be extremely detrimental, especially if it spreads into vegetated lakes in the Midwest. Some studies reported "better" habitat quality based on such criteria as reduction of "nuisance" vegetation and decreased eutrophication (e.g., Mitzner, 1978), whereas others document adverse effects to native fish populations because of reduced cover (Ware and Gasaway, 1976), or contradicting results with regard to native fishes (W. Bailey, 1978). The

Plate 28. *Ctenopharyngodon idella*, grass carp, 45.5 cm SL, Reelfoot L., TN.

greater danger may lie in potential impacts to vegetated habitats accessible from large rivers where natural reproduction of grass carp can occur. The population levels attainable by this species in North American waters and its potential impacts remain to be seen. Nonreproductive hybrids and artificially sexually reversed grass carp have been experimented with in efforts to control vegetation without having explosive grass carp populations (Boney et al., 1984). The Tennessee angling record is 50 lb, 8 oz (22.9 kg), 1991, taken by Joe Walters from Laurel Hill Lake, Lawrence County.

Distribution and Status: Grass carp, which were indigenous to large rivers of eastern Asia, such as the Amur, were introduced to fish culture facilities in Arkansas in 1963 and were successfully spawned in 1966 (Guillory and Gasaway, 1978). The Arkansas Game and Fish Commission made numerous stockings in succeeding years; including the open waters of the Arkansas River system in 1971, and, through interriverine dispersal and numerous interstate stockings, grass carp quickly spread into 35–40 states by 1976. In Tennessee, several records exist from the Mississippi River, where it is surely reproducing, and most of its major tributaries such as the Obion, Forked Deer, and Hatchie. Grass carp also occur in many ponds and lakes in the western part of the state (e.g., McKellar Lake in Memphis and others) and were stocked in Reelfoot Lake by TWRA in the early 1980s in an effort to control vegetation (Petit, 1984). It is reasonable to anticipate that grass carp will soon move upstream in both the Cumberland and Tennessee rivers to occupy all main channel reservoirs.

Similar Sympatric Species: The mullet-shaped head, coarse scales, posterior placement of the anal fin, and triangular shape of the premaxilla (dorsal view) should be sufficient to separate grass carp from other cyprinids with which it occurs. The two introduced species of *Hypophthalmichthys* are somewhat similar in appearance but have much finer scales (85 or more in lateral line vs. 34–37). Grass carp differ from suckers in having only 8 dorsal fin rays (10 or more in suckers) and in having a terminal mouth (subterminal or inferior in suckers).



Range Map 28. *Ctenopharyngodon idella*, grass carp (widely introduced throughout southern and central North America).

Etymology: *Cteno* = comb, *pharyngodon* = pharyngeal teeth, referring to the corrugate or comb-like cutting surfaces of the pharyngeal teeth; *idella* is probably derived from the Greek *id* or *ideo*, meaning distinctive.

Genus *Cyprinella* Girard

The genus *Cyprinella*, until recently treated as a subgenus of *Notropis*, contains large to moderately large species associated with more current than most *Notropis*. In addition to species formerly placed in *Notropis*, four species formerly in *Hybopsis* (*labrosa*, *zanema*, and a related undescribed relative, all of the Atlantic slope, plus *monacha* of the Tennessee River drainage) have been moved to *Cyprinella*. Feeding is usually near or at the surface. Many of the species spawn in log or rock crevices and develop red and yellow breeding colors on fins. The breeding season typically extends from spring through late summer or early fall with small complements of eggs intermittently spawned; they are thus termed "fractional" spawners. Characters include 1,4–4,1 pharyngeal teeth (Fig. 63b), dark pigment in posterior interradial membranes of dorsal fin, nuptial tubercles large on head and mostly on dorsal surface and lower jaw, and opaque milky white caudal, anal, and paired fins (this often obscured by development of yellow or red, leaving only tips of these fins white) in nuptial males. Scales are less deciduous than in many other shiners, and scale edgings typically form diamond-shaped patterns, the pattern continuing uninterrupted through the anterior portion of the lateral stripe. Tennessee species are *caerulea*, *callistia*, *camura*, *galactura*, *lutrensis*, *monacha*, *spiloptera*, *trichroistia, venustia,* and *whipplii.* Additional species occur in Atlantic and Gulf coastal drainages (*analostana*, *callisema*, *callitaenia*, *chloristia*, *gibbsi*, *labrosa*, *leedsi*, *pyrrhomelas*, *xaenura*, *zanema*) (Gibbs, 1957a; Howell and Williams, 1971). The *C. lutrensis* complex of the genus *Cyprinella* is distributed in central United States and Mexico and includes the nominal species *bocagrande*, *formosa*, *garmani*, *lepida*, *lutrensis*, *mearnsi*, *ornata*, *panarcys*, *proserpina*, *rutila*, and *xanthicara*, some of which have been treated as synonyms or subspecies of *lutrensis*, plus one or more undescribed forms (Hubbs and Miller, 1978; Chernoff and Miller, 1982; Matthews, 1987; Mayden, 1989). Gilbert (1964) suggested "fairly close ties" between *Cyprinella* and the genus *Luxilus* based on certain *Luxilus* characters in *C. pyrrhomelas,* and Mayden (1989) regarded *Cyprinella* and *Luxilus* as sister groups. Mayden and Matson (1988) hypothesized a closest relationship to members of *Notropis* s.s. and subgenus *Hydrophlox*, based on genetic analysis. Cavender and Coburn (1985) and Coburn and Cavender (1987) additionally hypothesized affinities with genera *Lythrurus*, *Opsopoeodus*, *Pimephales*, and subgenus *Pteronotropis*.

Etymology: *Cyprinella* is a diminutive of *Cyprinus*, the carp.

KEY TO THE TENNESSEE SPECIES OF THE GENUS CYPRINELLA

1. Body very deep, with depth contained about 3.5 times in standard length in adults, and about 3.8 times in standard length in juveniles; individuals with 8 anal fin rays often as frequent as those with 9; restricted to the Mississippi River proper and adjacent areas in west Tennessee ..... *C. lutrensis* p.152
   Body more slender, with depth contained more than 3.7 times in standard length in adults, and juveniles still more slender; anal fin rays consistently either 8 or 9 (but not both) in these species; widespread 2
2. Scales small, 52 or more in lateral line; rare and restricted to Tennessee River drainage .. *C. monacha* p.153
   Scales normal, 46 or fewer (42 or fewer in Tennessee River drainage) scales in lateral line 3
3. Modal number of anal fin rays 8 4
   Modal number of anal fin rays 9 7
4. Lateral stripe very dark and of uniform width from operculum to caudal peduncle where it enlarges to form a caudal spot (Pl. 29); Conasauga River .... *C. caerulea* p.147
   Lateral stripe noticeably darker and wider on caudal peduncle, fading anteriad 5
5. A distinct black caudal spot present that is abruptly wider than the lateral stripe 6
   Lateral stripe widens only slightly on caudal peduncle, forming a vague caudal spot at most (Pl. 35) .... *C. spiloptera* p.155

6. A narrow, dusky lateral stripe extending from caudal spot to operculum (Pl. 30); caudal spot with posterior half darker than anterior half; snout somewhat fleshy and rounded; Conasauga River . . . . *C. callistia* p.148
Lateral stripe present on peduncle, but fading and disappearing anteriad (Pl. 37); caudal spot not bicolored; snout sharply pointed . . . . *C. venusta* p.158
7. Basal third of anterior dorsal fin membranes with melanophores; lateral stripe wide above anal fin, then becoming narrower, and then widening again to form a distinct caudal spot (Pl. 36); Conasauga River . . . . *C. trichroistia* p.156
Basal third of anterior dorsal fin membranes not darker than distal membranes; distinct caudal spot absent; widespread but not in Conasauga River 8
8. Proximal one-third of dorsal and ventral caudal fin rays lacking melanophores, leaving a pale area or areas at caudal base; widespread 9
Caudal fin rays outlined with melanophores to their bases; common in Tennessee and Cumberland river systems, but very rare in Mississippi River and its direct tributaries . . . . *C. whipplii* p.159
9. Pale basicaudal areas in the form of a conspicuous dorsal and ventral white spot (Pl. 32); middle and east Tennessee . . . . *C. galactura* p.150
Pale basicaudal areas less distinct, forming a pale, vertical stripe at base of caudal fin (Pl. 31); west Tennessee . . . . *C. camura* p.149

Cyprinella caerulea (Jordan)

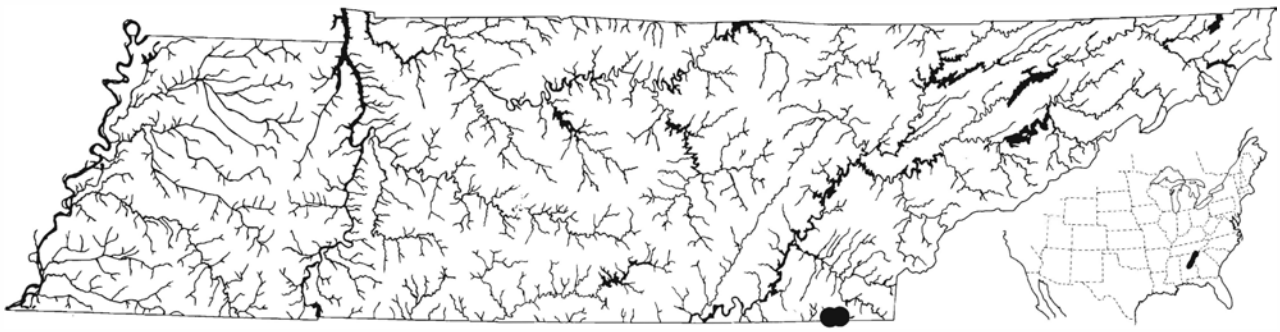
Blue shiner

Plate 29. *Cyprinella caerulea*, blue shiner, breeding male, 61 mm SL, Conasauga R., TN.

Characters: Lateral-line scales 38–39 (37–40), predorsal scale rows 16–18. Anal fin rays 8. Pectoral fin rays 14–16. Pelvic fin rays 8. Gill rakers 7–8, length of longest rakers 1.5 times their basal width. Pharyngeal teeth 1,4-4,1. Breast scaled. Color silvery on sides with dark dorsum and conspicuous dark lateral stripe. Nuptial males have yellow on all fins except the dorsal, bright silvery blue sides, and a pink tint to the pale area above the dark lateral stripe. Tubercles are as described for *C. venusta* except that nape tubercles are much smaller than those on the head and a few tubercles may develop on dorsal portions of opercles. The dorsal fin of males becomes somewhat elongate during the breeding season.

Biology: The blue shiner is restricted to the cooler, clearer portions of the Conasauga River system where it occurs over firm substrates in pools and areas of moderate current. Food of ten adults, 14 April through 4 August, contained mostly terrestrial insects supplemented with occasional mayfly and caddisfly immatures, indicating a typical *Cyprinella* surface and midwater feeding orientation. Nuptial tubercles were nearing peak development by 14 April in the Conasauga River, and showed similar development on 2 July, again suggesting the extended spring and summer reproductive period (fractional spawning) typical for the genus. Additional biological information is abstracted from R. S. Krotzer (1984, 1990). Spawning occurs from early May through late August, with mature females more numerous than mature males. Females 47–64 mm SL produced 152–610 ova per year and deposited them gradually during the summer. Sexual maturity apparently occurred in some males and females at the end of their second summer (age 1+) at 40–41 mm SL. Most spawners were in their third summer (age 2+), and some may have been age 3+. Food was dominated by terrestrial insects. Maximum SL 82 mm, or about 100 mm (2.9 in) TL.

Distribution and Status: Of sporadic occurrence in Coosa and Cahaba portions of the Mobile Basin, but apparently extirpated from the Cahaba, where it has not been taken since 1971. Apparently declining in numbers and range, a Threatened Species under the U.S. Endangered Species Act, and a likely future candidate for threatened status in Alabama (Ramsey, 1976; Ramsey and Pierson, 1986), Georgia (Helfman and Freeman, 1979), and Tennessee. Tennessee populations are dependent on protection of the Conasauga River which now is the stronghold for the species.



Range Map 29. *Cyprinella caerulea*, blue shiner.

Similar Sympatric Species: In all other Tennessee *Cyprinella* the lateral stripe fades anterior to the anal fin; in *caerulea* it is of almost uniform intensity and width from caudal fin base to operculum, and its continuation is visible around the snout.

Systematics: Mayden (1989) hypothesized that the species pair *C. trichroistia* and *C. gibbsi* are closest relatives of *caerulea*.

Etymology: *caerulea* = blue.

Cyprinella callistia (Jordan)

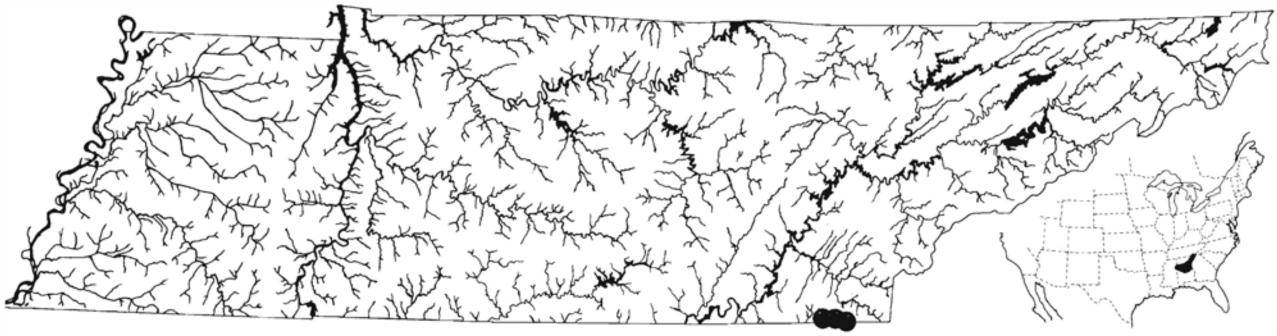
Alabama shiner

Plate 30a. *Cyprinella callistia*, Alabama shiner, 58 mm SL, Conasauga R., TN.

Plate 30b. *Cyprinella callistia*, Alabama shiner, breeding male, 90 mm SL, Conasauga R., TN.

Characters: Lateral-line scales 38–40, predorsal scale rows 16–17. Anal fin rays 8. Pectoral fin rays 14–16. Pelvic fin rays 8. Gill rakers 8–9, length of longest rakers 1.5–2 times their basal width. Pharyngeal teeth 1,4-4,1. Breast scaled. Color dark on back with dusky silver sides and a large basicaudal black blotch. Nuptial males with iridescent blue-black dorsal fin and dark red caudal fin. Anal fin opaque white, paired fins white with some orange near base. Peritoneum dark. Head and nape tubercles are in rows (one per scale on nape), as described for *C. trichroistia*, except they are much larger, there are numerous tiny tubercles on the entire dorsal surface of the head in addition to the large ones, and tubercles do not develop on the lower jaw. Large tubercles, one per scale, occur in two rows on each side of the ventral midline of the caudal peduncle in one male from the Black Warrior River system. Pectoral fin tubercles are considerably larger than those on other fins, and there is a single tubercle per fin ray segment on dorsal surfaces of rays 1–7 or 8. Pelvic fin tubercles are smaller, and distributed as on the pectorals. Tubercles on the dorsal and anal fins and lower lobe of the caudal fin are still smaller, and there are 1–3 per fin ray segment. Dorsolateral scales have a marginal row of about 15–20 small tubercles. Breeding males develop slightly enlarged dorsal fins.

Biology: The Alabama shiner is a large and showy minnow that occurs in habitats ranging from small creeks to rivers. Large adults typically occupy swift, boulder-strewn runs below riffle areas, with juveniles and young adults inhabiting quieter waters with less coarse substrates. It is the only shiner in the genus *Cyprinella* with a horizontal, subterminal mouth. This departure from the typical terminal and oblique mouth is reflected in its lacking their customary midwater- and surface-feeding pattern. *Cyprinella callistia* is a bottom-feeding insectivore, feeding primarily on midge and blackfly larvae. Case-building caddis larvae (genus *Micrasema*)



Range Map 30. *Cyprinella callistia*, Alabama shiner.

are ingested with their cases, and a few mayfly nymphs, hydropsychid caddis larvae, adult and larval elmid beetles, and water mites occurred in stomachs we examined. Terrestrial insects were essentially absent. These shiners are notably aggressive in feeding and will swim about the feet of persons working in the water to glean dislodged food items. As with other members of the genus *Cyprinella*, Ferguson (1989) reported crevice spawning in this species with males aggressively defending nest sites. A 95-mm female, collected 28 June, examined by us, apparently had not spawned and contained about 400 mature eggs and over 1,000 less developed eggs, some of which may have matured later that year. Tuberculate males are present in collections from mid May through early November, suggesting a prolonged breeding season. Growth is unstudied. Maximum total length 130 mm (5.1 in).

Distribution and Status: Occurring in all physiographic provinces above the Fall Line in the Mobile Basin. In Tennessee, restricted to the Conasauga River system where it is typically the dominant cyprinid.

Similar Sympatric Species: Most similar to *C. trichroistia*, another Conasauga *Cyprinella* lacking distinctly diamond-shaped scale outlines. The horizontal and subterminal mouth, very large caudal spot, and absence of yellow pigment on leading edges of pectoral, pelvic, and anal fins in *callistia* contrast with these characters in *trichroistia*, and usually allow accurate separation without counting anal fin rays.

Systematics: Its linear head tubercles and lack of diamond-shaped scale outlines led Gibbs (1957a) to consider it a primitive member of the subgenus. However Mayden (1989) regarded it as closest related to a group consisting of southern Atlantic and Gulf coastal drainage species *callisema*, *callitaenia*, *leedsi*, and *nivea*.

Etymology: *callos* = beautiful, *istia* = sail, referring to the iridescent blue-black dorsal fin of the nuptial male.

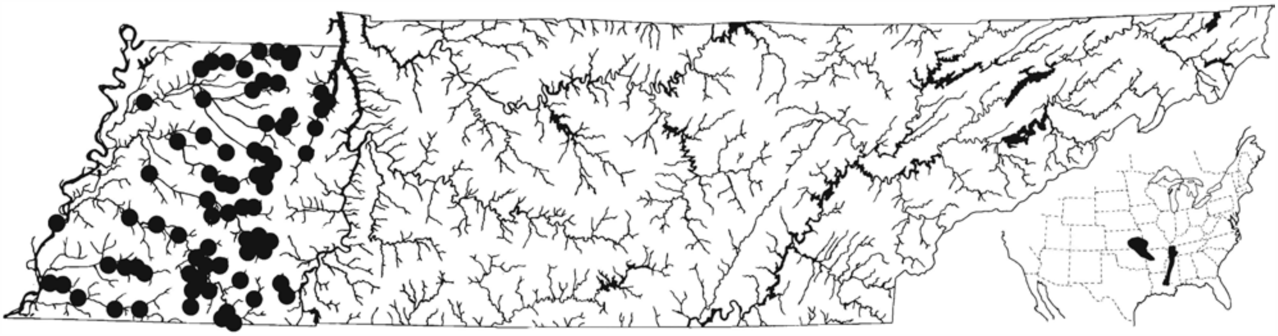
Cyprinella camura (Jordan and Meek)

Bluntface shiner

Plate 31a. *Cyprinella camura*, bluntface shiner, 50 mm SL, Hatchie R. system, TN.

Plate 31b. *Cyprinella camura*, bluntface shiner, breeding male, 110 mm SL, Hatchie R. system, TN.

Characters: Lateral-line scales 37–38, predorsal scale rows 16–17. Gibbs (1961) reported 36–37 lateral-line scales in populations west of Mississippi River. Anal fin rays 9–10 (occasionally 8). Pectoral fin rays 14–16. Pelvic fin rays 8. Gill rakers 8–10, length of longest rakers 1–1.5 times their basal width. Pharyngeal teeth 1,4-4,1. Breast scaled. Color in life is silvery with no distinctive markings. The pale vertical bar at the caudal fin base characterizing most populations of *C. camura* is often inconspicuous in Tennessee specimens. Nuptial



Range Map 31. *Cyprinella camura*, bluntface shiner.

males have red dorsal and caudal fins, opaque milky white on other fins, moderately enlarged dorsal fins, and red snouts. Tubercles are as described for *C. venusta* except there is no hiatus between snout tubercles and those on dorsum of head, nape tubercles are abruptly smaller than those on head, tubercles on body scales are scattered rather than concentrated on scale margins, belly scales have small tubercles, and fins tend to have only 1 (1–2) tubercles per fin ray segment.

Biology: The bluntface shiner is an inhabitant of headwater portions of primarily lowland river systems. It occurs in moderate to swift current over sand substrates. Its biology has not been studied, but is probably similar to that of *C. whipplii* and other *Cyprinella*. As in other *Cyprinella*, a prolonged spawning season is indicated by nuptial males in collections from May through August. Maximum total length 150 mm (6 in).

Distribution and Status: Common in eastern tributaries to the lower Mississippi River from Obion River south, where it occurs in the Coastal Plain above the Alluvial Plain, with strays occurring farther downstream and in the Mississippi River. Also occurs in a few southwestern tributaries to the Tennessee River, perhaps as a result of headwater exchange between these and the Hatchie River. Its invasion of the Big Sandy River system has apparently been recent, as Clark (1974) did not collect it there in the early 1970s. Curiously disjunct populations occur in the central Arkansas River drainage.

Similar Sympatric Species: Juveniles are virtually indistinguishable from the occasionally sympatric *C. whipplii*. See account under that species for differentiating characters.

Systematics: Gibbs (1961) suggested relationships with *C. galactura*. LeDuc (1984) analyzed eastern and western populations of *camura* using morphological and electrophoretic data, and used electrophoretic data to investigate relationships between *camura*, *galactura*, and *whipplii*. These data showed a closer relationship between *camura* and *galactura* than between either of these and *whipplii*. However, Mayden (1989) proposed a close relationship with a group consisting of *whipplii* and Atlantic slope species *analostana* and *chloristia*. Recognition of eastern and western subspecies of *camura* was not recommended by LeDuc (1984), since electrophoretic and morphological data did not show concordant variation.

Etymology: *camur* = turned inward, referring to the blunt snout.

Cyprinella galactura (Cope)

Whitetail shiner

Characters: Lateral-line scales 39–42, predorsal scale rows 18 (17–19). Anal fin rays 9 (8–10). Pectoral fin rays 15–16 (14–17). Pelvic fin rays 8. Gill rakers 9–11, length of longest rakers about twice their basal width. Pharyngeal teeth 1,4–4,1. Breast scaled. Silvery in life with pale basicaudal areas prominent in adults and visible in larger young. Breeding males have red on pectoral, dorsal, and caudal fins, and the dorsal fin is moderately enlarged. Other fins are milky white. Nuptial tubercles are as described for *C. venusta*, except tubercles on dorsum of head are continuous to snout tip (no hiatus), nape tubercles are abruptly much smaller than those on head, and belly scales have small tubercles in the highest males.

Biology: The whitetail shiner is a very common species of clear upland creeks and rivers that is more inclined to inhabit small streams than other *Cyprinella* of east and middle Tennessee. It shows some tolerance for our up-

Plate 32a. *Cyprinella galactura*, whitetail shiner, 71 mm SL, Clinch R., TN.

Plate 32b. *Cyprinella galactura*, whitetail shiner, breeding male, 94 mm SL, Hiwassee R. system, TN.

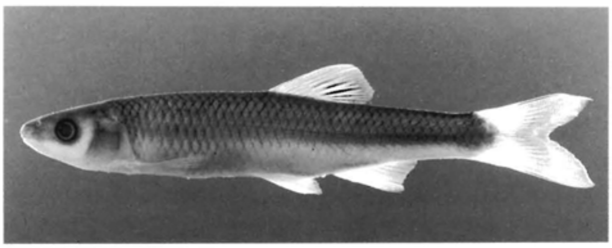


Plate 32c. *Cyprinella galactura*, whitetail shiner, preserved specimen showing pigmentation patterns, 85 mm SL, Barren Fk. R., TN.

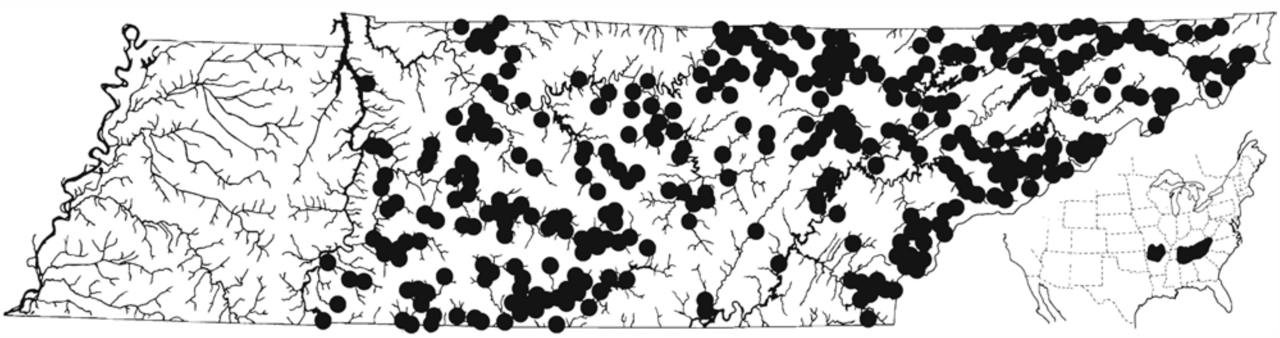
stream storage reservoirs, but is most abundant in swift runs or flowing pools in clear streams with coarse, firm substrates. Outten (1958) indicated it to be a midwater and surface feeder, ingesting both terrestrial insects and drifting aquatic larvae. Large adults are occasionally taken by anglers. The spawning period extends from early June through mid August, with sexual maturity reached by the third or occasionally the second summer, and eggs are deposited beneath bark of submerged logs and in bedrock crevices (Pflieger, 1975), or on the bottom or sides of rocks (Outten, 1961). Occasionally hybridizes with *C. spiloptera* (Gibbs, 1961), *C. whipplii,* see account under *C. whipplii,* and *C. monacha* (Burkhead and Bauer, 1983). Maximum total length 150 mm (6 in).

Distribution and Status: Common in all upland provinces of the Cumberland (uncommon above Cumberland Falls) and Tennessee drainages, and also present in headwaters of Savannah and Santee drainages of Atlantic slope, presumably as a result of headwater capture from the Tennessee. Apparently introduced in Big Sandy and upper New (Kanawha) systems of the Ohio River drainage. Disjunct populations are widespread in the Ozark region of southern Missouri and northern Arkansas.

Similar Sympatric Species: Juveniles and specimens with poorly developed white basicaudal areas can be confused with *C. whipplii* and *C. spiloptera.* Both of these species have terminal mouths, while that of *galactura* is definitely subterminal. *C. galactura* has more numerous predorsal and lateral-line scales than either of these species, and further differs from *spiloptera* in having pigment on anterior interradial membranes of the dorsal fin, and in having 9 rather than 8 anal fin rays. The only sympatric cyprinid with white basicaudal areas is *Luxilus coccogenis*, which lacks the diamond-shaped scales of *galactura* and most *Cyprinella*, has an extremely large and terminal mouth, and has a prominent oblique black bar just posterior to the operculum.

Systematics: Gibbs (1961) and LeDuc (1984) suggested closest affinities of *galactura* were with *C. camura* but Mayden (1989) regarded it as sister species to *C. venusta*.

Etymology: *galactos* = milk, *oura* = tail.



Range Map 32. *Cyprinella galactura*, whitetail shiner.

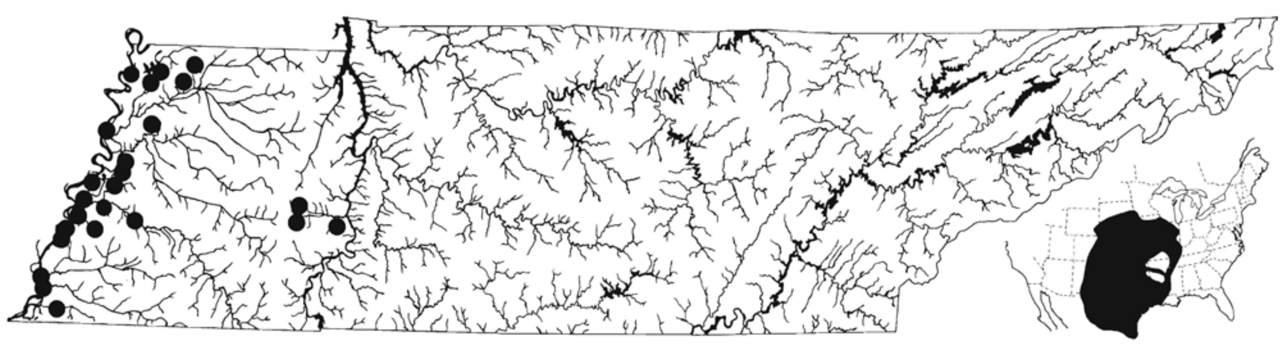
Cyprinella lutrensis (Baird and Girard)

Red shiner

Plate 33. *Cyprinella lutrensis*, red shiner, male, 43 mm SL, Forked Deer R. system, TN.

Characters: Lateral-line scales 33–36, predorsal scale rows 15–16. Anal fin rays usually 9 but 8 in about 1/3 of Tennessee specimens. Pectoral fin rays 13–15. Pelvic fin rays 8. Gill rakers 9–12, length of longest rakers 2–2.5 times their basal width. Pharyngeal teeth usually 1,4-4,1 in specimens east of the Mississippi River from Illinois through Mississippi, but more often 4-4 elsewhere (Eastman and Underhill, 1973; Manasek and Stasiak, 1976). Breast scales embedded anteriad. Silvery in life without distinctive markings or colors except in adult males. Nuptial males develop bright red pigment on all fins except the dorsal, iridescent blue sides, and a triangular dark blotch behind the operculum. Koehn (1965) described the sequence and pattern of nuptial tubercle development in Arizona, and our specimens agree in tubercle pattern. The dorsum of the head and lachrymal areas are covered with large tubercles except for a hiatus just anterior to the nares. These tubercles first form two rows between the eyes, but in later stages are more scattered. Sides and venter of head lacking tubercles, or rarely with a few on the lower cheeks or on the rami of the lower jaw. Large tubercles continue on middorsal scales behind head, with about 2–3 tubercles per scale that decrease in size toward the dorsal fin. Belly and breast scales lacking tubercles, but other scales with a marginal row of about 10 small tubercles, and midlateral scales often with 1–2 larger basal tubercles. These basal scale tubercles larger and more abundant (2–4 per scale) in area above anal fin and on lower caudal peduncle scales. Fin tubercles most prominent on pectoral, pelvic, and anal fin rays, with smaller tubercles developed on all rays of dorsal and caudal fins at maximum tuberculation. Fin tubercles form a single row basad that divides to form a row on each branch of the ray, with 1–2 tubercles per fin ray segment. Smaller tubercles develop on ventral surfaces of both pectoral and pelvic fin rays.

Biology: The red shiner is a deep-bodied southwestern shiner that barely penetrates into Tennessee in small streams immediately adjacent to the Mississippi River and also occurs in the river proper. It is very tolerant of altered or drastically fluctuating habitats (Cross, 1967). Brues (1928) collected *C. lutrensis* in New Mexico at water temperatures of 39.5 C (93 F), the highest thermal tolerance known for cyprinid fishes. Larimore and Smith (1963) and Page and R. Smith (1970) reported on its rather recent invasion and eastward spread in Illinois, and its replacement of native *Cyprinella* in the process. Matthews and Hill (1977) examined its tolerance to rapidly changing temperature, dissolved oxygen, pH, and salinity regimes and found it to have quite to extremely high tolerances to such environmental changes. Its tolerance to dissolved oxygen concentrations down to 1.5 ppm was attributed to its ability to swim near the surface and obtain its respiratory water from the relatively oxygen-rich surface film as described by Lewis (1970) for *Gambusia*. The diet has been reported to consist of both terrestrial and aquatic insects, and algae (Lewis and Gunning, 1959, as *C. whipplii;* Laser and Carlander, 1971). Minckley (1959) reported courtship and spawning behavior, and observed spawning over nests of green sunfish where one or two males courted single females, and males' fins were often erected in display both to females and competing males. Delco (1960) found that females produce species



Range Map 33. *Cyprinella lutrensis*, red shiner (native range only).

specific sounds when in the presence of breeding males, and that males respond positively to these "breeding calls," but not to those of the closely related *C. venusta*. Females produce about 500–1,000 eggs per year, and life span is 3 years (Lewis and Gunning, 1959; Laser and Carlander, 1971). Farrington et al. (1979) reported that the smallest sexually mature specimens were 30 mm SL, and that a small proportion of fish ending their first year of life were sexually mature, with most spawners 2 years old; breeding season extended from March through September in the southwest, but could be interrupted by midsummer drought. Massive hybridization often results when *venusta* and *lutrensis* occur together (Hubbs and Strawn, 1956; Smith, 1979) and has been noted in streams near Reelfoot Lake in Tennessee. Hybrids are intermediate between *lutrensis* and *venusta* in body depth, tubercle pattern, pigmentation, and scale counts. Because of its bright colors and hardiness, the red shiner has received some utilization by the aquarium trade, including Europe (Sterba, 1959). Maximum total length 90 mm (3.5 in).

Distribution and Status: Widespread, often abundant, and increasing its range in the Mississippi River basin; native westward to Rio Grande drainage. Introduced into Colorado River drainage where it is abundant and a serious threat to native species. Also introduced into several southeastern localities.

Similar Sympatric Species: Other *Cyprinella* that may occur with *lutrensis* are *venusta* and *camura*, both of which are more slender, have more lateral-line and predorsal scales, and lack excessive tubercle development on scales above the anal fin. In addition, *venusta* has a distinct caudal spot, 8 anal fin rays, and yellow rather than red on fins of nuptial males.

Systematics: Type species of genus *Cyprinella*. Forms a complex within *Cyprinella*, with a number of similar forms from Mexico and the Southwest considered as a separate phyletic lineage from that of all other of the more eastern species of *Cyprinella* (Mayden, 1989). Matthews (1987) treated systematics of *lutrensis* and related taxa, primarily in the area west of the Mississippi River.

Etymology: *lutra* = the otter, in reference to the type locality, Otter Creek, Arkansas.

Cyprinella monacha (Cope)

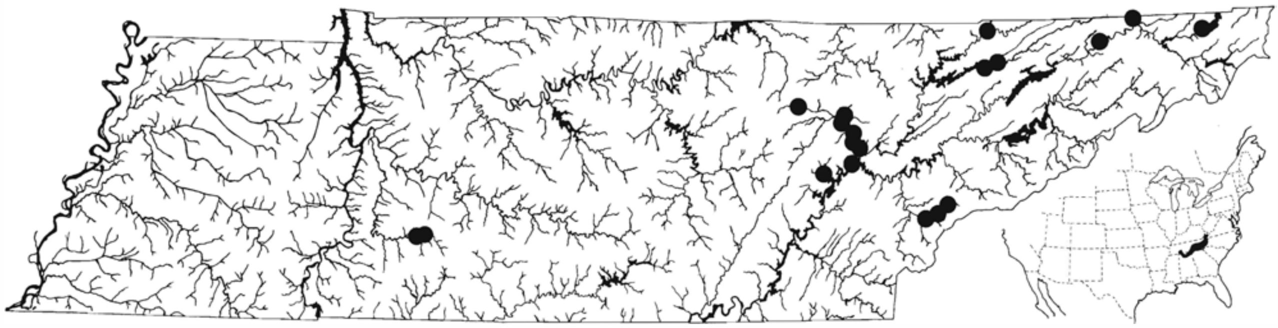
Spotfin chub

Plate 34a. *Cyprinella monacha*, spotfin chub, 70 mm SL, Emory R., TN.

Plate 34b. *Cyprinella monacha*, spotfin chub, breeding male, 75 mm SL, Emory R., TN.

Characters: Lateral-line scales 52–62, predorsal scale rows 24–29. Anal fin rays 8 (7–9). Pectoral fin rays 14–15 (13–16). Pelvic fin rays 8. Gill rakers 5–8, with longest rakers 1.5–2 times their basal width. Pharyngeal teeth 4-4. Breast naked or with embedded scales posteriad. Color bright silver on sides with dark basicaudal spot apparent. The blue-green sheen of nuptial males makes this one of our most strikingly beautiful cyprinids. In nuptial males large tubercles cover the top of the head from the occiput to the upper lip, with tubercles on the tip of the snout separated from the other tubercles by a hiatus just anterior to the nares. There is a row of tubercles over each orbit, and tubercles are present on the rami of the lower jaw and on the lower angle of the preoperculum. Scales above the lateral line and anterior to the dorsal fin typically have a row of small tubercles on their margins and tubercles may appear on scales elsewhere on the body. Pectoral and pelvic fins with uniserial tubercles on dorsal surfaces of rays, on outer 6–10 rays on pectoral fin, and rays 2 through 4–8 on pelvic fin.

Biology: The spotfin chub, an obligate inhabitant of clear upland rivers, is apparently disappearing from our fauna. Adults are typically associated with swift currents and boulder substrates, but juveniles are often encountered over small gravel substrates with moderate current. Gut contents of five small adult specimens collected in Emory River on 16 August included a wide



Range Map 34. *Cyprinella monacha*, spotfin chub.

variety of aquatic insects predominated by midge, blackfly, and caddisfly larvae. Most of the caddis larvae were case builders that had been ingested with the case. Some individuals may have specialized on certain prey items or feeding areas, because taxa represented by 10–20 individuals in certain fish were absent from gut contents of other specimens. Jenkins and Burkhead (1984) presented additional biological information. They found the diet dominated by larvae and pupae of midges and black flies (89.5%), with baetid mayflies also important. Spawning extends from mid May through mid August. This minnow is a fractional crevice spawner (N. Burkhead, pers. comm.), with females spawning repeatedly during the breeding season and depositing their eggs in boulder crevices. Young are 20–48 mm SL in May at age 1, 55–89 mm the following May (age 2); life span is slightly over 3 years, and males and females are sexually mature at about 60 mm SL, with some females and perhaps some males sexually mature by August of their second summer (age 1+). Maximum total length 120 mm (4.75 in).

Distribution and Status: The spotfin chub is recognized as a threatened species by the U.S. Fish and Wildlife Service and is considered endangered in Tennessee (Starnes and Etnier, 1980). A federal recovery plan has been devised for the species' protection, emphasizing habitat improvement and possible reintroductions (Boles, 1983). It formerly occurred in the Holston system in Va. and Tenn.; Swannanoa River and Spring Creek, French Broad system, N.C.; Little Tennessee River system in N.C. and Tenn.; Chickamauga Creek near Ringgold, northeast Ga.; Little Bear and Shoal creeks, Ala.; and Whites Creek, Roane Co., Tenn. It has been extirpated from many of these localities and is known to persist only in the North Fork Holston River in Va., and in the Little Tennessee River between Franklin and Fontana Reservoir, N.C., in addition to the Emory, Buffalo, and Holston river populations in Tennessee. Jenkins and Burkhead (1984) presented a detailed history of collections of *Cyprinella monacha*.

Similar Sympatric Species: Sympatric shiners of the genus *Cyprinella* (*galactura, spiloptera, whipplii*) are somewhat similar, but they lack caudal spots and have only about 42 or fewer lateral-line scales.

Systematics: This species had been included in *Hybopsis* based primarily on its having a barbel at the posterior tip of the maxilla. The nuptial tubercle pattern is virtually identical with that of several species of the genus *Cyprinella*, most of which also share the dark pigmentation in the posterior membranes of the dorsal fin and milky white anal fins during the breeding season. Cavender and Coburn (1985) aligned *monacha* with *Cyprinella* based on osteological features. Breeding behaviour (crevice spawning) is similar to that of *Cyprinella* (N. Burkhead, pers. comm.), and a hybrid with *Cyprinella galactura* has been reported (Burkhead and Bauer, 1983). Cloutman (1987) indicated that *monacha* hosts a monogenetic trematode parasite species indicative of *Cyprinella* affinities. On the other hand, nuptial male *C. monacha* share a cornified cheek pad with members of *Phenacobius* and *Erimystax*, and Mayden (1989) placed *monacha* in *Erimystax*; however, Dimmick (1988) has shown that the ornamentation of the barbels in *C. monacha* is unlike that shared by *Erimystax* species. It appears that the bulk of probable derived traits support an alignment with the genus *Cyprinella* rather than with other barbeled minnows.

Etymology: *monacha* = solitary, presumably reflecting Cope's opinion that the species was typically represented in collections by only a single individual. It is not an easy fish to capture with a seine.

Cyprinella spiloptera (Cope)

Spotfin shiner

Plate 35a. *Cyprinella spiloptera*, spotfin shiner, 57 mm SL, Clinch R., TN.

Plate 35b. *Cyprinella spiloptera*, spotfin shiner, breeding male, 82 mm SL, Little R., TN.

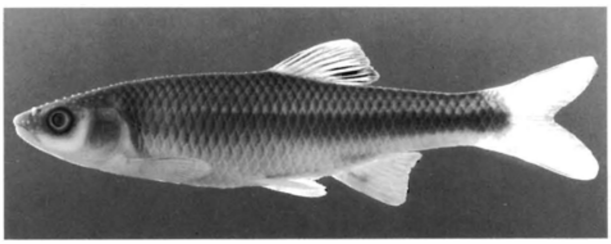
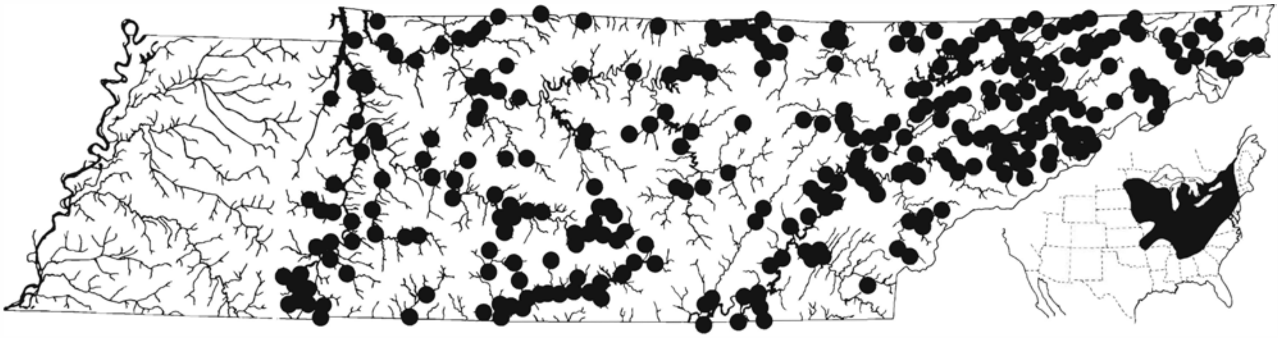


Plate 35c. *Cyprinella spiloptera*, spotfin shiner, preserved specimen showing pigmentation patterns, 65 mm SL, Buffalo R., TN.

Characters: Lateral-line scales 37–39 (36–40), predorsal scale rows 17–18. Anal fin rays 8 (rarely 9). Pectoral fin rays 13–16. Pelvic fin rays 8. Gill rakers 7–10, length of longest rakers 2–2.5 times their basal width. Pharyngeal teeth 1,4-4,1. Breast scaled. Vertebrae 37–39. Life color silvery on sides to gray on back, caudal fin faintly pale yellow. Breeding males have yellow fins and a tubercle pattern identical to that described for *C. venusta*, except there is a single row of tubercles on the rami of the lower jaw.

Biology: The spotfin shiner is a common fish in flowing pool areas of clear to moderately turbid streams and rivers, also occurring in reservoirs. Although common in the lower Tennessee River and its eastern tributaries, it almost completely disappears in western tributaries to that river. This certainly reflects their inability to successfully inhabit coastal plain streams (below the Fall Line). Adults feed on both surface insects and aquatic immatures (Starrett, 1950; Mendelson, 1975). Hankinson (1930), Pflieger (1965), and Gale and Gale (1977) provided detailed accounts of reproductive behavior. Spawning occurs from early June through late August or early September. Most spawners were in their third summer, but some spawned in their second summer at age 1+. Individual females deposit only a fraction (10–97%) of their egg complement during each spawning act. The eggs are forcefully sprayed into crevices in boulders or on the bark of submerged logs. These egg deposition sites are defended, at least briefly, by individual males, who often display their dorsal fins to rival males, prod them with their snout, or even bite and hold on to the rival's anal or pelvic fin and attempt to remove him from the site. Males swim over and make physical contact with the spawning site several times prior to spawning. Females may approach the spawning site voluntarily or be "herded" there by the male. During spawning, which may be upright to completely inverted depending on the spawning site, the male assumes a position on top of and in contact with the female, with his snout at the level of her pectoral fins. The male appears to force the female against the spawning surface. Heins (1990) and Rabito and Heins (1985) have suggested that males of the related *C. venusta* and *C. leedsi* may actually ejaculate sperm into the spawning crevice during their pre-spawning contact runs, prior to appearance of the female. A single female deposited 7,474 eggs over an 8-week period in an aquarium. Eggs hatch in about 5 days. Gale and Gale (1976) analyzed spawning site selection in detail. Pflieger (1965) suggested that visual cues prevented hybridization between *spiloptera* and the closely related *C. whipplii,* which were spawning on different areas of the same logs at the same time. Auditory cues (Delco, 1960; Gale and Gale, 1977), may also be important. Artificially produced F_1 hybrids between these two species showed no decrease in viability, but such hybrids are apparently uncommon in wild populations; we have only three specimens in our collection, but others might easily have been overlooked. Neff and Smith (1979) discussed characters of laboratory reared hybrids. Page and R. Smith (1970) reported hybridization between *lutrensis* and *spiloptera* in Illinois, with the former eventually replacing the latter. Maximum total length 122 mm (4.8 in).

Distribution and Status: Abundant in upland and glaciated areas of much of the Mississippi Basin south through Arkansas River and Tennessee River drainages, also occurring in Great Lakes (except Lake Superior)



Range Map 35. *Cyprinella spiloptera*, spotfin shiner.

drainage, Atlantic Coastal drainages from Hudson through Potomac river drainages, and in Red River (Hudson Bay drainage) in southeastern North Dakota. Occurs in all upland physiographic provinces in Tennessee, but mostly absent from the Coastal Plain.

Similar Sympatric Species: Although anal fin ray and gill raker counts will separate most specimens of *C. whipplii* and *C. spiloptera,* there are additional excellent characters for separating these very similar species. In fresh specimens *spiloptera* has a faint wash of yellowish pigment on the caudal fin; this fin is clear in *whipplii.* In *spiloptera,* the lateral stripe on the caudal peduncle extends little above the horizontal myoseptum, has a rather definite dorsal margin, and the oblique myosepta within the lateral stripe appear as narrow white lines; in *whipplii,* the lateral stripe on the peduncle extends well above the midline and fades more gradually dorsad, and pale myosepta are not visible within the stripe. In *spiloptera* (except nuptial males) the interradial membranes of the dorsal fin lack pigment except for the spot on the posterior membranes; in *whipplii* all dorsal fin interradial membranes are liberally sprinkled with melanophores in juveniles and adults. Nuptial males of *whipplii* have greatly enlarged dorsal fins, and nape tubercles are abruptly smaller than those on the head; in *spiloptera* the dorsal fin does not enlarge, and anterior nape tubercles grade gradually in size with those of the head. Also, see comments under *C. galactura*.

Systematics: Mayden (1989) considered *spiloptera* to be the sister species to the lineage containing all other of the eastern species (i.e., excluding *lutrensis* group) of *Cyprinella*. Gibbs (1957b) described populations from northern Illinois, Wisconsin, Minnesota, and areas west of the Mississippi River as a new subspecies, *C. s. hypsisomata*, that is characterized by having 36–37 lateral-line scales, a deeper body, and greater tubercle development on the lower caudal peduncle. Schaeffer and Cavender (1986) reviewed range-wide variation in *C. spiloptera* and did not recognize *N. s. hypsisomata* as valid, based on body shape characters being non-concordant with variation in scale counts.

Etymology: *spilos* = spot, *pteron* = wing or fin.

Cyprinella trichroistia (Jordan and Gilbert)

Tricolor shiner

Characters: Lateral-line scales 38–40 (36–43), predorsal scale rows 17–19 (16–20). Anal fin rays 9 (8–10). Pectoral fin rays 13–15. Pelvic fin rays 8. Gill rakers about 7, but only upper 3–4 with tips extending past tissues of arch. Pharyngeal teeth 1,4-4,1. Breast scaled. Vertebrae 38–40. Color silver on sides and dark gray on back, with large, dusky basicaudal spot. Large juvenile and adult specimens of both sexes have yellow on leading edges of pectoral, pelvic, and anal fins in life that becomes bright orange in nuptial males. Nuptial males with head tubercles large and forming four longitudinal rows, one above each orbit and two adjacent to the midline. There is a narrow hiatus between these tubercles and those on the snout tip. Tubercles are also present on the lachrymal area and form a poorly defined single row on rami of the lower jaw, with a few smaller tubercles occasionally developed on the upper or lower lips. Tubercles as large as those on the head continue down the dorsal midline, with 1 tubercle per scale, forming 3–5 rows near the occiput, decreasing to a single row of slightly smaller tubercles near the dorsal fin origin. Single large tubercles occur on scales above anal fin base and on lower caudal peduncle. Other lateral body scales have about two small tubercles located near scale centers. Pectoral fin tubercles are larger than those on other fins, and occur on dorsal surfaces of rays 1–7 or 8 with 1 (occasionally 2) tubercles per fin ray segment.

Plate 36a. *Cyprinella trichroistia*, tricolor shiner, 48 mm SL, Conasauga R. system, TN.

Plate 36b. *Cyprinella trichroistia*, tricolor shiner, breeding male, 71 mm SL, Conasauga R., TN.

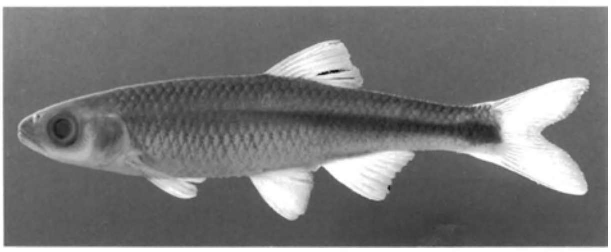


Plate 36c. *Cyprinella trichroistia*, tricolor shiner, preserved specimen showing pigmentation patterns, 61 mm SL, Conasauga R., TN.

Smaller tubercles, typically 1 tubercle per fin ray segment, occur on dorsal surfaces of first 3 pelvic fin rays, middle caudal fin rays, and on anal and dorsal fin rays.

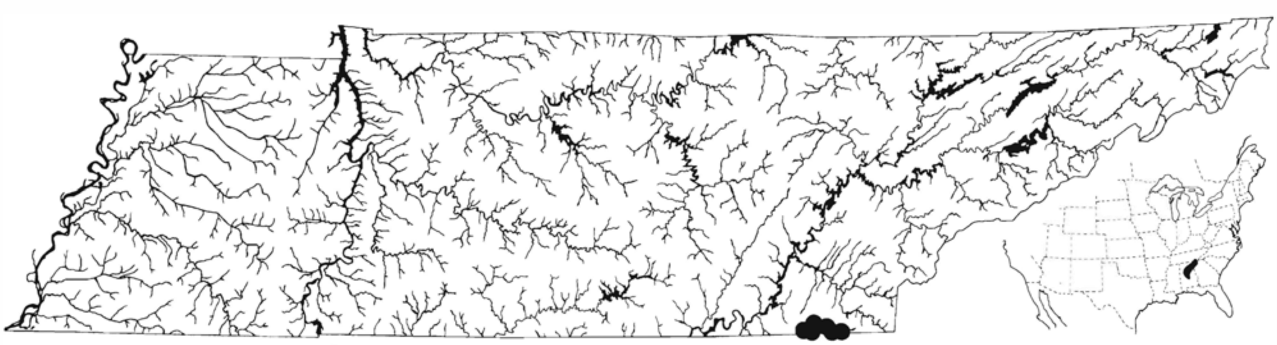
Biology: Preferred habitats of the tricolor shiner are pool areas with little or moderate current and firm substrates. Food of ten adults collected from 9 April through 1 September was about half terrestrial insects, half aquatic immatures dominated by mayfly nymphs. Howell and Williams (1971) noted maximum tubercle development from late June to mid July, and this presumably corresponds to peak breeding activity. Ferguson (1989) documented crevice spawning in this species, as in other members of the genus *Cyprinella*; better-developed males defended nest sites with lesser males occasionally sneaking in to spawn. Maximum total length 95 mm (3.75 in).

Distribution and Status: Cahaba and Coosa river portions of Mobile Basin above the Fall Line. Abundant in Conasauga River system in Tennessee.

Similar Sympatric Species: Other sympatric *Cyprinella* (*callistia*, *caerulea*, and *venusta stigmatura*) have 8 anal fin rays. In *callistia* the snout extends past the subterminal, horizontal mouth. Both *venusta stigmatura* and *caerulea* have distinctly diamond-shaped scale outlines. In the former the caudal spot extends onto the middle caudal rays, and in the latter the dark lateral stripe maintains about the same width and intensity from caudal base to and onto the head.

Systematics: Closely related to *C. gibbsi* of the Tallapoosa River system (Howell and Williams, 1971; Mayden, 1989); Mayden (1989) hypothesized *C. caerulea* as closest relative of this pair. Gibbs (1957a) considered *trichroistia* to be a rather aberrant and primitive *Cyprinella* because of the lack of diamond-shaped scale outlines and the linear head tubercle pattern.

Etymology: *tri* = three, *chro* = color, *istia* = sail, referring to the tricolored dorsal fin of nuptial males.



Range Map 36. *Cyprinella trichroistia*, tricolor shiner.

Cyprinella venusta Girard

Blacktail shiner

Plate 37a. *Cyprinella venusta*, blacktail shiner, 54 mm SL, Mississippi R., TN.

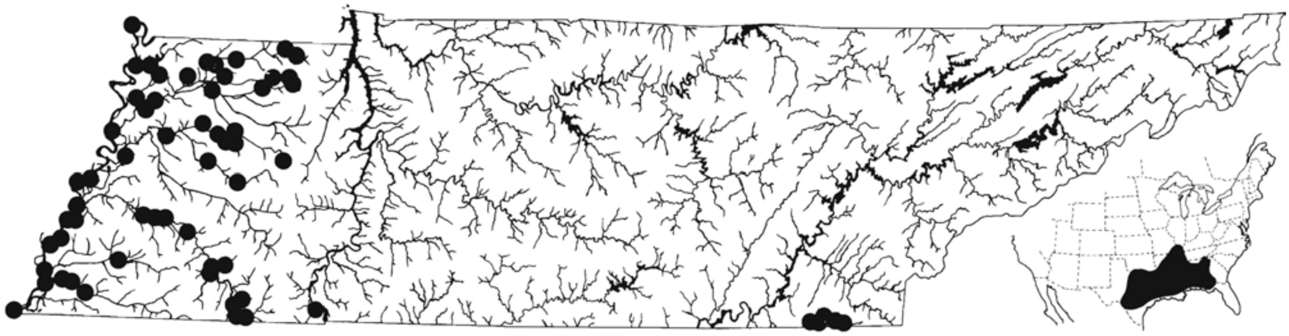
Plate 37b. *Cyprinella venusta venusta*, blacktail shiner, breeding male, 73 mm SL, Hatchie R. system, TN.

Plate 37c. *Cyprinella venusta stigmatura*, blacktail shiner, breeding male, 112 mm SL, Conasauga R., TN.

Characters: Lateral-line scales 36–39 in west Tennessee populations (*C. v. venusta*) and 39–46 in Mobile Basin (*C. v. stigmatura*), predorsal scale rows 15–18 in *venusta* and 19–24 in *stigmatura*. Anal fin rays 8. Pectoral fin rays 14–15 (13–17). Pelvic fin rays 8. Gill rakers 8–11, length of longest rakers 1.5–2 times their basal width. Pharyngeal teeth 1,4-4,1. Breast scaled. In life, silver on sides, dark gray on back, and with prominent black basicaudal spot. Nuptial males develop an opaque milky white coloration over all fins that is masked by yellow except on the dorsal fin, and a dark midlateral blotch just above the lateral line and near the tip of the pectoral fin. Large tubercles cover the top of the head, lachrymal areas, and occur as 2–3 poorly defined rows on rami of the lower jaw. Tubercles absent on dorsum between snout tubercles and nares, and elsewhere on head (occasionally a few on lower cheeks). Large tubercles continue down the nape to the dorsal fin origin, with about six tubercles per scale. All other body scales except those on breast and belly have 10–15 small tubercles, mostly on scale margins. Tubercles lacking on caudal fin, largest on pectoral fins, present on all other fins from leading edge through last ray (rays 1–7 or 8 on pectorals), and most prominent on anterior rays. Tubercles form a single row at base of ray, and a single row, 1–3 tubercles per fin ray segment, continues on each branch. Tubercles tiny on ventral surfaces of paired fins in highest males.

Biology: The nominate subspecies of *C. venusta* occurs in moderate to swift current over sandy substrates in small rivers and large creeks tributary to the Mississippi River in west Tennessee. Juveniles (and occasional adults) are often collected from the Mississippi River proper. *Cyprinella v. stigmatura* occurs in clear waters of the Conasauga River and its larger tributaries in flowing pool habitats with firm, coarse substrates. Adults of *C. v. venusta* fed on surface insects in Louisiana (Hambrick and Hibbs, 1977), and were most active just before sunset; Hale (1963) reported a diet of benthic invertebrates in Oklahoma. Tuberculate males in our collection suggest a spawning period from mid May through August. In southeastern Mississippi, *C. v. cercostigma* females reached sexual maturity at 32–42 mm SL, were in peak breeding condition from April through early August, and females 49–72 mm SL produced 139–459 ova per year (Heins and Dorsett, 1986). Heins (1990) reported on the breeding behavior in aquaria. Large males defended a particular spawning crevice from other males, and considerable fighting was observed. He believed that the purpose of these males swimming alone through the crevice was to deposit sperm and display the presence of the spawning area to females. Both large and small nonterritorial males made solo runs through the crevice when it was not being defended, suggesting that they were also depositing sperm. Delco (1960) found that females produce species-specific sounds when in the presence of breeding males, and that males respond positively to these "breeding calls", but not to those of the closely related *C. lutrensis*. However, massive hybridization often results when *venusta* and *lutrensis* occur together (Hubbs and Strawn, 1956; Smith, 1979) and has been noted in the Reelfoot Lake area in Tennessee. Maximum total length 128 mm (5 in).

Distribution and Status: Abundant in the Gulf Coastal Plain from Suwannee drainage of Florida to the Rio Grande. Upper Mobile Basin subspecies *C. v. stigmatura* occurs above Fall Line and is moderately common in Conasauga River in Tennessee, also occurs in



Range Map 37. *Cyprinella venusta*, blacktail shiner.

Tennessee drainage in Bear Creek system of Mississippi and Alabama, and has recently invaded the lower Tennessee River (Kentucky Reservoir), presumably via the Tenn-Tom Waterway. *Cyprinella v. cercostigma* occurs from Florida west through southeastern Louisiana, and *C. v. venusta* occurs from the lower Mississippi River and its tributaries north to southern Illinois, and in the western Gulf of Mexico drainages; introduced into Colorado River drainage (Branson, 1968).

Similar Sympatric Species: In west Tennessee only *Pimephales notatus*, *P. vigilax*, and *Phenacobius mirabilis* share a black caudal spot. These species are cylindrical rather than laterally flattened and have twenty or more predorsal scale rows. *Notropis hudsonius* may eventually be found in the Mississippi River in our state, and differs in having a sharply pointed dorsal fin, with anterior rays reaching well past tips of posterior rays when fin is depressed. In the Conasauga River system most cyprinids have black caudal spots, but this is the only species in which the spot extends onto the caudal fin.

Systematics: Mayden (1989) hypothesized *venusta* and *galactura* to be sister species. Gibbs (1957c) discussed subspecies and their distributions.

Etymology: *venusta* is derived from Venus, the Roman goddess of love; *cercostigma* = round spot; *stigmatura* = spot tail.

Cyprinella whipplii Girard

Steelcolor shiner

Characters: Lateral-line scales 37–38 (36–39), predorsal scale rows 16–17. Anal fin rays 9 (rarely 8 or 10). Pectoral fin rays 14–16 (13–17). Pelvic fin rays 8. Gill rakers 10–12, length of longest rakers 1–1.5 times their

Plate 38a. *Cyprinella whipplii,* steelcolor shiner, 90 mm SL, Clinch R., TN.

Plate 38b. *Cyprinella whipplii,* steelcolor shiner, breeding male, 94 mm SL, Clinch R., TN (photo N. M. Burkhead).

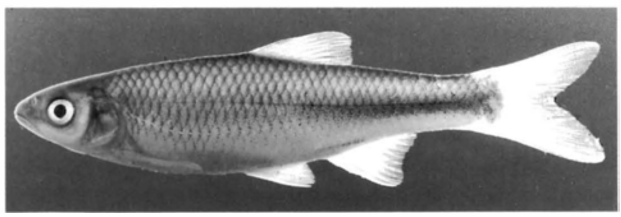
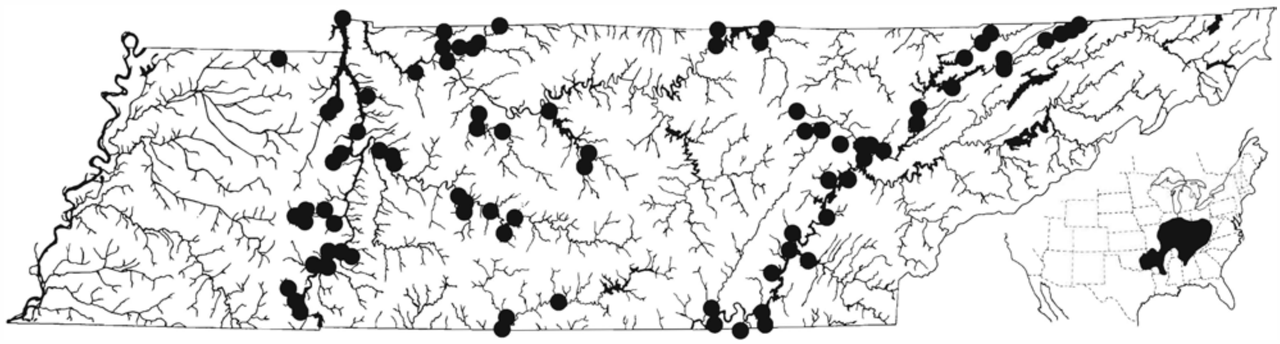


Plate 38c. *Cyprinella whipplii,* steelcolor shiner, preserved specimen showing pigmentation patterns, 52 mm SL, Sulphur Fk. R., TN.

basal width. Pharyngeal teeth 1,4-4,1. Breast scaled. Life colors silvery on sides to bluish gray on back, and lacking distinctive markings or other color. Breeding males have steel-blue sides, yellow pectoral, pelvic, and anal fins, conspicuous red snouts, and greatly enlarged dorsal fins, the depressed tips of which often extend past depressed tips of the anal fin rays. Nuptial tubercles are identical with those described for *C. venusta*, except that nape tubercles are abruptly much



Range Map 38. *Cyprinella whipplii,* steelcolor shiner

smaller than those on posterior head, tubercles on body scales are scattered rather than concentrated on margins, belly scales have small tubercles, scales above lateral line and behind dorsal fin lack or virtually lack tubercles, and on distal portions of posterior pectoral fin rays there are only 1–2 tubercles per fin ray segment. A few tubercles may appear on lower lobe of caudal fin.

Biology: The widespread and robust steelcolor shiner is associated with medium to large rivers where it occurs in flowing pool habitats over firm substrates. Unlike the very similar and usually sympatric *C. spiloptera*, *whipplii* rarely enters smaller streams, and appears to be more tolerant of streams below the Fall Line. According to Pflieger (1965) the early-June to mid-August spawning period broadly overlaps that of *spiloptera*, but peak spawning activity tends to be later than in that species. Spawning behavior is essentially identical to that of *spiloptera*, with adults congregating around submerged logs in areas of some current, and depositing eggs under loose bark or in crevices. Although often seen spawning with aggregations of *spiloptera*, hybrids are rare, and both visual and auditory cues were suggested as being responsible for preventing hybridization. We noted large numbers of apparent hybrids between *whipplii* and *C. galactura* in the Clinch River a few years after a chemical spill had drastically reduced fish populations, but more recent collections from this area have contained few obvious hybrids. *Cyprinella spiloptera* also occurs in this area, but hybrids were not noted between it and these other two *Cyprinella*. It seems likely that the *whipplii* x *galactura* hybrids resulted from a breakdown of reproductive barriers associated with unusually low population densities of one of the two species in combination with weaker isolating mechanisms between these infrequently sympatric species (*Cyprinella galactura* typically inhabits smaller and clearer streams). Pflieger (1965) indicated that most spawners were in their third summer, with a few spawning a year earlier. Gibbs (1963) pointed out that biological observations reported by Lewis and Gunning (1959) for *whipplii* were actually based on specimens of *C. lutrensis*. Diet has not been studied, but probably consists of both terrestrial and aquatic insects. Maximum total length 140 mm (5.5 in).

Distribution and Status: Mostly above the Fall Line in the Mississippi River drainage from Illinois River system, Illinois, southward, and also occurs in the Black Warrior portion of the Mobile drainage. In Tennessee it occurs mostly in rivers of the Highland Rim and Ridge and Valley. Gibbs (1963) examined very few specimens of the genus *Cyprinella* from west Tennessee tributaries to the Mississippi River, and mistakenly identified these as *whipplii.* We have examined several thousand specimens from these systems that are clearly *C. camura* with the exception of two tuberculate males (in the UT collection) from North Fork Obion River that are definitely *whipplii,* but, unlike *whipplii* from Tennessee and Cumberland river drainages, have somewhat larger tubercles on the anterior portion of the nape and lack tubercles on belly scales. *Cyprinella camura* has invaded several western tributaries to the lower Tennessee River just north of Pickwick Reservoir, and both *whipplii* and *camura* occur in these streams. Surprisingly, *whipplii* rather than *camura* occupies eastern Arkansas and Missouri, with *camura* reappearing to the west. We concur with Gibbs's (1963) identification of specimens from eastern tributaries to the Mississippi River in Mississippi as *camura*.

Similar Sympatric Species: See comments under *C. spiloptera* for characters used in separating these very similar species. Occasionally sympatric with *C. camura* in west Tennessee. Although *camura* is somewhat deeper bodied, has a more blunt snout, and a more diffuse lateral stripe on the caudal peduncle, we are unable to differentiate between these two species with certainty unless adults with tubercles or tubercle scars are available. In *camura* there is no hiatus between tubercles on tip of snout and those extending from the nares posteriad, caudal peduncle scales above lateral line are nearly as tuberculate as those below lateral line, the dorsal fin is less enlarged, the snout is more blunt, and dorsal and caudal fins are red in *camura*. Gill raker counts in the 20 or so specimens examined of each species appear to be higher in *whipplii* (10–12) than in either *camura* (8–10) or *spiloptera* (7–10).

Systematics: Gibbs (1963) and Mayden (1989) hypothesized closest relatives to be *analostana* and *chloristia* of Atlantic Slope drainages plus *camura*.

Etymology: *whipplii* is a patronym for Captain A. W. Whipple, who collected the type specimens.

Genus *Cyprinus* Linnaeus

Cyprinus carpio Linnaeus

Common carp

Characters: Lateral-line scales 32–41. Genetic mutants are frequently encountered that have only a few very large scales ("mirror carp") or lack scales entirely ("leather carp"). Both dorsal and anal fins preceded by a serrated spine and several anterior rudiments. Dorsal fin rays 15–23. Anal fin rays 4–6. Pectoral fin rays 14–17. Pelvic fin rays 8–9. Gill rakers 21–27. Pharyngeal teeth 1,1,3-3,1,1 and molariform. Vertebrae 35–36. Barbels present posteriorly on upper jaw (Fig. 64a). Breast scaled. Color brassy to yellowish, with lower fins often yellow-orange. Ornamental varieties have been bred which, like goldfish, may be bright orange, red, black, and white.

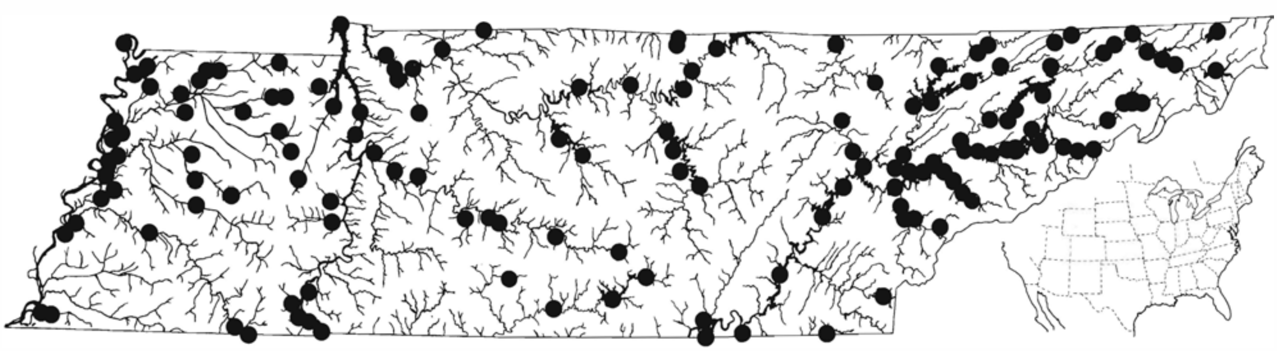
Biology: The carp is a native of Eurasia that was introduced into North America in the 1800s with alarming success. Colorful ornamental varieties, called "koi carp," have been bred over many hundred years in the Orient, and some are so highly valued by fanciers that they sell for many thousands of dollars. Unlike goldfish, colorful varieties are rarely if ever seen in the wild. Carp are present throughout Tennessee in large streams, rivers, and reservoirs. Large numbers are sold annually by commercial fishermen, but they are generally considered to be detrimental to populations of more desirable native species in the state. Carp exert their detrimental effects on waterfowl and native fish populations primarily by increasing water turbidity through their feeding activities. The added turbidity decreases light penetration and hence primary productivity by algae and vascular aquatic vegetation—in many cases eliminating rooted aquatic plants from small lakes. Silt, which causes the turbidity, may settle on fish eggs and deprive them of sufficient oxygen for normal development. Since our local reservoirs typically lack rooted aquatic vegetation, and excess silt in rivers is rapidly flushed off riffle areas that are preferred spawning sites

Plate 39a. *Cyprinus carpio*, common carp, 272 mm SL, Mississippi R., TN.

Plate 39b. *Cyprinus carpio*, common carp, "mirror carp variety," 310 mm SL, Ft. Loudon Res., TN.

for native species, the problem in Tennessee has not been as serious as it is in the natural lakes of the Midwest. Carp are quite edible, but rather bony. Baking and smoking are favorite methods of preparing them for the table, with large proportions of the commercial catch destined to become the primary ingredient of gefiltefish. The general feeling is that removal of the highly vascular, reddish streak of muscle underlying the lateral line and soaking filets in cold salt water for several hours eliminate much of the "muddy" flavor that is so objectionable to the consumer.

Carp are omnivores, eating aquatic vascular plants, algae, invertebrates, and occasional small fish. They are known to have sophisticated senses of taste (Stein et al., 1975). Their pharyngeal teeth are adapted for crushing, and the larger teeth resemble human molars. They will occasionally take slow-moving artificial lures, but are more commonly sought with worms, doughballs, whole-kernel corn, or other natural bait. Although they are very strong swimmers, they lack the speed and agility of our more popular sport fishes. Carp spawn in spring, with spawning activity often more vigorous immediately following heavy rains, after which carp move into flooded fields where eggs are deposited on submerged vegetation. Their commotion is often heard along the shallow shores of reservoirs at spawning time. A single female is typically accompanied by two to four males. Large carp may produce over 2 million eggs per season, and 600,000 or more may be extruded in a single spawning (Mansueti and Hardy, 1967). Eggs develop quickly and hatch in about 4 or 5 days. According to Scott and Crossman (1973) and Jester (1974), carp reach total lengths of 100–125 mm (4–5 in) during their first growing season, mature during their third or fourth year, and live to be about 20 years old. Schoffman (1957) reported average total lengths of Reelfoot Lake carp at about 38 cm at age 4, 45 cm at age 6, 55 at 8, 65 at 10, and 70 at 12. A carp weighing over 36 kg (80 lb) was netted in Parley Lake near St. Bonifacius, Hennepin County, Minnesota, in 1955. The Tennessee angling record is 19.3 kg (42.5 lb), from Boone Reservoir, 1956, caught by Al Moore. Tennessee specimens rarely exceed 12 kg. The world angling record of 55 lb, 5 oz, from Clearwater Lake, Minnesota, could easily be broken. Additional information on carp is compended in Cooper (1987).



Range Map 39. *Cyprinus carpio*, common carp (North American range extends from Mexico north to southern Canada).

Distribution and Status: Native to Eurasia but widely established throughout North America north to southern Canada, and present in larger waters throughout Tennessee. Most abundant in reservoirs and sluggish rivers.

Similar Sympatric Species: See comments under *Carassius auratus*. Buffalo-fishes (*Ictiobus*) and carpsuckers (*Carpiodes*) also resemble carp, but they are members of the sucker family; all suckers lack barbels and serrate dorsal and anal spines.

Etymology: *Cyprinus* = old world name for the carp; *carpio* = the carp, Latinized.

Genus *Ericymba* Cope

The monotyic genus *Ericymba* is unique in the extreme development of the lateralis system on the head. Externally visible large chambers occupy the bones (preoperculum and dentary) underlying the infraorbital and preoperculomandibular canals. Close phylogenetic relationships with other cyprinids are unclear. Mayden (1989) included *Ericymba* in a broad grouping including *Hybopsis amblops* and allies plus some species currently referred to *Notropis* (e.g., *dorsalis*, *longirostris*, etc.), and it has been included in *Notropis* by Robins et al. (1991). Such a "wastebasket" reallocation of an established genus name in the absence of demonstrated close relationships seems premature.

Ericymba buccata Cope

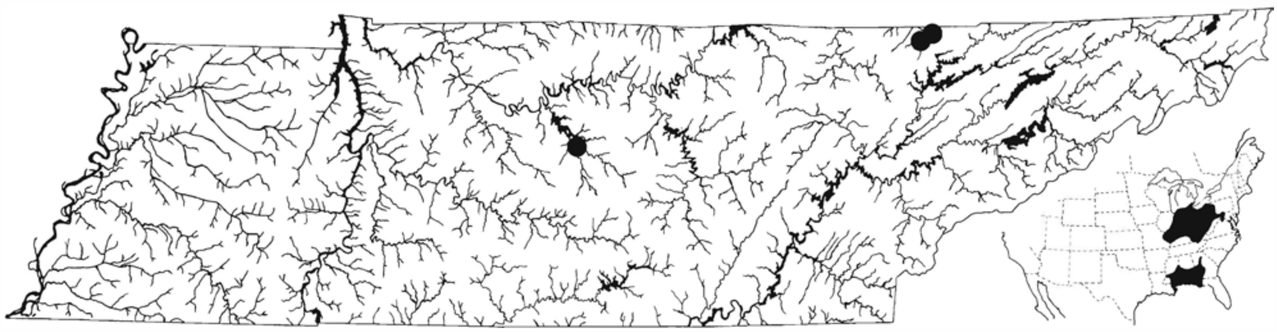
Silverjaw minnow

Plate 40. *Ericymba buccata*, silverjaw minnow, 56 mm SL, upper Cumberland R. system, KY.

Characters: Lateral-line scales 31–36, predorsal scale rows 12–13. Anal fin rays 8 (7–9). Pectoral fin rays 14–16. Pelvic fin rays 8. Gill rakers 3–5, length of longest rakers 1.5 times their basal width. Pharyngeal teeth reported to be 1,4-4,1, 1,4-4,0, or 4-4 in various references but of 28 specimens examined by us from Ala., Ga., Ill, Ky., and La., the single deviation from the 1,4-4,1 pattern was 2,4-4,2. Breast and anterior belly usually naked. Color silvery overall. Nuptial males with a shagreen of small tubercles on dorsal surfaces of pectoral fin rays 2–5, with rays 6–7 occasionally bearing similar tubercles distally. Small tubercles present on top of head and on dorsal scales in highest males.

Biology: The silverjaw minnow prefers sandy substrates with moderate current and occurs in small creeks as well as large rivers. The following biological information is abstracted from Hoyt (1971) and D. Wallace (1971, 1972, 1973a, 1976). Food of young is primarily entomostracans (cladocerans, copepods, and ostracods). Adults continue to consume these (mostly in daytime) in addition to increasing numbers of midge larvae (chironomids) which are taken at night. Fish feed in schools, the members of which respond positively to the increased activity of other members of the school that have apparently located a food concentration. The moderately developed eyes are apparently used little in food detection, with this a function of tactile and taste receptors. Life span is 3–4 years, with sexual maturity reached in the second or late in the first summer of life. Two spawning peaks may occur with older fish participating in the mid-spring spawning and the preceding year's young contributing to the July spawning. Spawning behavior has not been reported. Maximum total length 97 mm (3.8 in) reported by Trautman (1981).

Distribution and Status: Disjunct northern and southern ranges, with northern range from tributaries to Chesapeake Bay and southern Great Lakes; Ohio River drainage; and north of mouth of Ohio River in Mississippi River tributaries in Illinois and the southern half of Missouri. Southern range extends from Apalachicola River drainage west through the Pearl River drainage and in Bayou Pierre in Mississippi. The almost complete lack of records of this species from the Tennessee and Cumberland river drainages, despite its abundance both to the north and south, is perplexing. Wallace (1973b) suggested that it never became established in these systems. Perhaps the rarity of suitable sand substrates throughout these drainages is responsible for the virtual absence of this species and the sand-inhabiting darters of the genus *Ammocrypta*. The only record from the Tennessee River drainage, from Cypress Creek near Florence, Ala. (Gilbert, 1891), is not represented by any specimens, and is quite likely in error. Wallace (1973b) tentatively accepted the single record from the



Range Map 40. *Ericymba buccata*, silverjaw minnow.

Cumberland River drainage below Cumberland Falls, taken from the Stones River below the dam at Walter Hill, Rutherford Co., and deposited at Cornell University (CU 41462). This locality has been collected many times, and the source of the single specimen is questionable. It may represent a vestige of a former population, but a bait bucket introduction is more likely. Gilbert's (1980) reference to a record from the upper Tennessee River system is not valid, being based on an A. R. Cahn specimen deposited at the University of Michigan, from "Hickory Creek, tributary to Norris Reservoir, ten miles north of Lafollette." There is a Hickory Creek ten miles north of Lafollette. It is not tributary to Norris Reservoir (Clinch River system) but is part of the upper Cumberland drainage, the only area in Tennessee where *Ericymba* occurs. Its absence from tributaries to the Mississippi River in west Tennessee, where apparently suitable sand habitats abound, is more perplexing, since the Mississippi River seems to offer an adequate dispersal route from either the north or south. With the exception of the Hatchie River, occupied by *Ammocrypta beanii* and *A. vivax,* sand darters are also absent from eastern tributaries to the Mississippi River in Tennessee. *Ammocrypta clara* and *A. vivax* do occur in western tributaries to the Mississippi River in Mo., Ark., and La. The cyprinids *Notropis chalybaeus*, *N. hubbsi*, and *N. texanus*, also unknown as native to Tennessee, occur in western tributaries to the Mississippi River in this region. The last species is also an inhabitant of streams with sandy substrates, while the other two occur in swamps and heavily vegetated streams. The more westerly pre-Pleistocene channel of the Mississippi River is likely responsible for many of these unusual distributional patterns (Starnes and Etnier, 1986).

The silverjaw minnow is on the verge of extirpation from the upper Cumberland drainage in Tennessee (two recent records, Straight Creek, Campbell County, 1974, and Clear Fork at mouth of Valley Creek, Claiborne County, 1991). Streams in this area are heavily impacted by surface-mining activities. It certainly warrants its current threatened status in Tennessee (Starnes and Etnier, 1980).

Systematics: A thorough comparison of northern and southern populations has not been published. We have noted a tendency for the northern specimens to have more extensive breast and belly squamation and more and longer gill rakers.

Etymology: *Eri* = an intensifying prefix, *cymba* = cavity; *buccata* = cheek.

Genus *Erimystax* Jordan

Erimystax comprises a group of five species that had been included in the genus *Hybopsis*, but Mayden (1989) hypothesized *Erimystax* to be the sister group of *Phenacobius*. All species of *Erimystax* occur over firm substrates and moderate currents in small to medium upland rivers. Harris (1986) indicated that they spawn during a 3– to 4–week period in April and May, perhaps stimulated by rising water levels after heavy rains. Shared characters include 4–4 pharyngeal teeth, 7 anal fin rays, a hardened pad on the cheek region of nuptial males, similar nuptial tubercle pattern, and lack of bright breeding colors. Dimmick (1988) demonstrated the similarity in barbel ultrastructure in the four species he examined (*E. harryi* was not included). In addition to the species treated here, the genus contains *E. harryi* of the Ozark region and *E. x-punctata* of central United States.

Etymology: *Erimystax* = approximately "very large lip or mustache," perhaps in reference to the enlarged upper lip or barbels.

1. Lateral-line area typically marked with a horizontal row of dark blotches; predorsal and postdorsal streaks with alternating dark spots 2
   Lateral-line area lacking dark blotches; predorsal and postdorsal streaks of uniform intensity throughout; Clinch and Powell rivers above Norris Reservoir .... *E. cahni*
2. Lateral blotches about the size of the pupil and round or in the form of horizontally elongate ovals (occasionally absent) (Pl. 42); lateral-line scales usually more than 45 .... *E. dissimilis* p.166
   Lateral blotches distinctly larger than pupil and in the form of vertically elongate rectangles (Pl. 43); lateral-line scales usually 43 or fewer .... *E. insignis* p.167

Erimystax cahni (Hubbs and Crowe)

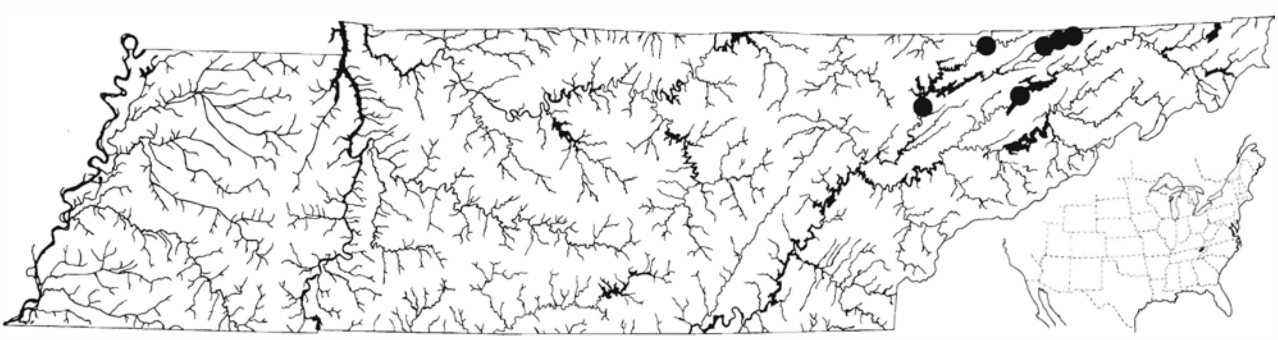
Slender chub

Plate 41. *Erimystax cahni*, slender chub, 81 mm SL, Clinch R., TN (photo N.M. Burkhead & R.E. Jenkins).

Characters: Lateral-line scales 39–45 (39–49), predorsal scale rows 18–21. Anal fin rays 7 (6–7). Pectoral fin rays 14–16. Pelvic fin rays 8 (7–9). Gill rakers 5–6, about half as long as their basal width. Pharyngeal teeth 4-4. Breast and anterior belly naked. Vertebrae 39–40. Caudal fin with a black spot basad, with dark pigment extending to edge of fin along middle fin rays, adjacent rays weakly pigmented, and dorsal and ventral rays again darkly pigmented. Lateral stripe prominent posteriad, formed of broad, anterior-directed "V-shaped" marks that have their points on the lateral line and are separated from each other by narrow pale areas representing the myosepta. Nuptial males develop small tubercles on dorsolateral portions of head and body, larger, uniserial tubercles on pectoral fin rays 2–10, and small tubercles on pelvic fin rays 2–6, anal fin rays 2–4, and dorsal fin rays 2–4, 5, or 6 (Harris, 1986).

Biology: The slender chub occurs over small gravel substrates with swift to moderate currents and depths ranging from 25 cm to at least 1 m. While abundant at times in such areas (early fall), it is absent at other times, perhaps indicating seasonal or occasional movement to deeper waters. The following biological information is gleaned from Jenkins (1975). Spawning is apparently from late April through May. Food of 14 specimens consisted primarily of small snails, and immature midges, caddisflies, and mayflies. Life span is probably 4 years, with sexual maturity reached during the second year. Maximum total length 94 mm (3.7 in).

Distribution and Status: Confined to major headwater tributaries to the Tennessee River in the Ridge and Valley. Until recently believed to be endemic to the Clinch and Powell rivers in Tennessee. Etnier et al. (1979) discovered a single specimen from an unsorted 1941 preimpoundment collection from the Holston River. This area is now covered by Cherokee Reservoir. Through 1964 this rare species was known from only 15 specimens (Davis and Reno, 1966), but it was known to be fairly common in portions of the Clinch River between Kyles Ford and Sneedville in Hancock County, and somewhat less common in the Powell River from the Virginia border downstream to the headwaters of Norris Reservoir in the 1960s and 1970s (Burkhead and Jenkins, 1982a). Though not extensive, recent collect-



Range Map 41. *Erimystax cahni*, slender chub.

ing attempts have failed to yield this species from those habitats, and its status may be deteriorating. The slender chub is considered as Threatened on a national level and in Tennessee (Starnes and Etnier, 1980). A federal recovery plan (USFWS, 1983a) has been devised in an attempt to insure its survival. It is an obligate inhabitant of large rivers, and extensive fine gravel shoal areas may be necessary to sustain a population. It has been extirpated from the Holston River system by impoundment and industrial pollution, and recently jeopardized in the Powell River (the type locality) by wildcat gravel removal operations just above the U.S. 25E bridge and sediments from coal surface-mining upstream. Protection of both Clinch and Powell rivers from additional gravel removal, coal-washing operations, and other abuses of water quality will be necessary for the continued success of this, one of the most geographically restricted of eastern North American minnows.

Similar Sympatric Species: Might be confused with *Phenacobius uranops*, which lacks a barbel; *Hybopsis amblops*, which has 36 or fewer lateral-line scales and sharply pointed dorsal and anal fins; or poorly marked specimens of *E. dissimilis*, which have an interrupted predorsal dark streak in contrast to the uniformly pigmented streak in *cahni*, and 14–17 rows of caudal peduncle scales (11–13 in *cahni*). In all these species caudal fin pigmentation is less evident and the snout is shorter than in *cahni*.

Systematics: Systematics discussed by Hubbs and Crowe (1956) and Harris (1986).

Etymology: Named in honor of A. R. Cahn, a former TVA biologist involved with many TVA preimpoundment fish surveys and responsible for collecting the first specimens of this species.

Erimystax dissimilis (Kirtland)

Streamline chub

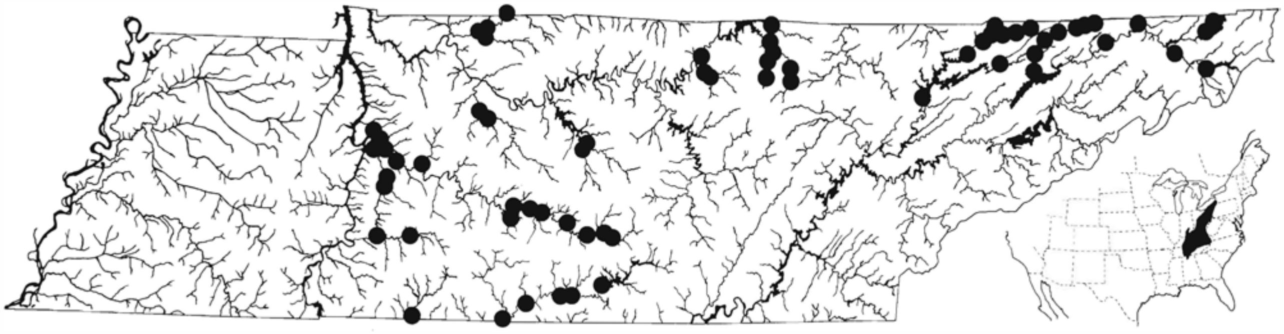
Characters: Lateral-line scales 43–49 (38–53), predorsal scale rows 20–24 (19–25). Anal fin rays 7 (6–7). Pectoral fin rays 16–18. Pelvic fin rays 8. Gill rakers 5–10, short, best developed dorsad. Pharyngeal teeth 4-4. Breast mostly naked. Vertebrae 40–41. Life color silvery with dark lateral blotches usually evident. Males with nuptial tubercles conspicuous and uniserial on dorsal surfaces of pectoral fin rays 2–10. What appear to be tiny tubercles may develop on posterior portions of pelvic, anal, and dorsal fin rays. The tiny, granular tubercles on the dorsal and lateral surfaces of the head are difficult to differentiate from the abundant taste buds in these areas. Small tubercles also occur on the exposed edges of most body scales.

Plate 42. *Erimystax dissimilis*, streamline chub, 78 mm SL, Clinch R., TN.

Biology: The streamline chub occurs in large creeks and rivers, typically in moderate to swift current over fine gravel substrates. Harris (1986) presented biological information. Spawning season extends from mid April through May, apparently triggered by high stream discharge when water temperature approaches 15 C (60 F). Both males and females mature at age 1, and life span is slightly more than 2 years. Females produce up to 1,200 eggs per year. Food is dominated by periphyton and a wide variety of aquatic insect larvae, especially midges, mayflies, and caddisflies. Maximum total length 140 mm (4.5 in).

Distribution and Status: This handsome minnow is widespread in the Tennessee and Cumberland drainages, and in the Ohio River drainage from southern New York and western Pennsylvania downstream, but it is known from relatively few localities. Although not currently being considered for endangered or threatened status, it is an obligate inhabitant of large, relatively pristine creeks and rivers. It has disappeared from much of its original range, and maintenance of at least present water quality in its remaining habitats will be necessary to prevent its reaching threatened status in the future.

Similar Sympatric Species: Very similar to and formerly confused with *E. insignis*, but differing from that species in its larger size, more slender body, and higher counts of predorsal scale rows (19–25 vs. 16–19), in addition to characters mentioned in the key. Specimens lacking or virtually lacking lateral blotches are not uncommon, and might be confused with *Hybopsis amblops* and *E. cahni*, both of which have a uniformly pigmented middorsal streak in contrast to the alternating dark and pale streak in *E. dissimilis*.



Range Map 42. *Erimystax dissimilis*, streamline chub.

Systematics: Systematics discussed by Hubbs and Crowe (1956) and Harris (1986). The isolated population in the Missouri and Arkansas Ozarks formerly considered a subspecies, *E. d. harryi* (Hubbs and Crowe), was shown to be a valid species by Harris (1986).

Etymology: *dissimilis* = dissimilar.

Erimystax insignis (Hubbs and Crowe)

Blotched chub

Plate 43. *Erimystax insignis*, blotched chub, 59 mm SL, Sulphur Fork R., TN.

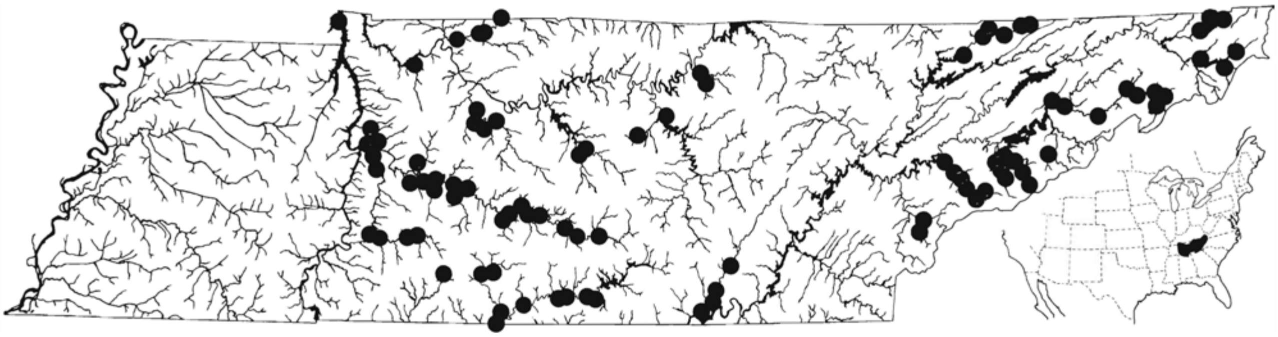
Characters: Lateral-line scales 38–45 (36–47), predorsal scale rows 16–19. Anal fin rays 7 (6–7). Pectoral fin rays 15–17. Pelvic fin rays 8. Pharyngeal teeth 4-4. Gill rakers 5–7 (4–8), the longest rakers 1.5 times their basal width. Breast with embedded scales or occasionally naked. Vertebrae 38–39 (37–40). Color silvery gray with conspicuous lateral blotches. Males with nuptial tubercles similar to those described for *E. dissimilis*, but differing in having three poorly defined rows of tubercles on the first pectoral fin ray, and small tubercles on the ventral surface of the gular area, branchiostegal rays, and belly.

Biology: The blotched chub occurs in riffle areas in moderate-sized creeks to small rivers, and differs in habitat from the streamline chub in preferring slightly coarser substrates and tolerating much smaller streams. Harris (1986) provided biological information. Spawning occurs from mid April through early May as water temperature approaches 15 C (60 F), but is apparently not dependent upon high stream discharge as in *E. dissimilis*. On the occasion when probable spawning was observed, about 50 adults had gathered in a flowing pool devoid of vegetation and with gravel, rock, and cobble substrate at the head of an inundated bed of water willow. Water depth was 50–80 cm. A male would approach a female lying on the substrate and settle on top of her. If she responded appropriately, the pair would assume a side-by-side position and engage in rapid vibrations that lasted 2–3 seconds. Most males and females are sexually mature at age 1 at an average size of 57 mm SL; at age 2 mean SL was 73 mm. Life span is 2.5 years. Food consists of about half periphyton and half aquatic insect larvae dominated by dipterans (midges and blackflies) and mayflies (Baetidae and *Potamanthus*). Maximum total length 100 mm (4 in).

Distribution and Status: Endemic to and occurring throughout most of the Cumberland and Tennessee river drainages, where it is moderately common. Upper Tennessee River subspecies (see Systematics) occurs mostly in Blue Ridge and upper Ridge and Valley habitats; lower Tennessee and Cumberland subspecies mostly in Highland Rim and Nashville Basin habitats, and uncommon on Cumberland Plateau.

Similar Sympatric Species: See comments under *E. dissimilis*.

Systematics: Hubbs and Crowe (1956) recognized two subspecies: *E. i. insignis*, with a linear upper lip and smaller mouth, in the Cumberland and lower Tennessee river drainages; and *E. i. eristigma*, with a median swelling on the upper lip and a relatively larger mouth, in the upper Tennessee drainage south to the Georgia portion of the Hiwassee River system. Clinch and



Range Map 43. *Erimystax insignis*, blotched chub.

Powell river populations were considered intergrades. Harris (1986) supported recognition of these two subspecies, and considered upper Holston River populations, along with those from the Clinch and Powell rivers, as intergrades.

Etymology: *insignis* = remarkable, referring to the distinct pigment pattern; *eri* = intensifying prefix, *stigma* = spot.

Plate 44a. *Hemitremia flammea*, flame chub, 43 mm SL, Caney Fork R. system, TN.

Plate 44b. *Hemitremia flammea*, flame chub, breeding male, 43 mm SL, Cypress Cr. system, TN.

Genus *Hemitremia* Cope

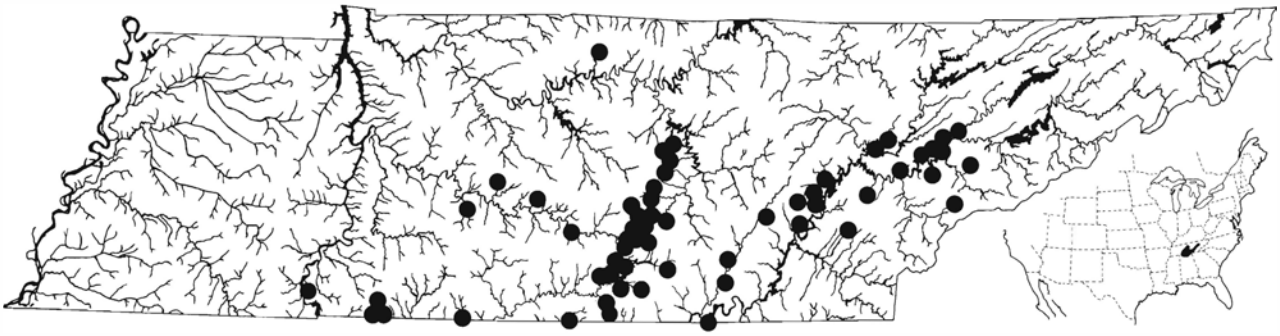
The genus *Hemitremia* contains a single species restricted to southeastern United States. The red breeding colors, breast tuberculation, and pharyngeal tooth pattern suggest possible phylogenetic affinity with North American genera such as *Semotilus* or *Clinostomus*. Coburn and Cavender (1989) hypothesized relationships of this genus with a group containing *Semotilus*, *Couesius*, *Phoxinus*, and several other genera.

Hemitremia flammea (Jordan and Gilbert)

Flame chub

Characters: Lateral line incomplete with about 8–15 pored scales and 36–41 scales in lateral series, predorsal scale rows 18–22. Anal fin rays 8. Pectoral fin rays 13–15. Pelvic fin rays 8. Gill rakers 6–8, length of longest rakers half their basal width. Pharyngeal teeth 2,5-4,2. Breast scaled. Males typically have some red coloration throughout the year, and during the breeding season have the entire venter and a blotch at the dorsal fin base bright red. Nuptial males have uniserial tubercles on pectoral rays 2–5 or 6. Small, granular projections on top and sides of head and on dorsolateral scales probably represent nuptial tubercles. Breast scales underlying the edge of the gill membranes are enlarged and have edges produced into numerous sharp points, and small, sharp tubercles develop on the branchiostegal rays and on the free edges of the operculum, preoperculum, and suboperculum. Large tubercles, about 1 tubercle per fin ray segment, develop on the distal half of the dorsal surface of pectoral fin rays 2–6, and some of these appear to have 2 cusps per tubercle base.

Biology: The flame chub is an inhabitant of springs and spring runs, usually occurring in areas of lush aquatic vegetation. Biological information is abstracted from Sossamon (1990) and our observations. Spawning occurs from late January through May, and peaks in March. Mature females were 47 mm TL or larger and in their second or third years of life. Females contained an average of about 800 total eggs, but eggs were of two distinct size classes, and this number may over-



Range Map 44. *Hemitremia flammea*, flame chub.

estimate annual fecundity. Tuberculate males were available from October through May. Reproductive behavior and egg-deposition site are not known. We observed what appeared to be a spawning aggregation in a shallow seepage area of a pasture in late February, where they were associated with *Etheostoma (Ozarka) boschungi*. In Sossamon's year-long study, the diet was primarily midge larvae supplemented with isopods, oligochaetes, hemipterans, and snails. Twenty adults we examined contained mostly adults of terrestrial and aquatic insects plus filamentous algae. Scale and length-frequency analysis indicated that mean total lengths of about 40 mm and 50 mm were reached at the end of the first and second year, respectively, and few individuals lived past age 2. Females reach larger size than males. Maximum total length 78 mm (3.2 in).

Distribution and Status: Occurs in Tennessee River drainage from the Knoxville area downstream through the Mud Creek system south of Savannah, Hardin County, Tennessee. Also occurs in upper Duck River and in the middle Cumberland drainage, primarily in the upper Caney Fork system. One record (Kelley Creek, Talladega County, Alabama) is available from the upper Coosa River system of the Mobile Basin. The flame chub occurs sporadically in spring habitats in the Ridge and Valley but is more continuously distributed in springs of the southern Highland Rim, particularly the Barrens Plateau region. It is considered In Need of Management in Tennessee (Starnes and Etnier, 1980). Because of its fragile habitat, this species has certainly decreased in abundance and range within the past 50 years and has nearly disappeared from east Tennessee. Continued alteration of spring habitats is expected and will result in continued extirpation of populations.

Similar Sympatric Species: This is our only middle- and east-Tennessee cyprinid with an incomplete lateral line and fewer than 45 scales in lateral series. In addition, it has a shorter snout than other Tennessee cyprinids. Young of *Semotilus* and *Phoxinus erythrogaster* have much smaller scales, longer snouts, and lack the distinct caudal spot of the flame chub.

Etymology: *Hemi* = half, *tremia* = aperture, in reference to the incomplete lateral line; *flammea* = flaming, in reference to the bright red breeding colors.

Genus *Hybognathus* Agassiz

The Silvery Minnows

Members of *Hybognathus* are silvery fishes that are widespread in eastern and central North America. All of the species are very similar to *Notropis*, differing primarily in the coiled structure of the intestine (Fig. 81) and the jet black peritoneum. Phylogenetic affinities with other cyprinid genera are unclear. Similarities in gut coiling and jaw structure with species of the southwestern genus *Dionda* led earlier workers to consider these genera synonymous or closely related. Later, Hubbs and Brown (1957) and Swift (1970) suggested that these genera were not closely related, but recently (Cavender and Coburn, 1988; Schmidt, 1988) a close relationship with both *Dionda* and *Campostoma* has been hypothesized based on similarities in feeding mechanisms and osteology; Mayden (1989) did not hy-

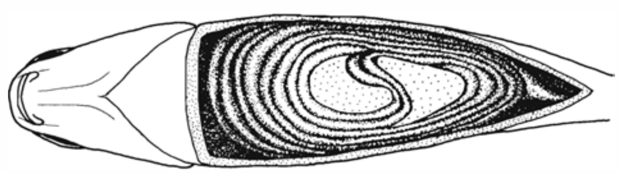


Figure 81. Whorled intestinal pattern of *Hybognathus*.

pothesize a sister group relationship between those genera and *Hybognathus*. It is noted that the type species of *Dionda*, *D. episcopa* Girard, differs trenchantly from *Hybognathus* in breeding tubercle patterns, having large and rather linear head tubercles, and uniserial tubercles on pectoral rays two through about ten of nuptial males. A number of Mexican cyprinids of uncertain affinities have been provisionally referred to *Dionda* (Hubbs and Miller, 1974, 1977), and their nuptial tubercle patterns are sufficiently different from that of *D. episcopa* to maintain their generic placement as provisional. Swift (1970) appears to be correct in removing the Ozarkian *Dionda nubila* (Forbes), to the subgenus *Hydrophlox* of *Notropis*.

Hybognathus is currently treated as containing six or seven species (Schmidt, 1988). In addition to the three Tennessee species, *H. hankinsoni* Hubbs is a midwestern species of bog lakes and sluggish streams (the single Tennessee specimen [in the UT collection], Powell River, 1973, certainly represents a bait bucket introduction); *H. argyritis* Girard is a Missouri River species that occurs in the Mississippi River downstream to the mouth of the Ohio River and may eventually be found in Tennessee; and *H. regius* Girard and *H. amarus* (Girard) are, respectively, East Coast drainage and Rio Grande River species similar in appearance to *H. nuchalis*. All members of *Hybognathus* have 35–40 lateral-line scales, 8 rays in dorsal, anal, and pelvic fins, 14–16 pectoral fin rays, 4-4 pharyngeal teeth, 9–12 gill rakers with length of the longest 1.5–2.5 times their basal width, and well-scaled breasts. The dorsal fin is pointed and falcate (except in *hankinsoni*), with the tip of the anterior ray extending well past the tips of the posterior rays when the fin is depressed. The mouth structure (Fig. 75a) is unusual due to the enlargement of the anterior suborbital (lachrymal) bone, but there are several species of *Luxilus* and *Notropis* in which the resulting additional groove on the side of the snout is present. Except for *H. hankinsoni*, which has a bright brassy sheen, nuptial colors do not develop. The complex gut structure and black peritoneum are trophic adaptations, and all species feed on organic ooze containing diatoms, filamentous algae, decaying organic matter, and probably some small insects. The pharyngeal filtering apparatus of all species was recently analyzed in detail by Hlohowskyj et al. (1989). All species are used as bait minnows, and Schwartz (1963) reported the use of *H. regius* as a food fish along the East Coast.

Etymology: *Hybo* = swollen, *gnathus* = jaw.

KEY TO THE TENNESSEE SPECIES

Shape of the basioccipital process is an important taxonomic character in *Hybognathus*. It is best examined by cutting across the isthmus with a scissors and then bending the head dorsad until the vertebral column separates from the skull. The basioccipital process will appear as a bony process with attached muscles, extending posteriad from the ventral portion of the brain case and immediately dorsal to the esophagus (Fig. 82).

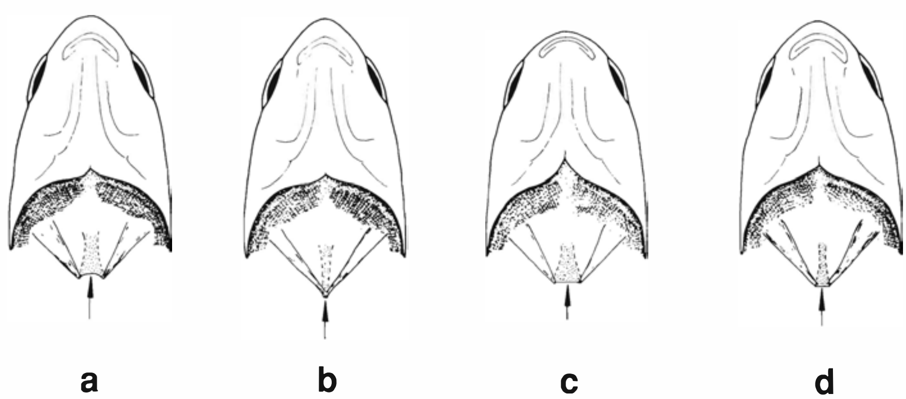


Figure 82. Shapes of basioccipital processes of *Hybognathus*: a) *H. nuchalis*; b) *H. placitus*; c) *H. hayi*; d) *H. argyritus*.

1. Mouth oblique and nearly terminal, snout barely extending in front of tip of upper lip, tip of upper lip at level of middle of eye; dorsolateral scale edgings diamond-shaped in appearance (Pl. 45) . . . *H. hayi*
Mouth subterminal and nearly horizontal, snout extending beyond tip of upper lip, tip of upper lip at level of lower margin of eye; dorsolateral scale edgings appear rounded 2
2. Basioccipital process with posterior edge broad and concave in ventral view (Fig. 82a); eye diameter contained 4.2 or fewer times in head length . . . . *H. nuchalis* p.172
Basioccipital process narrow in ventral view, almost pointed, with posterior edge straight (Fig. 82b); eye diameter contained 4.4. or more times in head length . . . . *H. placitus* p.173

Hybognathus hayi Jordan

Cypress minnow

Plate 45a. *Hybognathus hayi*, cypress minnow, 74 mm SL, Forked Deer R. system, TN.

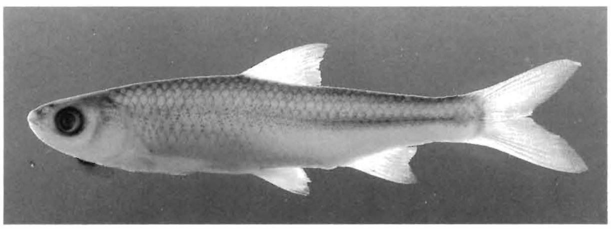


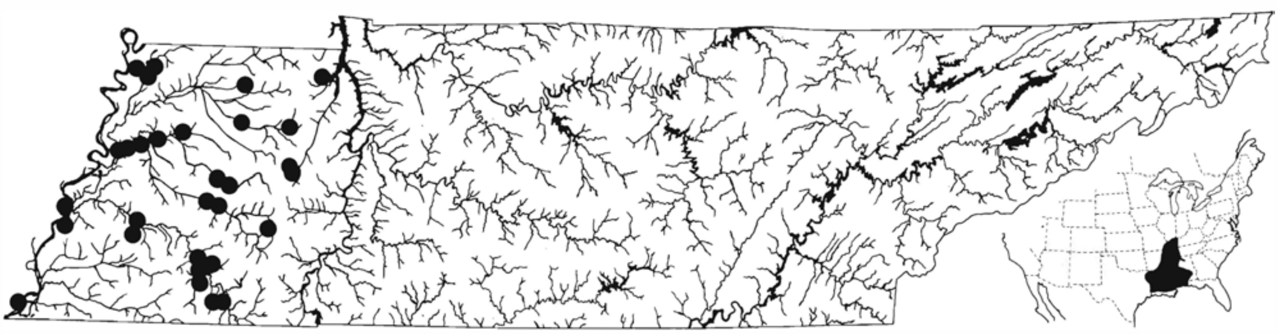
Plate 45b. *Hybognathus hayi*, cypress minnow, preserved specimen showing pigmentation patterns, 74 mm SL, Forked Deer R. system, TN.

Characters: Predorsal scale rows 14–16, other characters same as for genus (above). Basioccipital process (Fig. 82c) truncate. Coloration silvery with no distinctive markings other than the diamond-shaped dark edgings of dorsolateral scales. We have not examined tuberculate material.

Biology: The cypress minnow, as its name implies, is an inhabitant of the quiet waters of oxbows and swamps. Although the gut is shorter than in *H. nuchalis* (Fingerman and Suttkus, 1961), the gut contents reflect the same detritivore feeding pattern of other members of the genus. Nothing has been recorded concerning its biology, and our small collections do not facilitate biological inferences. Maximum total length 115 mm (4.5 in).

Distributión and Status: Occurs primarily below Fall Line in Mississippi River basin from southern Illinois and southwestern Indiana downstream, and east and west of the Mississippi River through the Escambia drainage of the Florida Panhandle west through the Sabine River drainage of Louisiana and Texas. Confined to swamps and sluggish streams including the lower Tennessee River drainage upstream through north central Alabama. Although generally not common in collections, its preferred habitats are not well sampled. Burr and Mayden (1982c) and Warren and Burr (1989) reported the near extirpation of the cypress minnow from Illinois in the past 40 years and range reductions in adjacent states, indicating it may succumb easily to habitat alterations linked to agricultural practices.

Similar Sympatric Species: The cypress minnow bears a striking resemblance in shape and the diamond-shaped dorsolateral scale pattern to species of the genus *Cyprinella*. *Cyprinella* typically occupy flowing waters of streams and rivers, but *C. camura*, *C. lutrensis*, *C.*



Range Map 45. *Hybognathus hayi*, cypress minnow.

whipplii, and *C. venusta* occur in close proximity to populations of *H. hayi*. All of these species have a silvery peritoneum, simple S-shaped intestines, rounded rather than pointed dorsal fin outlines, and typically 9 anal fin rays and 1,4-4,1 pharyngeal teeth. *Notropis shumardi*, apparently restricted to the Mississippi River proper in Tennessee, is very similar in appearance and has a pointed dorsal fin, but otherwise differs as above and has 2,4-4,2 pharyngeal teeth, 9 pelvic fin rays, and no pigment on scales below the lateral line. The often sympatric *Opsopoeodus emiliae* lacks a coiled gut and black peritoneum, has a nearly vertical mouth, 9 dorsal fin rays, and 5–5 pharyngeal teeth.

Etymology: *hayi* is a patronym for O. P. Hay, an early student of lower Mississippi River fishes and discoverer of the species.

Hybognathus nuchalis Agassiz

Mississippi silvery minnow

Plate 46a. *Hybognathus nuchalis*, Mississippi silvery minnow, 47 mm SL, Hatchie R., TN.

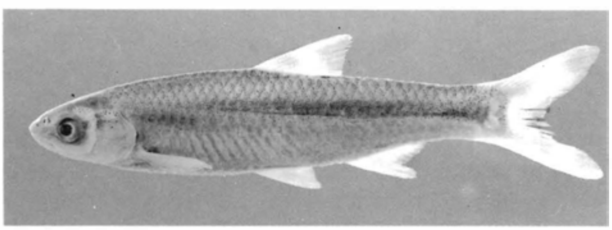
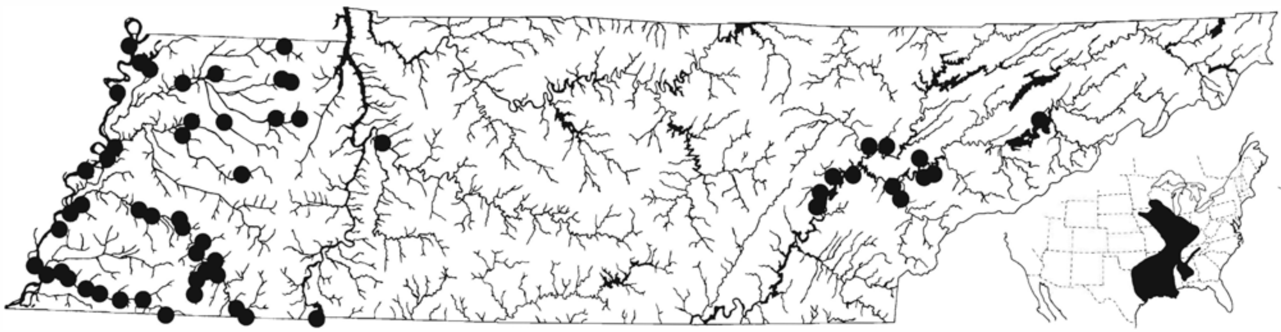


Plate 46b. *Hybognathus nuchalis*, Mississippi silvery minnow, preserved specimen showing pigmentation patterns, about 65 mm SL; Mississippi R. system, TN.

Characters: Predorsal scale rows 14–16. Basioccipital process concave (Fig. 82a). Vertebrae 38–41. Color silver with no distinctive markings. Nuptial males have small tubercles on the top of the head and smaller tubercles on the cheeks, opercles, and branchiostegal area. Specimens we examined lacked tubercles on the jaws and on the head anterior to the nares. On the dorsal surface of pectoral fin rays 1–10 or 11, tubercles are small and in a single row basad, increasing slightly in size and forming two rows near the branching of the ray; on the branched portion of rays 2–10 or 11 there is a single row with 2–3 tubercles per ray segment on the anterior branch and 2 rows with a total of 5–6 tubercles per ray segment on the posterior branch of the ray. Tubercles also occur on other fins but are smaller, less abundant, and apparently more transient. Small tubercles also occur on the scale margins and are best developed anteriodorsally. Tiny tubercles may develop on the head and on body scales of nuptial females. Other characters same as for genus.

Biology: The silvery minnow occurs in silty creeks and rivers, typically associated with gentle to moderate currents and sand or silty sand substrates. Spawning occurs in early to mid spring. Reproductive biology of the central form has not been reported but may be similar to that of the eastern form, *H. regius* Girard, reported by Raney (1939b). Males congregate in backwater areas, and two males typically accompany each female that enters to spawn. The non-adhesive eggs were scattered near the edge of the area over silt substrates interspersed with newly sprouted aquatic vegetation, but successful spawning can apparently occur in the absence of vegetation. Eggs hatched in one week, and the larger females produced 6,000–7,000 eggs per season. Some females probably reach sexual maturity at the end of their first year, but all reproductively active males were believed to be in their second year. Males were much more darkly pigmented than females. Becker (1983) reported growth averaging about 75 mm TL at age 1 and 100 mm at age 2 in Wisconsin with maturity reached at age 2 and a possible life span of 3 years. Its virtual disappearance from the Tennessee River drainage in the 40 or so years since impoundment (Etnier et al., 1979) would seem to indicate that large, free-flowing rivers are important in some phase of the silvery minnow's life history despite the fact that adults are often encountered in smaller streams. This situation exemplifies the fact that there is much yet to be learned about the basic biologies of many of our fishes. Maximum total length 152 mm (6 in) (Trautman, 1981).

Distribution and Status: Widespread in Mississippi River drainage from southeastern Minnesota south, and in Gulf Coast drainages from Mobile Basin west through Brazos River drainage of Texas. In Tennessee the silvery minnow occurs in the Coastal Plain in tributaries to the Mississippi River, where it is extremely common, and occasionally in the river proper. It has dramatically disappeared from the Tennessee drainage within the past 40 years, following impoundment; it was apparently abundant and formerly occurred up-



Range Map 46. *Hybognathus nuchalis*, Mississippi silvery minnow.

stream to slightly above Knoxville (Etnier et al., 1979). It persists in the extreme lower Cumberland River in Kentucky and a single large adult was taken in lower Duck River in 1986.

Similar Sympatric Species: Very similar to and often taken with *Notropis blennius*. Mouth shape offers the best character for field separation of these species, with *blennius* having a larger jaw, a more pointed snout, and lacking the additional oblique groove paralleling the upper jaw just anterior to the lachrymal bone. In addition, *blennius* has 2,4-4,2 teeth, only 7 anal rays, a simple S-shaped gut, and a silvery peritoneum. The somewhat similar and often sympatric *Pimephales vigilax* differs consistently in having a distinct caudal spot. The similar *H. argyritis* Girard, known from the Mississippi River just north of Tennessee, has a small eye like that of *H. placitus*, and the basioccipital process is flattened like that of *H. nuchalis*, but has a straight or only slightly concave posterior margin (Fig. 82d). Also, see comments under *H. placitus*.

Systematics: Pflieger (1971) considered Atlantic Coastal populations (*H. regius*), formerly synonymized with *nuchalis*, to warrant species status on the basis of differences in the shape of the basioccipital process. Schmidt (1988) hypothesized that *regius* is actually closest related to *H. hankinsoni* of the Midwest. These views are strengthened by differences in the biology of *nuchalis* and *regius*. While *H. nuchalis* has no tolerance for reservoirs, as noted above, the Atlantic Coast form, based on our records, appears to be very tolerant of reservoir habitats. Genetic studies of Cook et al. (1992) support the removal of Rio Grande populations, *H. amarus,* from the synonymy of *H. nuchalis* or *H. placitus*, where they had previously been placed.

Etymology: *nuchalis* refers to the nape.

Hybognathus placitus Girard

Plains minnow

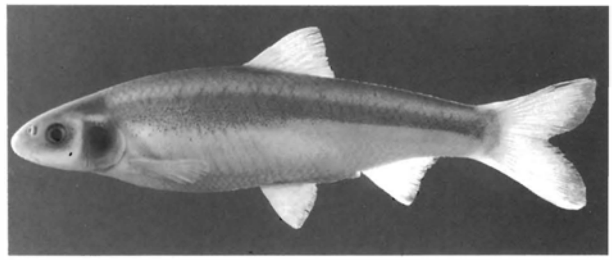
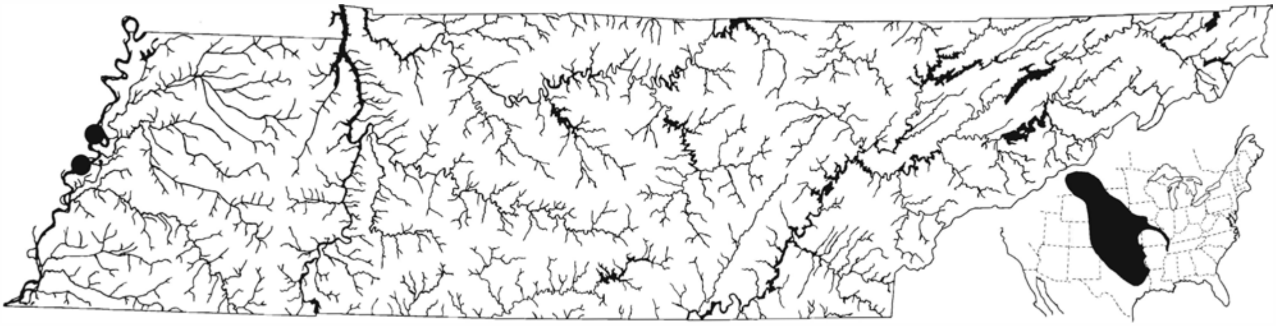


Plate 47. *Hybognathus placitus*, plains minnow, preserved specimen, 75 mm SL, Pecos R., NM.

Characters: Predorsal scale rows usually 18–22. Basioccipital process not expanded distally (Fig. 82b). Vertebrae 37–40. Color silver with no distinctive markings. In the few nuptial males we have examined, tubercle pattern was similar to that of the silvery minnow except that tubercles on the pectoral fin rays are curved toward the body (erect in *nuchalis*). Other characters same as for genus.

Biology: Despite its abundance, little is known concerning the biology of the plains minnow, but it is inferred to be similar to that of the silvery minnow. Pflieger (1971, 1975) noted that the plains minnow was more often encountered in river channels with moderate current over sandy substrates, while the silvery minnow seemed to prefer backwater areas with gentler currents and more silty substrates. Maximum length about 100 mm (4 in).

Distribution and Status: Occurs in western tributaries to the Mississippi River from the upper Missouri River south, and in the western Gulf of Mexico through the Colorado River drainage of Texas. Uncommon in Mississippi River main channel below mouth of Missouri



Range Map 47. *Hybognathus placitus*, plains minnow. Introduced populations in Rio Grande drainage not shown.

River. This Great Plains species has been placed on the Tennessee list of Species of Special Concern because of its limited distribution in our state, the extreme southeastern extent of its range. The only Tennessee records are from the Arkansas side of the Mississippi River across from Dyer and Lauderdale counties.

Similar Sympatric Species: Virtually identical to and long confused with *H. nuchalis*. The two species differ primarily in eye size and shape of the basioccipital process as noted in the key. In specimens we have examined, predorsal scale rows are usually 17 or more (16–23), whereas in *nuchalis* the count is 14–16. Bailey and Allum (1962) suggested an additional scale count as useful in separating these species. Scale rows across the belly, counted just anterior to the pelvic fin base up to but not including the lateral-line scale row, are usually 15–21 in *placitus* and 16 or fewer in *nuchalis*. *Hybognathus argyritis*, which should be looked for in the Tennessee portion of the Mississippi River, is similar to *placitus* in eye size but differs from both *placitus* and *nuchalis* in the shape of the basioccipital process (Fig. 82d).

Systematics: Variation in the plains minnow was treated by Al-Rawi and Cross (1964), who chose not to recognize any subspecific taxa.

Etymology: *placitus* = broad surface, possibly referring to the relatively broad head.

Genus *Hybopsis* Agassiz

For many years *Hybopsis* had served as the generic repository for most species of barbeled North American minnows. As new information concerning relationships of these species accumulated, it became increasingly evident that many "*Hybopsis*" were more closely related to species in other genera than to other *Hybopsis*, and at least one species (*Notropis amnis*) in a genus outside *Hybopsis* had its closest relatives in *Hybopsis*. In an effort to establish as many natural (monophyletic) genera as possible, *Hybopsis* of earlier workers has been split up, primarily by recognizing presumably monophyletic subgenera as genera. Genus *Nocomis*, formerly in *Hybopsis*, has been treated as a valid genus for several decades (Jenkins and Lachner, 1971). We follow current trends (e.g., Mayden, 1989; Robins et al., 1991) by recognizing as genera the following former subgenera of *Hybopsis*: *Erimystax* (*cahni*, *dissimilis*, *harryi*, *insignis*, *x-punctata*); *Macrhybopsis* (*aestivalis*, *gelida*, *meeki*, *storeriana*); *Oregonichthys* (*crameri*); and *Platygobio* (*gracilis*). In addition, species formerly placed in *Hybopsis* have been relocated (*harperi* to *Notropis*; *labrosa*, *monacha*, and *zanema* to *Cyprinella*), although some controversy remains concerning allocation of these species. All that remains of what was once a fairly large genus is the former, and presumably monophyletic, subgenus *Hybopsis* (*amblops*, *hypsinotus*, *lineapunctata*, *rubrifrons*, *winchelli*) to which we add *amnis* (formerly in *Notropis*, see Systematics under *amnis*) and retain as genus *Hybopsis*. This more restricted genus *Hybopsis* may have its closest relatives among species currently remaining in genus *Notropis*, and is included in *Notropis* by some workers (e.g., Robins et al., 1991). However, the phylogenetic position of species here referred to *Hybopsis* has not been established among species currently assigned to *Notropis*, particularly with regard to *Notropis* sensu strictu. It thus seems unwarranted at this time to subsume a formally recognized group into *Notropis* in the absence of demonstrable relationships, particularly when the monophyly of *Notropis* as currently constituted has not been demonstrated.

Hybopsis as used herein contains the five species mentioned above (*H. winchelli* may represent two species). All are similar in appearance, have 8 anal fin rays, 1,4-4,1 pharyngeal teeth, large scales with about 36 in the lateral line and 13–15 predorsal rows, and sharply pointed fins. Habitats are typically gently flowing pools with sandy substrates in creeks to small rivers.

Etymology: *Hybopsis* = rounded face.

KEY TO THE TENNESSEE SPECIES

1. Pale area above lateral stripe with abundant melanophores, especially on scale edges; widespread in middle and east Tennessee 2
   Pale area above lateral stripe virtually lacking melanophores (Pl. 50); confined to Conasauga River tributaries in Bradley and Polk counties . . . . *H. lineapunctata* p.177
2. A conspicuous barbel present at posterior tip of maxilla (Fig. 64b) . . . . *H. amblops*
   Barbel absent . . . . *H. amnis* p.176

Hybopsis amblops (Rafinesque)

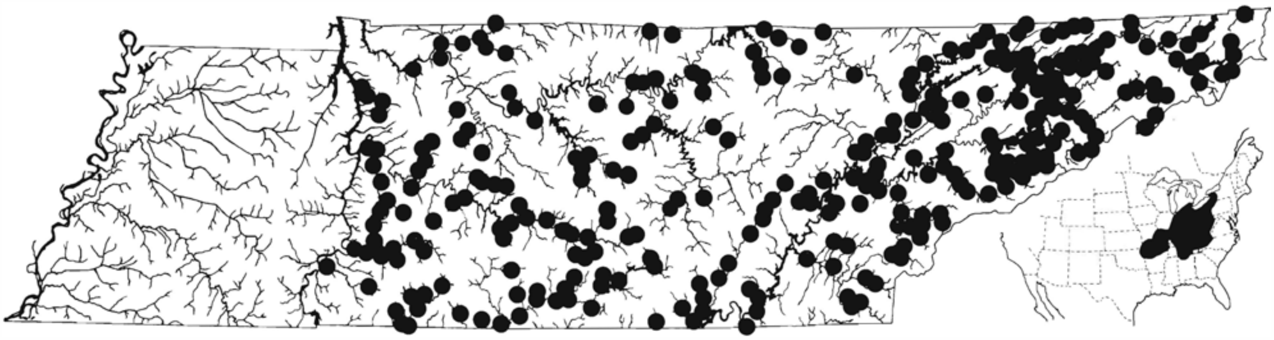
Bigeye chub

Plate 48. *Hybopsis amblops*, bigeye chub, 62 mm SL, Duck R. system, TN.

Characters: Lateral-line scales 34–36 in Tennessee specimens (34–38 elsewhere), predorsal scale rows 13–14 (12–15). Anal fin rays 8. Pectoral fin rays 13–14. Pelvic fin rays 8. Gill rakers reduced to 4–5 bulbous projections dorsad. Pharyngeal teeth 1,4-4,1. Vertebrae 36–38. Breast naked. Color silvery, the black lateral stripe becoming prominent only in preservative. Bright breeding colors do not develop. Nuptial males have small tubercles covering the top and posterior sides of the head, the anterior dorsolateral scales, and the dorsal surfaces of the outer 7–10 pectoral fin rays. On the pectoral fin rays these tubercles are in a single row basad and in two (first ray) or three rows distad. On the branched rays these tubercles continue as a single row on the outer branch and as a double row on the inner branch. Tiny tubercles may develop near tips of the anal, dorsal, and pelvic fin rays of males, and on the head and occipital scales of females.

Biology: The bigeye chub is a commonly encountered species in east and middle Tennessee, where it is most frequently collected over sandy or silty sand substrates in areas of little or moderate current in larger creeks and small to medium rivers. It is typically absent from large rivers and headwater areas of streams. Davis and Miller (1967) suggested that it was adapted for feeding in both clear and turbid environments on the basis of brain development. Reno (1969) indicated a probable specialization for clear waters based on the size of pores and completeness of canals of the lateralis system. Gut contents of 10 adult and subadult specimens from Tennessee revealed, in addition to the expected midge larvae, about equal numbers of surprisingly large mayfly and stonefly nymphs (*Stenonema*, *Ephemera*, *Isoperla*) and a single caddisfly larva (*Hydropsyche*). This suggests the possiblity that much of their feeding activity is associated with substrates coarser than those typical of their described habitat. Spawning occurs during late spring and early summer. Pflieger (1975) indicated that bigeye chubs reach about 50 mm TL after the first summer of life and attain about 65–80 mm the second summer. Our specimens indicate that sexual maturity occurs at about 55 mm. Maximum total length is about 100 mm (4 in).

Distribution and Status: Original range of *H. amblops* included southern Great Lakes Basin, and Mississippi Basin from Illinois River through entire Ohio, Cumberland, and Tennessee river drainages, but widely extirpated in Midwest. Also west of Mississippi River from Central Arkansas River northeast to Meramec River, tributary to the lower Missouri River. An intolerance of siltation was suggested by Trautman (1957, 1981) and Smith (1979) in explaining its recent near extirpation from Ohio and Illinois streams. Since it exhibits little tolerance for reservoirs, many Tennessee populations are essentially isolated at present. It continues to be



Range Map 48. *Hybopsis amblops*, bigeye chub.

common in the Tennessee, Cumberland, and Barren river systems in Tennessee in all physiographic provinces except the Coastal Plain (absent) and Cumberland Plateau.

Similar Sympatric Species: The overall appearance of the bigeye chub is very similar to that of many *Notropis*, especially *N. volucellus* and its allies. In addition to consistently lacking a maxillary barbel, these species have less elongate snouts, smaller eyes, and 4-4 pharyngeal teeth. *Macrhybopsis aestivalis* has randomly scattered spots on the sides in contrast to the dark midlateral band of *H. amblops* (often not visible until well after preservation). *Ericymba buccata* is similar in shape and pigmentation, and in most meristic characters. In addition to having unique cephalic lateralis canals, it lacks the maxillary barbel, distinct lateral band, and falcate dorsal fin of *H. amblops*. Other sympatric minnows with maxillary barbels have 38 or more lateral-line scales.

Systematics: Type species of genus *Hybopsis*. Clemmer (1971) studied systematics of this species, *H. lineapunctata*, *H. rubrifrons*, *H. winchelli*, and *Notropis amnis*. Jenkins and Lachner (1971) and Mayden (1989) considered *Hybopsis hypsinotus* to be an additional member of the group.

Etymology: *amblops* = blunt face.

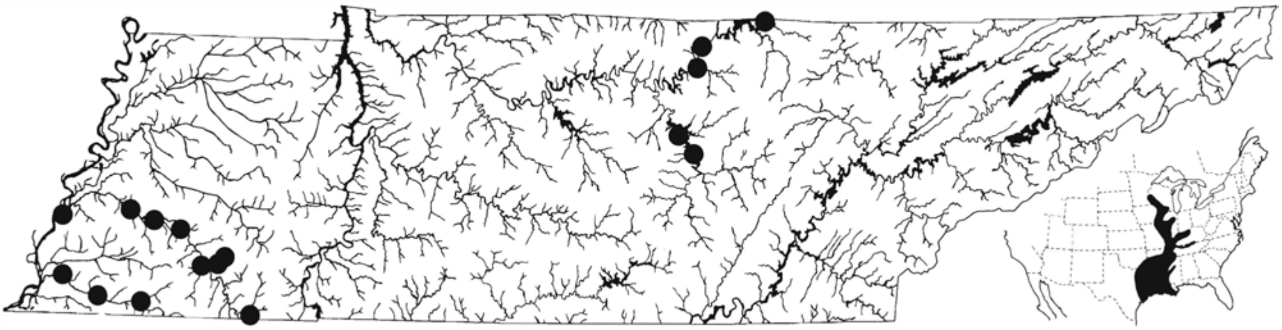
Hybopsis amnis (Hubbs and Greene)

Pallid shiner

Characters: Lateral-line scales 35–36 (34–37) and scarcely elevated anteriad, predorsal scale rows 13–15. Anal fin rays 8. Pectoral fin rays 12–15. Pelvic fin rays 8. Gill rakers reduced to 2–7 blunt knobs on dorsal portion of arch. Pharyngeal teeth 1,4-4,1. Breast naked anteriad to naked with 1–2 scales at pectoral fin bases. Vertebrae 35–36 (2 specimens). Lateral stripe narrow, distinct, and continuous around snout, but typically not conspicuous in life. Chromatic breeding colors do not develop. Mouth subterminal and horizontal. Dorsal, anal, and pectoral fins with concave margins, the tip of the depressed dorsal fin reaching to or past the middle of the anal fin base. Nuptial tubercles of males (Hubbs, 1951, and our observations) are largest on the cheeks, lachrymal area, and on top of the head between the orbits. Smaller tubercles occur on the posterior portion of the head and continue as tiny marginal tubercles on nape scales. Tubercles absent anterior to nostrils, but large ones present and directed laterad on lower jaw, and occasionally present on branchiostegal rays. Pectoral fin with a single row of small dorsal tubercles, about two per fin ray segment, on first ray. Rays 2–8 with shagreen of small tubercles that form about three rows basad and extend on branches of rays as two and then (distally) one row per branch, with about 4 tubercles per segment. Tubercles not developed elsewhere.

Plate 49. *Hybopsis amnis*, pallid shiner, 45 mm SL, Hatchie R., TN.

Biology: The pallid shiner is a widespread but extremely rare minnow typically associated with big rivers. In Tennessee we have found it most abundant in habitats such as larger tributaries to the Hatchie River and its main channel, and a persistent population occurs in Center Hill Reservoir, Caney Fork River system, in middle Tennessee. Collections are typically made in



Range Map 49. *Hybopsis amnis*, pallid shiner.

quiet waters over silty substrates. According to Clemmer (1971), spawning occurs from late winter through early spring. Our tuberculate specimens are from late May. Becker (1983) reported lengths of 34 and 49 mm TL at ages 1 and 2 and a life span of at least 3 years in a small sample of Wisconsin specimens. Additional information concerning its biology is not available. Maximum total length 70 mm (2.75 in).

Distribution and Status: Occurs in the Mississippi River and its larger tributaries from Minnesota southward and west through the Guadalupe River drainage, Texas. Locally common in Hatchie River and its larger tributaries. Our numerous collections from the Mississippi River main channel have yielded only two specimens. The Center Hill Reservoir population is apparently an isolated relict from a population once much more widespread in the Cumberland River drainage from mouth of Roaring River, Jackson Co., Tenn. (Univ. Mich. Mus. Zool. Collection), upstream to near Cumberland Falls in Kentucky (Burr, 1980). Recent Cumberland drainage records, except for those from Center Hill, are not available. Indications are that the species may be on the decline in the Midwest as well (Warren and Burr, 1988).

Similar Sympatric Species: *Pimephales vigilax* and *P. notatus* have distinct caudal spots and more than 20 predorsal scale rows. In *N. volucellus*, *N. stramineus*, *N. buchanani*, and *N. wickliffi* the lateral stripe does not encircle the snout and pharyngeal teeth are 4-4, in addition to characters that can be gleaned from the keys and character descriptions. *Notropis ammophilus* has 7 anal fin rays, 4-4 pharyngeal teeth, and is yellowish in color. None of the above species has the extremely falcate fins of *H. amnis*.

Systematics: We concur with Clemmer (1971), Coburn (1983), and Mayden (1989) that the closest relatives of *amnis* are *Hybopsis amblops* and its allies, a possibility first noted by Hubbs (1951). Hubbs (1951) studied intraspecific variation in this species and recognized two subspecies: *H. a. amnis* from the Mississippi Valley region, and *H. a. pinnosa* (Hubbs and Bonham) from southwestern states.

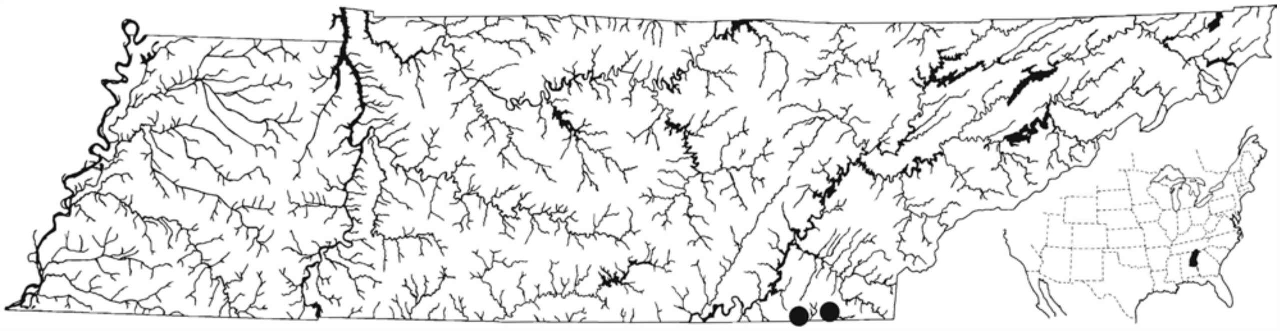
Etymology: *amnis* = stream or river.

Hybopsis lineapunctata Clemmer and Suttkus

Lined chub

Plate 50. *Hybopsis lineapunctata*, lined chub, 38 mm SL, Tallapoosa R. system, GA.

Characters: Lateral-line scales 35–37, predorsal scale rows 12–14. Anal fin rays 8 (8–9). Pectoral fin rays 14–15 (13–16). Pelvic fin rays 8. Four to 6 bulbous gill rakers on dorsal portion of arch. Pharyngeal teeth 1,4-4,1. Vertebrae 36–37 (36–38). Breast squamation varying from naked to almost completely scaled. Barbels are often lacking in Tennessee specimens, especially juveniles. Of 27 Tennessee specimens less than 42 mm standard length, only 3 had a detectable maxillary barbel. Color silvery with dark midlateral stripe and caudal spot. Nuptial tubercles are similar to those described for its close relative, *H. amblops*, except that head tubercles are somewhat larger, do not extend forward onto the snout, and are more concentrated above the orbital rims.



Range Map 50. *Hybopsis lineapunctata*, lined chub.

Biology: Lined chubs are typically found in small upland creeks over sandy substrates with gentle current. The two Tennessee localities for the species are 2–4 m wide with moderate gradient. According to Clemmer and Suttkus (1971) the breeding season is from mid May to early June. A 47-mm standard length female from the Tallapoosa River system, 3 April, contained about 200 maturing eggs. Examination of gut contents of five specimens from this Tallapoosa River collection indicated a benthic diet primarily of chironomid larvae and pupae. Also included in gut contents were numerous larger aquatic insects (*Hydropsyche* and *Glossosoma* trichopteran larvae, heptageniid and baetid mayflies, and a large coenagrionid damselfly nymph). Several terrestrial spiders, snails, beetles, and hemipterans included in gut contents also suggest opportunistic scavenging on terrestrial organisms washed into the stream. Maximum total length 85 mm (3.3 in).

Distribution and Status: Confined to the Coosa and Tallapoosa portions of the upper Alabama River system in the Piedmont and Ridge and Valley. Rare in the Conasauga River system, and known in Tennessee only from Mills Creek near Red Clay, Bradley County, and Old Fort Creek, Polk County. Recent efforts to collect lined chubs from these localities have not been successful. It is treated as a Species of Special Concern in Tennessee (Starnes and Etnier, 1980).

Similar Sympatric Species: This is the only cyprinid in the Conasauga River system with a combination of 14 or fewer predorsal scale rows, 8–9 anal fin rays, a horizontal and inferior mouth, and a pale band above the lateral stripe. *Notropis asperifrons*, *N. chrosomus*, and *N. xaenocephalus* are somewhat similar, but they have terminal oblique mouths, 2,4-4,2 pharyngeal teeth, and consistently lack barbels.

Etymology: *lineapunctata* refers to the prominent dark lateral band and caudal spot.

Genus *Hypophthalmichthys* Bleeker

Two of the three members of the East Asian genus of large cyprinids, *Hypophthalmichthys*, have recently been introduced into central North America, and it is likely that both species are reproducing in the wild. They are somewhat similar to the introduced grass carp (*Ctenopharyngodon*) in appearance but have much smaller scales (85 or more in the lateral line), a deeper body, and the eye is in an unusual position on the anteroventral portion of the head. Additional shared characters include a terminal mouth, smooth midventral keel on the abdomen, 8 dorsal fin rays, dorsal fin origin posterior to pelvic fin origin; pharyngeal teeth are molariform (4-4) and oppose a grinding surface on the basioccipital area. The gill rakers are extremely closeset for filtering midwater food particles which are apparently further consolidated and ground by the pharyngeal apparatus. A specialized structure, the epibranchial (or suprabranchial) organ (Wilamovsky, 1972) is present on the rear palate area and presumably functions in propelling food particles into the gill strainers. The gut is long and convoluted.

Our information concerning these recent additions to the Tennessee fish fauna is primarily from Robison and Buchanan (1988) unless otherwise indicated. Both species treated here were introduced into European countries, particularly the Soviet Union, decades ago and were subsequently introduced into Arkansas in 1971 as potentially valuable species for pond culture for food and control of algal blooms (Henderson, 1979; Cremer and Smitherman, 1980), and by the mid 1970s they were being cultured in private, state, and federal hatcheries in Arkansas for stocking in that state. Both species were being taken in natural waters of Arkansas by the mid 1980s, primarily in the state's large rivers, including the Mississippi. They now appear with regularity in commercial catches from the Mississippi River in and near the area bordering Tennessee (pers. comm. B. M. Burr, W. L. Pflieger). They are both pelagic planktivores that reach sizes of 27 kg (60 lbs) or more. Large rivers are apparently required for successful spawning, as the eggs, which are negatively buoyant, must remain suspended in the water column for successful hatching; Henderson (1979) concluded that they would not spawn in a lentic (pond) environment. In their native Asian rivers, spawning is typically associated with flooding. Preferred water temperatures for spawning are 22–24 C (72–75 F). The potential impacts of these fishes (and the grass carp, also first introduced in Arkansas) on native species remains unknown but can hardly be positive. It is certain that Tennessee could have survived without these unwanted gifts from our neighbors to the west.

In addition to *H. molitrix* and *H. nobilis* accounted herein, the genus contains a third East Asian species, *H. harmandi* Sauvage. Until recently, the bighead carp, *H. nobilis*, was included in the genus *Aristichthys* but was recently allocated to *Hypophthalmichthys* based on numerous shared specializations by Howes (1981). His detailed study of the anatomy of *Hypophthalmichthys* and potentially related genera, all Eurasian, concluded that it was sister to the genus *Xenocypris* and in the subfamily Abraminae along with that genus plus *Abramis*, *Rutilus*, and *Chondrostoma*.

Etymology: *Hypo* = under or beneath, *phthalm* = eye, *ichthys* = fish, referring to the unusual position of the eye.

KEY TO THE TENNESSEE SPECIES

1. Ventral keel on abdomen extends forward only to base of pelvic fins; gill rakers long and slender; body with scattered dark blotches . . . . *H. nobilis* p.180
   Ventral keel on abdomen extends forward past pelvic fin base to isthmus; gill rakers forming a compact mass covered by a net-like matrix; lacking scattered dark blotches . . . . *H. molitrix*

Hypophthalmichthys molitrix (Valenciennes)

Silver carp

Characters: Lateral line complete with 95–103 scales. Anal fin rays 12–13. Pectoral fin rays 15–18. In adults the first ray of the anal, dorsal, and pectoral fins is spine-like, and that of the pectoral fin develops small posterior serrae. Gill rakers extremely numerous and thin, the length about 200 times the width, and covered by a net-like matrix. Also, see comments under discussion of the genus.

Biology: Silver carp are pelagic filter feeding fishes of large rivers. According to information presented by Cremer and Smitherman (1980), the silver carp is capable of filtering particles as small as 4 microns in diame-

Plate 51. *Hypophthalmichthys molitrix*, silver carp, juvenile, 130 mm SL, Malone Hatchery, Lonoke, AR.

ter with its modified and highly specialized gill rakers and generally concentrates on a diet of nanno- and phytoplankton and detritus in the range 17–50 microns. This filtering capability makes tiny green and blue-green algal cells available as food, along with somewhat larger zooplankters. In culture, silver carp are capable of attaining 5.4 kg (12 lbs) in 1 year (Henderson, 1979). We do not have information on growth rates in wild populations, but weights of 27 kg (60 lbs) are attainable. Other aspects of biology are similar to *H. nobilis* (below).

Distribution and Status: Native to large rivers of eastern China, but widely introduced elsewhere. Specimens have been collected in the Mississippi River and other major rivers in Arkansas and Missouri, and the lower Ohio River (Burr and Warren, 1986). It is likely to appear in the lower Cumberland and Tennessee rivers in the near future.

Similar Sympatric Species: See Key relative to distinction from *H. nobilis*. The grass carp, *Ctenopharyngodon idella*, is similar in shape but has much larger scales (34–37 in lateral line).

Etymology: *molitrix* = approximately "grinder," perhaps in reference to the pharyngeal grinding apparatus.

Hypophthalmichthys nobilis (Richardson)

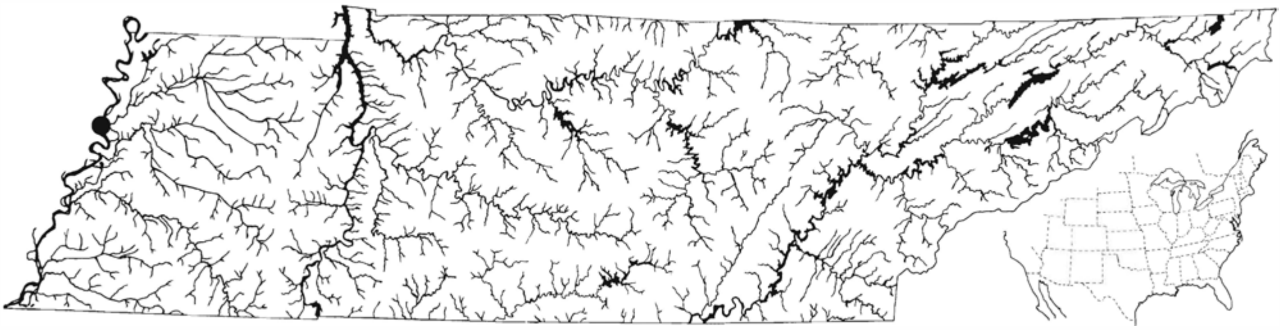
Bighead carp

Characters: Lateral line complete with 85–100 scales. Anal fin rays 13 (13–14). Pectoral fin rays 16–21. Gill rakers long and slender, the length about 40 times the width. In adults the first ray of the anal, dorsal, and pectoral fin is hardened and spine-like, but posterior serrations do not develop. Mature males have sharp ridges along several of the anterior pectoral fin rays. Also, see generic account.

Biology: Like silver carp, bighead carp naturally occur in large rivers and are pelagic filter feeders, but, according to Cremer and Smitherman (1980), their food consists of somewhat larger items such as zooplankton, clumps of algae, and insect larvae. However, this species is capable of switching to phytoplankton and detritus if zooplankton is scarce. According to information summarized in Jennings (1988), these carp spawn near the surface with much chasing activity and butting of the female's abdomen by males. Fecundity is very high, averaging about 290,000 eggs, and with up to 1,000,000 or more eggs in very large females. There may be two or three spawning cycles per year. Spawning is from April to June in China, occurs in swift currents during periods of flooding, and is associated with some upstream migration. Eggs remain suspended in the current during development and hatch about 1 day after fertilization at water temperatures of 22–26 C (72–79 F). At these temperatures, hatchlings absorb their yolk sac and begin to feed in 7 days at 8–9 mm TL; at 1.5 months they are about 15 mm TL. In China, under presumably natural conditions, bighead carp reach 0.75 to 1.5 kg (1.6–3.3. lbs) by their second year and are 3–4 kg (6.6–8.8 lbs) their third year; they are capable of attaining 40 kg (nearly 90 lbs) in reservoir habitats in 9 years. Average total lengths reported from a Polish study were 12.5, 24.2, 39.2, 50.3, 58.0, 66.7, and 71.6 cm at ages 1–7, respectively. Maximum total length is probably about 1 m. Additional comments appear in the generic account.

Distribution and Status: Bighead carp are native to large rivers of eastern China such as the Yangtze and Huang Ho (Herre, 1934), but have been widely introduced as a species with potential for food production in pond culture and were introduced to the United States from Taiwan in 1972 (Henderson, 1979). Escapees (or their progeny) from Arkansas hatcheries first appeared in Arkansas rivers in 1986 (Robison and Buchanan,

Plate 52. *Hypophthalmichthys nobilis*, bighead carp, 43 cm SL, U.S. Fish & Wildlife Station, Stuttgart, AR.



Range Map 51. *Hypophthalmichthys nobilis*, bighead carp (likely to spread throughout much of Mississippi Basin in near future).

1988). They are now being taken with some regularity in commercial catches from the Mississippi River in Missouri (pers. comm. W. L. Pflieger), and Tennessee (pers. comm. Ronnie Capps; our observation) and are to be anticipated in the lower Ohio, Cumberland, and Tennessee rivers in the near future.

Similar Sympatric Species: See *H. molitrix* above and *Ctenopharyngodon*.

Etymology: *nobilis* = noble.

Genus *Luxilus* Rafinesque

Characters include 2,4-4,2 pharyngeal teeth, 9 (9–10) anal fin rays, 37–44 lateral-line scales, and dorsal fin origin directly over pelvic fin origin. Pectoral fin tubercles are unique, with multiple cusps (2–6) developing on many tubercle bases. Head tubercles are large and mostly on the dorsum, and in one or two rows on rami of the mandibles; tubercles are smaller on body scales (marginal row) and other fins, when present. Nuptial males with red developed on fins and body. *Luxilus* are moderately large, deep-bodied species with the exposed portion of anterior lateral line scales much deeper than long (less noticeable in *coccogenis* and *zonistius*). Habitat is typically small to medium streams with clear water and firm substrates. Life history studies on a limited number of species indicate utilization of surface and benthic invertebrates as well as filamentous and unicellular algae. Spawning occurs in late spring or early summer over unaltered gravel substrates, nests of other cyprinids, or in gravel depressions constructed by breeding males. Tennessee taxa include *L. coccogenis*, *L. c. chrysocephalus*, and *L. c. isolepis*. *Luxilus cornutus* occurs in the Midwest north to southern Canada and on the East Coast south to Virginia. The Ozarkian uplands contain three closely related species, *L. cardinalis*, *L. pilsbryi*, and *L. zonatus*. *Luxilus zonistius*, a close relative of *L. coccogenis*, occurs in the Chattahoochee and Savannah river drainages of the Gulf Coast. *Luxilus albeolus* and *L. cerasinus* occur in Atlantic Coastal drainages of Virginia and North Carolina, and in the New River system of those states and West Virginia. Gilbert (1964) suggested a phylogenetic relationship of *Luxilus* with *N.* (*Notropis*?) *ariommus* or *Cyprinella pyrrhomelas*. Mayden (1989) regarded *Luxilus* as the sister group to *Cyprinella*, but Mayden and Matson (1988) also included species allocated to *Hydrophlox*, *Notropis* s.s., and *Pimephales* in this sister group. Important studies on this group include Gilbert (1964), Menzel (1976, 1977), Rainboth and Whitt (1974), Buth (1979a), Dowling and Moore (1984, 1985a, 1985b, 1986), Dowling and Brown (1989), Dowling et al. (1992), and Powers and Gold (1992).

Etymology: Possibly from *Lux* = light and *illus* = small. Rafinesque (1820) called these fishes shiners, but did not indicate the derivation.

KEY TO THE TENNESSEE SPECIES

1. Caudal fin with white base; dorsal fin with black vertical bar; dark scapular bar prominent . . . . *L. coccogenis* p.185
   Lacking any of these characters . . . . *L. chrysocephalus*

Luxilus chrysocephalus Rafinesque

Striped shiner

Plate 53a. *Luxilus chrysocephalus*, striped shiner, 77 mm SL, Cumberland R. system, TN.

Plate 53b. *Luxilus chrysocephalus*, striped shiner, breeding male, 163 mm SL, Stones R. system, TN.

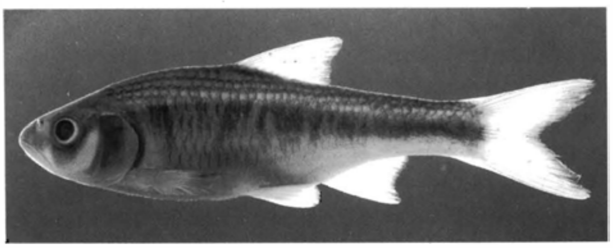


Plate 53c. *Luxilus chrysocephalus isolepis*, striped shiner, preserved specimen showing pigmentation pattern, 75 mm SL, Homochitto R. system, MS.

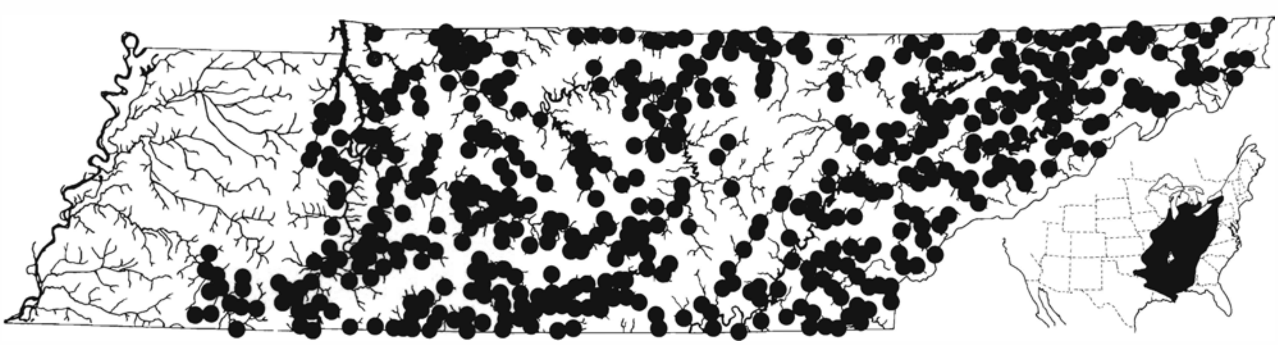
Characters: Lateral-line scales 37–40, predorsal scale rows 14–16. Anal fin rays 9 (8–10). Pectoral fin rays 15–17. Pelvic fin rays 8. Gill rakers 8–11. Pharyngeal teeth 2,4-4,2. Breast scaled. Peritoneum black. Vertebrae 39–40 (38–41). Color silvery, with caudal fin yellowish, but otherwise lacking distinctive markings. Nuptial males have pink or rose coloration on anterior sides, venter and sides of head, and as a broad submarginal band in all fins. They have large, scattered, conical tubercles covering dorsal surface of head, becoming more dense and slightly larger on snout. A single row of 5–7 (up to 10) large tubercles occurs on rami of mandibles, but none occur at tip of lower jaw. About 6 large tubercles present on lachrymal area, and we noted a row of large tubercles along lower cheeks in occasional specimens of *L. c. isolepis*. Nape tubercles (2–4 at scale base and 8–10 in marginal row) smaller than those on head. All body scales (except those on belly, breast, and below anterior lateral line) with marginal row of about 10 small tubercles. First pectoral fin ray often with single row of large, blunt tubercles. Large tubercles with multiple cusps per tubercle base may occur on dorsal surface of all remaining pectoral fin rays, the cusps forming a single row basad, splitting to form 2 rows well before branching of ray, and continuing on both branches of the ray with one tubercle and cusp per fin ray segment on anterior branch and one tubercle with 1–3 cusps per fin ray segment on posterior branch. Leading edge of dorsal fin with forward-pointing tubercles, and middle portions of rays occasionally developing single small tubercles located at fin ray joints. Other fins lacking tubercles in our specimens. Raney (1940a) also noted tubercles on leading edges of pelvic fins, ventral surface of pectoral fin rays, posterior portions of opercles, and belly scales in the closely related *L. cornutus*.

Biology: The striped shiner is a widespread and familiar minnow that occurs in sandy streams in west Tennessee (*L. c. isolepis*), and pool areas in gravel-bottom streams in middle and east Tennessee (*L. c. chrysocephalus*). It inhabits streams of all sizes but is most common in smaller creeks. The more northerly and closely related *L. cornutus* occurs in glacial lakes as well as streams, but its ability to successfully reproduce in lakes is uncertain (Moyle, 1973). Studies on *L. c. chrysocephalus* by Gillen and Hart (1980) and by Starrett (1950) and Moyle (1973) on the related *L. cornutus*, and on *L. chrysocephalus isolepis* by Hambrick and Hibbs (1976), indicate a diet of terrestrial insects, filamentous and unicellular algae, and a variety of aquatic invertebrates often dominated by mayfly nymphs. Prey items are larger than those consumed by species of related genera and even include small crayfish. Seasonal changes in the importance of the three above categories have been noted, and apparently reflect changes in availability. Most feeding is at the surface or in midwater areas, but common shiners are also adept at bottom feeding (Breder and Crawford, 1922). Raney (1940a) provided a detailed report of his own and earlier observations associated with reproductive activities of *L. cornutus*. Spawning occurs in late spring to early summer (our two forms are apparently similar) at water temperatures above 60 F. Activity over a particular spawning site lasts for 10 days or less. Spawning may occur over unaltered gravel substrates in swift current swept free of silt by swimming and digging activities of the males, over nests of other cyprinids (e.g., *Nocomis*) in swift to quiet water, or shallow depressions (nests) may be built by males. These last are constructed by males thrusting their snouts between small stones and moving them aside by vigorous shaking of the head. Males are pugnacious toward rival males, nonreceptive females, and potential egg predators while occupying spawning areas. Females remain downstream from the spawning site and individually approach one of the males when ready to spawn. The pre-spawning ritual is of short duration and leads to the spawning act, in which the female lies on her side while being clasped by the curved body of the male. Actual spawning takes only a fraction of a second, and 50 or fewer eggs are laid per spawning act. Pectoral fin tubercles of the male apparently aid in maintaining contact during spawning. A relatively small proportion of the population consists of sexually active males, and tuberculate males are not abundant in most preserved material. Extremely large specimens are usually males, which often die shortly after spawning. Hybrids with other cyprinid species have been noted frequently and have been attributed to these shiners spawning over active nests of other minnows. In southern Illinois, striped shiners averaged 36, 74, 102, 122, and 165 mm total length at ages 1–5 (Lewis, 1957). Large adults are occasionally taken by anglers. Although not hardy in minnow buckets, they are quite popular as bait minnows. Maximum total length 240 mm (9.3 in) reported by Marshall (1939).

Distribution and Status: The nominate subspecies occurs in the southern Great Lakes drainage and in eastern Mississippi River tributaries from northern Illinois south through the Ohio, Cumberland, and Tennessee drainages, and in the upper Mobile Basin; also occurs in western Mississippi River tributaries from northeastern Missouri south through the White and middle Arkansas river systems of Arkansas and eastern Oklahoma. Subspecies *L. c. isolepis* occurs primarily below the Fall Line from the Mobile Basin west through the lower Arkansas, Ouachita, and Red river systems of southern Arkansas, central Oklahoma, and eastern Texas. Both subspecies are common and widespread in Tennessee. *Luxilus c. isolepis* is restricted to Coastal Plain habitats, while *L. c. chrysocephalus* occurs in all physiographic provinces of east and middle Tennessee. Clark (1974) interpreted populations from western tributaries to the lower Tennessee from Benton County southward as representing intergrades between *L. c. chrysocephalus* and *L. c. isolepis* brought about by the entry of *isolepis* into the Tennessee drainage via exchange with Hatchie River tributaries to the west.

Similar Sympatric Species: See comments under *Clinostomus funduloides*, *Notropis ariommus*, and *Luxilus coccogenis*. The rounded snout and rather small, dorsally placed eye provide a facial appearance unique to this species, but difficult to quantify. Specimens from clear waters may have a distinct and persistent dark lateral stripe, but usually the species is poorly marked. The pattern of straight (*isolepis*) or irregular (*chrysocephalus*) dark longitudinal dorsolateral lines is similar to that of *N. telescopus*, which has a much larger eye, less deepened anterior lateral-line scales, and a well pigmented lateral-line canal.

Systematics: Gilbert (1961a, 1964) provided characters for separating the two forms discussed above and the very similar *L. cornutus* (Mitchill) of northern states, southern Canada, and Atlantic coastal drainages south to the James River. In *L. cornutus* anterior dorsolateral dark lines are lacking between scale rows, chin pigment (except on Atlantic slope) is restricted to anterior portion of lower jaw, and predorsal scales are relatively small, with the sum of circumferential scales (counted around body just anterior to dorsal fin) and anterior dorsolateral scales (counted in scale row three fourths distance between lateral line and middorsal line from head to area directly under dorsal fin origin) usually 48 or



Range Map 52. *Luxilus chrysocephalus*, striped shiner.

more. In both *chrysocephalus* and *isolepis*, dorsolateral dark lines are present, chin pigment is more extensive, and the above scale count index is usually 44 or fewer. In *isolepis* dark anterior dorsal lines between scale edges are more straight and regular than in *chrysocephalus*, scales are slightly larger, and gill rakers tend to be 8–9 vs. 10–11 in *chrysocephalus*.

Modern speciation concepts are consistent with the occurrence of formerly isolated and differentiated forms coming into secondary contact when the differentiation between these forms is not sufficient for them to behave as "biological" species, but more than that typically associated with traditional concepts of "subspecies." The three forms treated here clearly represent that situation. Recent taxonomic treatment of these three forms by contemporary ichthyologists has been highly controversial. Prior to 1961 the forms were consistently treated as subspecies, but Gilbert (1961a) offered evidence supporting his consideration of *cornutus* and *chrysocephalus* as distinct species, with *isolepis* implied as a subspecies of *chrysocephalus*, and retained that view in a later paper (Gilbert, 1964). R. J. Miller (1968) offered arguments for treating *cornutus* and *chrysocephalus* as something less than species (subspecies), and this view was supported by Resh et al. (1971) and followed in practice by numerous recent authors. Menzel (1976) used biochemical evidence in support of his contention that *cornutus* and *chrysocephalus* should be treated as subspecies, but *isolepis* was sufficiently distinct to warrant species status. Buth (1979a) used the names *cornutus* and *chrysocephalus* in the species context but provided no convincing evidence supporting either species or subspecies treatment. His contention that *isolepis* be treated as a subspecies is supported by his studies and Clark's (1974) report of an intergrade area (but see comment below) in tributaries to the lower Tennessee River north of Pickwick Dam. A survey of 19 state and regional "fish books" published between 1962 and 1983 revealed 13 authors treating *chrysocephalus* as a species and 6 authors treating or implying subspecies status. It is likely that many of the former based their decision on the widely accepted list of common and scientific names of North American fishes (Bailey et al., 1970; Robins et al., 1980). Valid arguments were presented for both positions, and the question became philosophical. A pertinent argument (although one having little evolutionary validity) for species recognition of *cornutus* and *chrysocephalus* is that many authors fail to utilize subspecies names even for distinct subspecies taxa, and two well-differentiated forms can thus be artificially amalgamated by the author's usage. Currently, *cornutus* and *chrysocephalus* are allopatric in Missouri (Pflieger, 1975) and virtually so in Illinois (Smith, 1979), even though there are no drainage barriers to prevent sympatry. Were these states to contain the entire zone of secondary contact, there would be little justification for treating the forms as anything but species. In Indiana, Michigan, Ohio, Pennsylvania, and Wisconsin, however, sympatric populations behave variously as "biological" species, with few or no intermediate forms, or, under traditional concepts, as subspecies, with intermediate morphs equally or more abundant than parental morphs (Gilbert, 1961a). We had been treating *chrysocephalus* as a subspecies of *cornutus*, but a thorough analysis of the problem (Dowling and Moore, 1984) documented their species status (supported by additional studies—Dowling and Moore, 1985a, b, 1986; Dowling et al., 1989). An electrophoretic analysis of 42 populations from the area of sympatry in Illinois, Indiana, Michigan, Ohio, and Pennsylvania indicates that gene flow between these species (introgressive hybridization) occurs, but in 41 of the 42 populations allele frequencies revealed that at least partial reproductive isolation was being maintained (hybrid genomes were less prevalent than would have been the case if mating between and among the species were random). Selection against hybrid genomes prevents fusion of gene pools and allows the two taxa to maintain their integrity. Factors causing selection against hybrids are not known, but both lack of fitness of hybrids and non-random selection of mates due to behavioral or habitat attributes were suggested. At present, individuals not choosing mates from among their own species are selected against, since the resulting hybrid genomes are selected against. Refinement of pre-mating isolating mechanisms, which increase an individual's fitness by preventing wastage of gametes, is the anticipated ultimate outcome. Why these shiners and several species of sunfishes (*Lepomis*) in which introgressive hybridization has presumably been occurring for over 10,000 years, since retreat of the most recent (Wisconsinan) phase of continental glaciation, have not evolved more perfect pre-mating isolating mechanisms continues to be a perplexing problem.

Gilbert (1964) identified only a single population (Black Warrior River tributary, Ala.) as potential intergrades between the putative subspecies *L. c. chrysocephalus* and *L. c. isolepis*. However, we note that both taxa were present at that locality plus intermediates raising the possibility of interspecific hybrids. A study, such as that conducted by Dowling and Moore (1984) on *cornutus* and *chrysocephalus*, if conducted on the *chrysocephalus* x *isolepis* "intergrade" area in the lower Tennessee drainage, might have implications regarding the status of these taxa as well. However, Dowling et al. (1992), based on mitochondrial DNA data, contend that *isolepis* may not even be a monophyletic group, as presently recognized, further confusing the issue.

The nearest relative of *chrysocephalus* and *cornutus* is hypothesized to be *L. albeolus* of central Atlantic slope drainages (Gilbert, 1964; Rainboth and Whitt, 1974; Menzel, 1977; Buth, 1979a).

Etymology: *chrysocephalus* = golden head, *isolepis* = equal scales, in reference to the more regular scale pattern.

Luxilus coccogenis (Cope)

Warpaint shiner

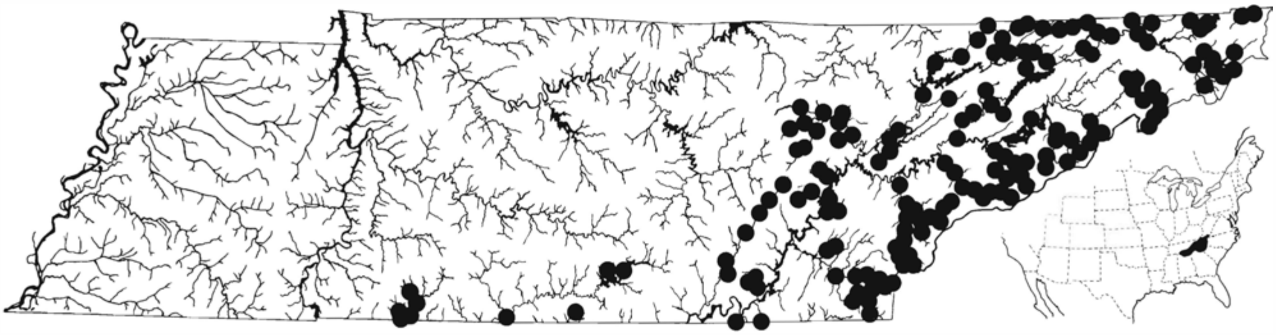
Plate 54a. *Luxilus coccogenis*, warpaint shiner, 31 mm SL, Little R., TN.

Plate 54b. *Luxilus coccogenis*, warpaint shiner, breeding male, 84 mm SL, Hiwassee R. system, TN.

Characters: Lateral-line scales 39–44, predorsal scale rows 17–18 (16–19). Anal fin rays 9 (8–10). Pectoral fin rays 15–17. Pelvic fin rays 8. Gill rakers 5–8, about as long as wide. Pharyngeal teeth 2,4-4,2. Breast scaled. Vertebrae 40–42. Adults and large young have pale basicaudal areas and red-orange at anterior dorsal fin base, on snout, and on posterior margin of preopercle apparent throughout the year. Nuptial males have large tubercles on the snout tip and in 2 (2–3) rows along the lower jaw. Snout tubercles extend posteriad over the lachrymal area and continue between the nares and orbit, terminating as a single row over the anterior half of each orbit. Pectoral fins have tubercles on rays 1–8 or 9. On the first ray there is a single row of tubercles with one tubercle base per fin ray segment, each base giving rise to 1–2 cusps that form a single row. Rays 2–8 or 9 have a single row of tubercle bases proximad that splits with the branching of the ray to form two rows distad. Again, there is a single tubercle base per fin ray segment, but each base produces 1–6 cusps that may form a double row. Much smaller tubercles occur (1–3 per fin ray segment, single cusps) near tips of pelvic and anal fin rays, and on distal half of dorsal fin rays. Outten (1957) also noted small tubercles on distal portion of caudal fin rays. Body scales lack tubercles. Lower jaw tubercles develop in very small and certainly immature specimens of both sexes and are remarkably persistent from late April through early November. These tubercles were consistently present on specimens as small as 30–40 mm total length. *Notropis semperasper* of the James River drainage (see Gilbert, 1961b) and *N. telescopus* also develop tubercles prior to sexual maturity in both sexes.

Biology: The warpaint shiner is a large, active, and brightly colored shiner of the upper Tennessee River drainage. It is most common in cool, clear streams with rocky substrates where it occurs in areas of moderate to swift currents. It is quite tolerant of water temperatures sufficiently cold to support trout populations, and larger specimens are occasionally taken by anglers. Outten (1957) provided the following information concerning its biology. Spring food consists primarily of mayfly nymphs and other aquatic immatures, with some terrestrial insects. Summer diet consists mostly of insects taken at the surface, with aquatic immatures (mostly as drift organisms from midwater areas) taken less frequently. Spawning was observed in mid June, with males congregating over the upstream ends of *Nocomis micropogon* nests. Females remained slightly downstream from the males, with occasional individuals approaching a male. After a short period of midwater contact, the pair settled to the bottom and eggs were deposited in crevices between stones bordering the upstream end of the chub nest. Average annual female fecundity was 300–750 eggs, with a maximum of over 1,600 in an extremely large specimen. Warpaint shiners grow to about 50 mm SL by the end of the first summer, and to about 80 mm in their second year. Most fish are not sexually mature until their third summer, and few fish live to see their fifth summer. Maximum total length 120 mm (4.7 in).

Distribution and Status: Abundant in Blue Ridge and Ridge and Valley portions of the Tennessee River drainage; less common on the Cumberland Plateau and southern Highland Rim portions of Tennessee drainage. Also occurs in the upper Savannah and Santee drainages of Georgia and the Carolinas, presumably due to headwater piracy from the Tennessee, and is well established



Range Map 53. *Luxilus coccogenis*, warpaint shiner.

in the upper New (Kanawha) system where probably introduced.

Similar Sympatric Species: Young of *L. chrysocephalus* are very similar but lack the dark bar behind the operculum, have a much smaller mouth, and lack lower jaw tubercles. The only sympatric cyprinid that has white basicaudal areas is *Cyprinella galactura*, which has diamond-shaped scale outlines, and a concentration of melanophores in posterior interradial membranes of dorsal fin; in *coccogenis* scales are not distinctly diamond-shaped, and dorsal fin pigment, if present, is in the form of a vertical band extending through middle of fin. Also see *N. rubricroceus*.

Systematics: Systematics studied by Gilbert (1964), and Buth (1979a) who regarded *L. zonistius* of the Apalachicola River drainage as sister species with *L. cerasinus* of the Roanoke drainage region as the nearest relative to this pair.

Etymology: *coccogenis* = berry-red cheek.

Genus *Lythrurus* Jordan

Shared characters for members of *Lythrurus* include 2,4-4,2 pharyngeal teeth, small predorsal scales with typically 21 or more predorsal scale rows, dorsal fin origin well behind pelvic fin origin, scaled breast, red breeding colors (except in *fumeus* and *lirus*), and multiple pectoral fin tubercles per fin ray segment that are moderately large but do not form a dense shagreen (except in *fumeus*). The various species are small to moderate in size, occur in small to medium streams, and studied species have late-spring to late-summer spawning periods, spawn over sand and gravel substrates often in association with nests of other fishes, and are surface or midwater insectivores. Tennessee forms include *ardens*, *fumeus*, *lirus*, and *umbratilis cyanocephalus*. Four additional taxa occurring in Gulf Coastal drainages are *atrapiculus*, *b. bellus*, *b. alegnotus*, and *roseipinnis*. *Lythrurus snelsoni* occurs in the Little River system of Arkansas and Oklahoma. Snelson (1972, 1973) indicated a relationship between *Lythrurus* and the *N. atherinoides* species group of the subgenus *Notropis* based on the pectoral fin tubercle pattern of *Lythrurus fumeus* being rather intermediate between patterns typical for the two groups, among other characters. Mayden (1989) recognized *Lythrurus* at the generic level and hypothesized its closest relatives to be *Cyprinella* and *Luxilus*. Whatever its relationships, *Lythrurus* does appear to be a compact, easily recognizable, monophyletic group of minnows warranting recognition at the generic level.

Etymology: *Lythr* = blood or gore, *urus* = tail, presumably referring to the bright red breeding colors.

KEY TO THE TENNESSEE SPECIES

1. A concentration of melanophores at the anterior base of the dorsal fin, usually extending onto the membranes of the anterior rays and appearing as a distinct spot when viewed from above 2
   Dark spot at dorsal fin origin absent 3

2. Anal fin rays 9–11, mode 10 for Tennessee populations; body depth contained 4.5 or more times in standard length . . . . *L. ardens*
Anal fin rays 10–13, mode usually 11, often 12; body depth contained fewer than 4.5 times in standard length . . . . *L. umbratilis* p.190
3. Lower jaw with dark pigment restricted to extreme tip of mandibles; body depth contained 5.2 or more times in standard length; modal number of anal fin rays 10; lateral stripe extends ventrad to lateral line along its entire length; east and middle Tennessee . . . . *L. lirus* p.189
Lower jaw with dark pigment extending back onto gular area; body depth goes fewer than 5.2 times in standard length; anal fin rays modally 11; lateral stripe does not extend ventrad to decurved portion of lateral line; west Tennessee and western middle Tennessee . . . . *L. fumeus* p.188

Lythrurus ardens (Cope)

Rosefin shiner

Plate 55a. *Lythrurus ardens*, rosefin shiner, 58 mm SL, Cumberland River system, TN.

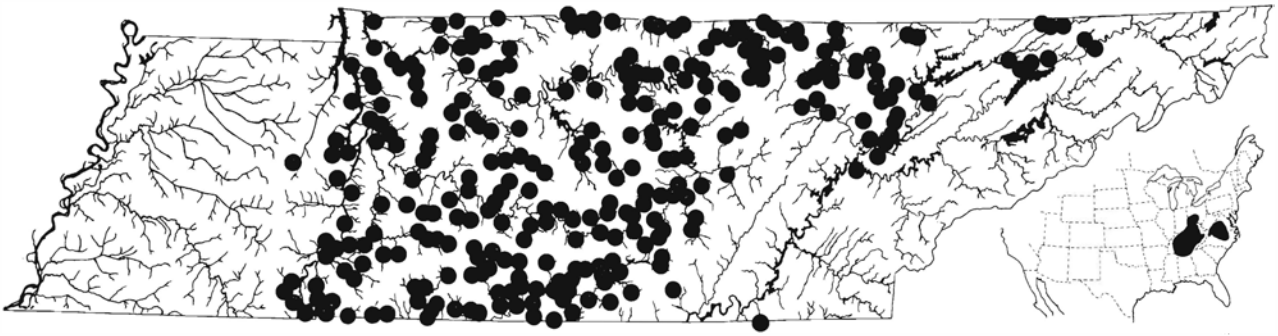
Plate 55b. *Lythrurus ardens*, rosefin shiner, breeding male, 71 mm SL, Barren R. system, TN.

Characters: Lateral-line scales 38–53, mean 44–47 throughout range, predorsal scale rows 24–28. Anal fin rays 9–11 (9–12), modally 10; modally 11 (10–12) in New River and Atlantic drainages. Pectoral fin rays 12–16, modally 14. Pelvic fin rays 8 (7–9). Gill rakers 8–10, length of longest rakers 1–1.5 times their basal width. Pharyngeal teeth 2,4-4,2. Breast naked to covered with embedded scales. Vertebrae 37–40. Nuptial males are brilliant red on the fins and have a bluish cast to the sides that is interrupted by a series of vertical bars of darker pigment. Tubercles are large, conical, and antrorse from the tip of the snout to the dorsal fin origin, and their whitish cast gives the appearance of a fungal growth on live fish in the water. Smaller tubercles, about 3–6 per scale, may occur on lateral scales except those below the lateral line posterior to the anal fin. The leading edge of the dorsal fin, and less frequently of the anal and pelvic fins, have scattered tubercles. The first pectoral fin ray has a single row of tubercles, and rays 2–9 have a single row of small tubercles basad that splits into two rows on the middle portion of the ray, each row extending onto one of the branches of the ray as somewhat larger tubercles, 1–2 tubercles per ray segment. Pectoral fin tubercles are only on the dorsal surface. Tubercles are typically absent from opercles, cheeks, and the preorbital area. On the lower jaw there are one or two rows of large tubercles.

Biology: The rosefin shiner is an extremely common inhabitant of small to medium, clear, rocky streams where it swims in midwater in quiet or gently flowing areas. Adults feed on insects taken in midwater areas and from the surface (Meredith and Schwartz, 1959), but Surat et al. (1982) reported considerable consumption of midge larvae and mayfly nymphs. The spawning season extends from mid May through late August in our area. Spawning often occurs over the active nests of sunfish (Yokely, 1974) or nest-building cyprinids (Raney, 1947). Life span, based on length-frequency distribution of specimens in our collection, is probably 2 or 3 years. Maximum total length 90 mm (3.5 in).

Distribution and Status: Occurs throughout much of the Ohio, Cumberland and Tennessee river drainages, Atlantic slope drainages from York through Neuse rivers, and upper Black Warrior River system of Mobile Basin. *Lythrurus a. ardens* occurs from the York River drainage (introduced) south through the Neuse River drainage on the Atlantic slope and in the New River system of the upper Ohio River drainage; *L. a. fasciolaris* Gilbert occupies the remainder of the species range (Snelson, 1990). Widespread and often very common, especially in Highland Rim habitats. Less common in Nashville Basin and Cumberland Plateau, and very localized in Ridge and Valley.

Similar Sympatric Species: Members of the genus *Lythrurus* have small, crowded predorsal scales (24 or more rows). This character is shared by *Pimephales* and



Range Map 54. *Lythrurus ardens*, rosefin shiner.

Semotilus, all species of which are more cylindrical in cross section, have the dorsal fin origin directly above that of the pelvic fins, and have 7–8 anal fin rays. Both *Pimephales vigilax* and *P. notatus* have distinct caudal spots, and *P. promelas* has an incomplete lateral line. *Semotilus atromaculatus* and *Lythrurus umbratilis* are the only other Tennessee minnows with a dark spot at the anterior dorsal fin base. Most similar to other *Lythrurus*, and potentially sympatric with *L. fumeus*, *L. lirus*, and *L. umbratilis*. In addition to lacking a dark spot at the anterior dorsal fin base, *fumeus* and *lirus* lack red breeding colors. *Lythrurus umbratilis* differs in that nuptial males have large tubercles below the eye, and black pigment virtually obscures the red in all fins except the caudal, in addition to characters noted in the key.

Systematics: Snelson (1972) included *ardens* in a complex with *L. lirus*: Mayden (1989) hypothesized that it was sister species to *L. umbratilis*. Snelson (1980b) suggested that nominal subspecies *L. a. fasciolaris*, and *L. a. matutinus*, a distinctly colored form of the Tar and Neuse drainages, may not warrant recognition. After a more thorough analysis, Snelson (1990) recognized the subspecies *L. a. ardens* (Atlantic slope and New River) and *L. a. fasciolaris* (interior drainages). Page and Burr (1991) recognized *matutinus* as a species.

Etymology: *ardens* = burning.

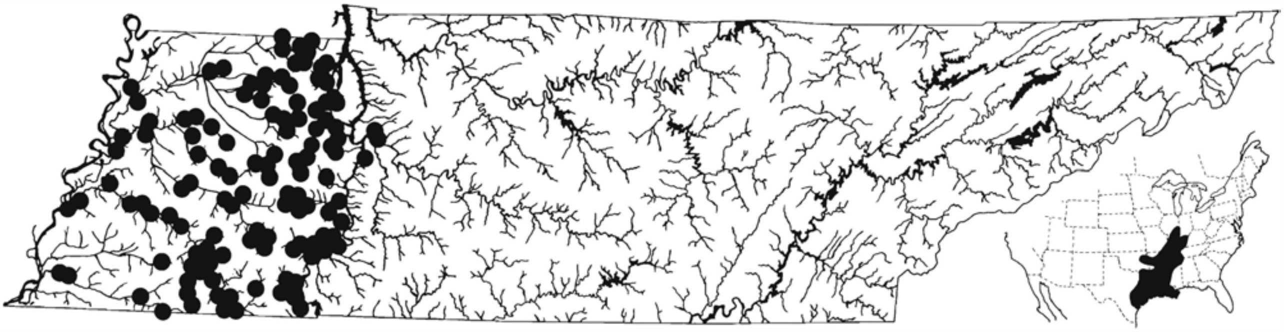
Lythrurus fumeus (Evermann)

Ribbon shiner

Characters: Lateral-line scales 38–42 (36–44), predorsal scale rows 22 or more in Tennessee specimens but occasionally 18–21 elsewhere (Snelson, 1973). Anal fin rays 11–12 (10–13). Pectoral fin rays 12–15. Pelvic fin rays 8. Gill rakers 7–10, length of longest rakers 1.5–2 times their basal width. Pharyngeal teeth 2,4-4,2. Breast with embedded scales except on midline. Vertebrae 35–38. Life color silvery with pale yellow background often apparent. Nuptial males have yellow on rays of dorsal and caudal fins, and along midlateral and anteriodorsal areas of body. The pattern of nuptial tubercles has been described by Snelson (1973). Small tubercles on dorsal surface of head most prominent from interorbital area back to occiput. Lower jaw with lateral row of tubercles that project to the side, and often with additional tubercles scattered over the ventral surface; these tubercles smaller than largest ones on top of head. Pectoral fins with dense shagreen of tiny tubercles on dorsal surface of rays 1–8 or 9, best developed on rays 2–5, where 20 or more tubercles occur per fin ray segment proximal to major branching of rays. These tubercles most numerous on posterior branch of ray and absent from distal fourth of rays. Other fins lack tubercles. Nape and anteriolateral body scales with marginal row of 5–8 tubercles per scale, largest on nape. Breast and belly scales with somewhat larger and more blunt tubercles, about 2–3 per scale.

Plate 56. *Lythrurus fumeus*, ribbon shiner, 44 mm SL, Hatchie R. system, TN.

Biology: The ribbon shiner is often the most abundant fish in small to moderate streams in the Coastal Plain area of west Tennessee. It prefers pool areas with little current and silty sand substrates. It is quite tolerant of silt, and the few populations in western Highland Rim streams east of the lower Tennessee River probably represent recent invasions. Spawning period implied from



Range Map 55. *Lythrurus fumeus*, ribbon shiner.

occurrence of tuberculate males extends from May through early August. Maximum total length 66 mm (2.6 in). Its biology has not been studied.

Distribution and Status: Widespread in lower Mississippi Basin below Fall Line and extending well above Fall Line in Arkansas River drainage of Arkansas and eastern Oklahoma, lower Ohio River tributaries in Kentucky and Indiana, and southern Illinois from lower Ohio River tributaries northwest through the Kaskaskia River system. Also occurs in Gulf of Mexico drainages both east and west of the Mississippi River in Lake Ponchartrain tributaries on the east, and west through the Matagorda Bay drainages of Texas. Common in Coastal Plain streams of west Tennessee, but usually uncommon in the few western Highland Rim areas where it occurs.

Similar Sympatric Species: Easily recognizable as a *Lythrurus* due to the placement of the dorsal fin origin well behind the pelvic fin insertion, and the presence of tiny, crowded predorsal scales. Potentially sympatric with all other Tennessee *Lythrurus* (*ardens*, *lirus*, *umbratilis*). Characters utilized in the key, in conjunction with locality information, should prove adequate for separating all but juveniles of these species. Also, see comments under *L. umbratilis*.

Systematics: Snelson (1973) treated the taxonomic history of this widespread but, until recently, poorly understood species. He suggested that *fumeus* was somewhat "intermediate" between *Lythrurus* and the subgenus *Notropis*, primarily on the basis of the extremely small and dense pectoral fin tubercles, a character shared by the subgenus *Notropis* but not by other *Lythrurus*. However, Mayden (1989) placed *Lythrurus*, including *fumeus*, in a lineage remote from *Notropis* s.s.

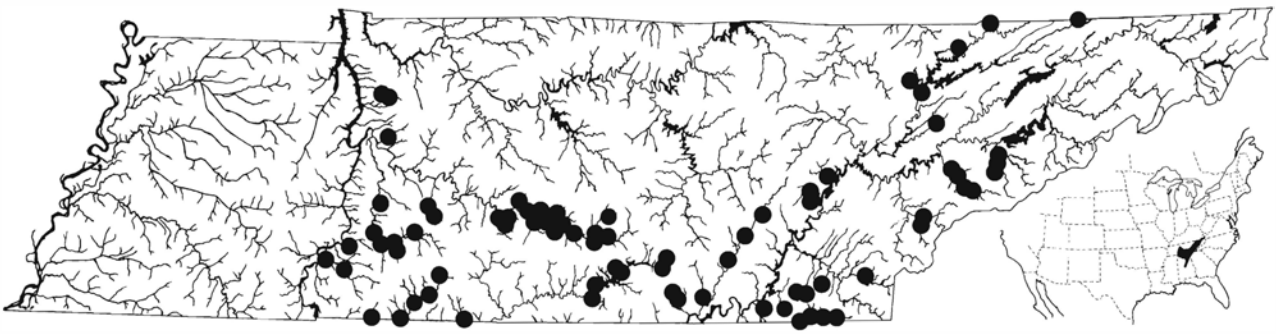
Etymology: *fumeus* = smoky.

Lythrurus lirus (Jordan)

Mountain shiner

Plate 57. *Lythrurus lirus*, mountain shiner, 45 mm SL, Hiwassee R. system, TN.

Characters: Lateral-line scales 39–45 (36–49), predorsal scale rows usually 23–30 with rows irregular and difficult to count. Anal fin rays 10–11 (9–12). Pectoral fin rays 12–15. Pelvic fin rays 8. Gill rakers 6–8, length of longest rakers equal to their basal width. Pharyngeal teeth 2,4-4,2. Breast scaled. Vertebrae 37–38. Silvery gray in life with the dark gray lateral stripe often apparent. Bright breeding colors are apparently ephemeral and variable. Red colors have been reported from Coosa River system specimens (Snelson, 1980a), but in the Tennessee River drainage yellows predominate, especially on the head and caudal fin, and occasionally along the sides. Live males may have a band of pink-lavender iridescence along the horizontal myoseptum that disappears quickly upon confinement or preservation. Large tubercles are crowded over the top of the head from occiput to snout tip, and cause the top of the head to appear white in life. A few large tubercles occur on tip of lower jaw; tubercles absent elsewhere on head. Large tubercles continue, decreasing in size, on dorsal midline from occiput to dorsal fin, with 1–3 tubercles per scale. Other body scales with 1–8 marginal tubercles per scale best developed on anterior half of body and usually absent from belly and breast. Dorsal surfaces of pectoral fin rays 1–8 with moderate-sized tubercles, best developed on rays 2–5, and often absent from first ray. These tubercles are in 1–2 rows at



Range Map 56. *Lythrurus lirus*, mountain shiner.

base of ray, form about 4 rows with 8–15 tubercles per fin ray segment proximal to primary branching of ray, and continue as a single row on each branch. Tubercles absent on outer 1/4 of fin rays. Other fins lacking tubercles, or with a few on leading edges of dorsal, anal, and pelvic fins.

Biology: A tiny, slender, and delicate shiner, *L. lirus* occurs in pool areas in habitats ranging from moderate-sized creeks to medium-sized rivers. Its biology has not been studied. Males with maximum tuberculation occur in collections from mid May through late July. Maximum total length reported to be about 72 mm (2.9 in) by Snelson (1980a), but our largest specimens are 60 mm (2.4 in).

Distribution and Status: Generally uncommon in Ridge and Valley of Tennessee drainage and Mobile Basin, and southern portion of Highland Rim in the Tennessee drainage.

Similar Sympatric Species: *Pimephales notatus*, *P. vigilax*, and *Semotilus atromaculatus* also have tiny predorsal scales, but these are cylindrical rather than laterally compressed species, have only 7–8 anal fin rays, and have the dorsal fin placed directly above rather than well behind the pelvic fin insertion. Both *N.* (*Notropis*) *atherinoides* and *N.* (*Hydrophlox*) *rubellus* have the posterior dorsal fin placement of *lirus*, but have 21 or fewer predorsal scale rows. Often sympatric with the closely related *Lythrurus ardens*, which has more extensive chin and gular pigment (restricted to tip of chin in *lirus*), and a dark blotch at base of anterior dorsal fin rays. In middle Tennessee, *L. lirus* occurs in western Highland Rim streams east of the lower Tennessee River, while Coastal Plain streams on the west side of the river contain both *L. fumeus* and *L. umbratilis*. Both of these species are potentially sympatric with *lirus* in this area, and juveniles of all three species are very similar. In *umbratilis*, a dark predorsal blotch is usually evident, and both species modally have 11 rather than 10 anal fin rays and lower jaw pigment extending back onto gular area. In the Conasauga River most like *Notropis stilbius*, which is a larger species with fewer than 20 predorsal scale rows and anterior lateral stripe pigment that does not extend down to the lateral line.

Systematics: Snelson (1980a) found no significant differences between Tennessee and Mobile drainage populations of *lirus*. He considered *lirus* to be closely related to *L. ardens*; Mayden (1989) did not resolve its relationships within *Lythrurus*.

Etymology: *lirus* = lily white.

Lythrurus umbratilis (Girard)

Redfin shiner

Plate 58a. *Lythrurus umbratilis*, redfin shiner, 59 mm SL, Obion R. system, TN.

Plate 58b. *Lythrurus umbratilis*, redfin shiner, breeding male, 60 mm SL. Hatchie R. system, TN.

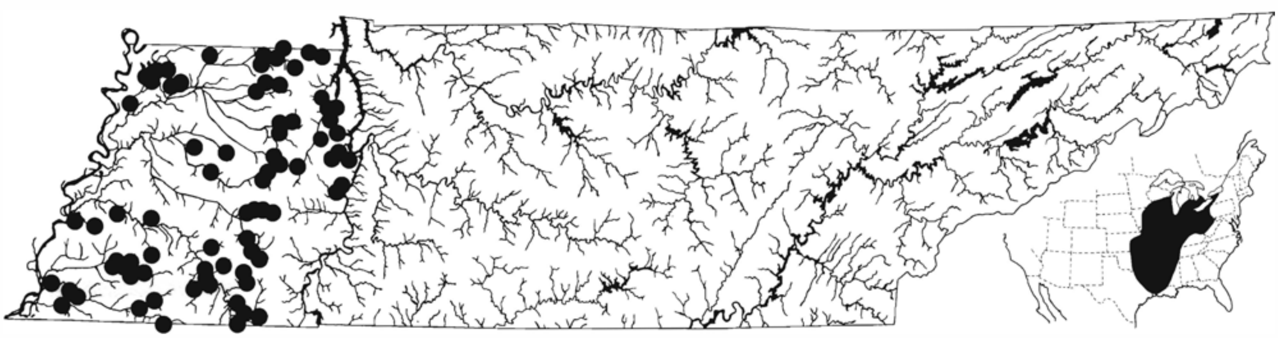
Characters: Lateral-line scales 38–55, predorsal scale rows 21–31. Anal fin rays modally 11 (10–12). Pectoral fin rays 12–15. Pelvic fin rays 8. Gill rakers 7–8 (6–9), length of longest rakers .5–1 times their basal width. Pharyngeal teeth 2,4-4,2. Breast scaled. Vertebrae 36–38. Life color silvery gray with dark spot at anterior dorsal fin base. Nuptial males develop metallic blue or green on sides and bright red on all fins. In peak breeding color, dark pigment may virtually obscure the red on pectoral, pelvic, and anal fins. Nuptial tubercles (Snelson and Pflieger, 1975; and our observations) are moderately large on dorsum of head from occiput to snout tip, occur in two rows on rami of mandibles; and are present on pre- and suborbital areas, occasional branchiostegal rays, and membranous extensions of gill covers posterior to opercles. Tubercles absent or virtually so from opercles and postorbital regions of cheeks in our subspecies. Except for interpectoral area and portions of belly, all body scales have tubercles that are largest on nape, where they merge smoothly in size and shape with those on head. Scale tubercles decrease in size posteriad, and occur as marginal rows with 5–7 per scale above, and 1–3 per scale below lateral line. Moderately large tubercles occur on dorsal surfaces of pectoral fin rays 1–8 or 9, and are most prominent on rays 2–5 where there is a single row basad, splitting to form 3–4 poorly defined rows near the branching of the rays. In this area there are 8–12 tubercles per fin ray segment. Tubercles extend only a few segments past the major ray branching, with a single row on outer branch and 2 rows on inner branch. Tubercles on leading edges of pelvic, anal, and dorsal fins larger than those scattered over other rays of these fins. Small tubercles may also occur on caudal fin rays (most extensive on lower lobe) and on ventral surfaces of pectoral fin rays.

Biology: The redfin shiner is a widespread and abundant species of small, warm, low gradient streams in central United States. The redfin shiner occurs in pools, often in large schools. Pflieger (1975) indicated it to be a surface feeder. Spawning season extends from late April through July and early August. Spawning often occurs over active sunfish (*Lepomis*) nests (Snelson and Pflieger, 1975), but Trautman (1957) also observed spawning over sandy substrates in sluggish current, while on the same day *Lythrurus ardens* was seen spawning over gravel substrates with swift current in the same stream. Matthews and Heins (1984) also noted a prolonged breeding season, extending from early May through August in Mississippi. Females produced 219–887 ova per clutch, but were presumed to produce several clutches per spawning season. Both males and females were sexually mature at 1 year, and few individuals lived more than 2 years. Maximum total length 88 mm (3.5 in).

Distribution and Status: Common and widespread in Mississippi Basin and southern Great Lakes drainage and westward through Galveston Bay drainage of Texas. All of our Tennessee records are from the Coastal Plain.

Similar Sympatric Species: Often sympatric with the very similar *L. fumeus*, but strikingly different from that species in nuptial color and tuberculation, and in having a dark blotch at anterior dorsal fin base. Juveniles of these two species may be very difficult to separate, even utilizing characters listed in Snelson (1973, p. 184–186). Occasionally sympatric with *L. ardens*, which is more slender and has modally 10 instead of 11 anal fin rays. *Semotilus atromaculatus* also has a dark blotch at the anterior dorsal fin base, but is a cylindrical rather than slab-sided species, and has only 8 anal fin rays.

Systematics: Hypothesized to be most closely related to *L. roseipinnis* complex by Snelson (1972) and to *L. ardens* by Mayden (1989). Snelson and Pflieger (1975) recognized two subspecies, *L. u. umbratilis* from the



Range Map 57. *Lythrurus umbratilis*, redfin shiner.

Salt, Missouri, and Arkansas river systems; and the more widespread *L. u. cyanocephalus* (type of the genus) occurring to the north, east, and south of this range. Supposed intergrades occur in eastern Missouri and west-central Arkansas. The nominate subspecies differs from *cyanocephalus* in having a well-pigmented cleithrum and in having cheeks and opercles covered with nuptial tubercles. A third form, lacking dark fin pigment, from the upper Ouachita River of Arkansas is under study by W. C. Starnes and H. W. Robison; we have collected nuptial males with similar colors from the Homochitto River system in Mississippi.

Etymology: *umbra* = shade.

Genus *Macrhybopsis* Cockerell and Alliston

We follow Robins et al. (1991) in including four species long included in *Hybopsis* (*aestivalis*, *gelida*, *meeki*, *storeriana*) in *Macrhybopsis*. Monophyly of this group is not firmly established, as Cavender and Coburn (1988) and Coburn and Cavender (1989) include *aestivalis* in *Macrhybopsis*, while Mayden (1989) places *aestivalis* in genus *Extrarius* and considers *Platygobio* as sister genus to his more restrictive *Macrhybopsis*. Shared characters include 8 anal fin rays, 1,4-4,1 pharyngeal teeth (4-4 in most forms of *aestivalis*), and a darkened lower lobe of the caudal fin with a white ventral border (often scarcely developed in *aestivalis*). Nuptial tubercles on the pectoral fins are very similar in *aestivalis* and *storeriana*, but we have not seen tuberculate specimens of either *gelida* or *meeki*. We note that the unusual caudal fin pigmentation of these fishes (shared by *Platygobio gracilis*) is approximately shared by the catostomids *Moxostoma poecilurum* and *Cycleptus elongatus*, indicating the possibility that it may have evolved more than once in big river chubs as some sort of an adaptation to living in swift currents over sandy substrates. The four species included in *Macrhybopsis* are strikingly dissimilar in appearance relative to species in other genera of native minnows recently elevated from the synonymy of *Hybopsis* and *Notropis*.

Etymology: *Macr* = large or long, *hybopsis* = genus of barbeled minnows. Cockerell and Alliston (1909), who proposed the name, indicated it to be based on the elongated body form of the type species, *M. gelida*.

KEY TO THE TENNESSEE SPECIES

1. Body with randomly scattered black dots (Pl. 59); pharyngeal teeth 4-4 except in Conasauga River . . . . *M. aestivalis*
   Body lacking randomly scattered black dots; pharyngeal teeth 1,4-4,1 2
2. Pectoral fins long and sickle-shaped, their tips extending past origin of pelvic fins (Pl. 61) . . *M. meeki* p.195
   Tips of pectoral fins not reaching origin of pelvic fins 3
3. Eye of normal size, its diameter contained about 3.5 times in head length; dorsal scales lacking a longitudinal ridge or keel; lateral-line scales 39 or fewer; widespread . . . . *M. storeriana* p.195
   Eye small, its diameter contained more than 5 times in head length; longitudinal ridge or keel present on dorsal scales; lateral-line scales 40 or more; restricted to main channel of Mississippi River . . . . *M. gelida* p.194

Macrhybopsis aestivalis (Girard)

Speckled chub

Characters: Lateral-line scales 34–41, predorsal scale rows 15–17. Anal fin rays 8 (7–8). Pectoral fin rays 13–16. Pelvic fin rays 8. Pharyngeal teeth 4-4 (1,4-4,1 in upper Mobile Basin). Gill rakers absent except for 1–3 dorsal rudiments. Breast and much of belly naked. Color silvery, translucent, and faintly yellow in turbid rivers, more opaque in clear waters. Sides of body with

Plate 59. *Macrhybopsis aestivalis*, speckled chub, 51 mm SL, Conasauga R., TN.

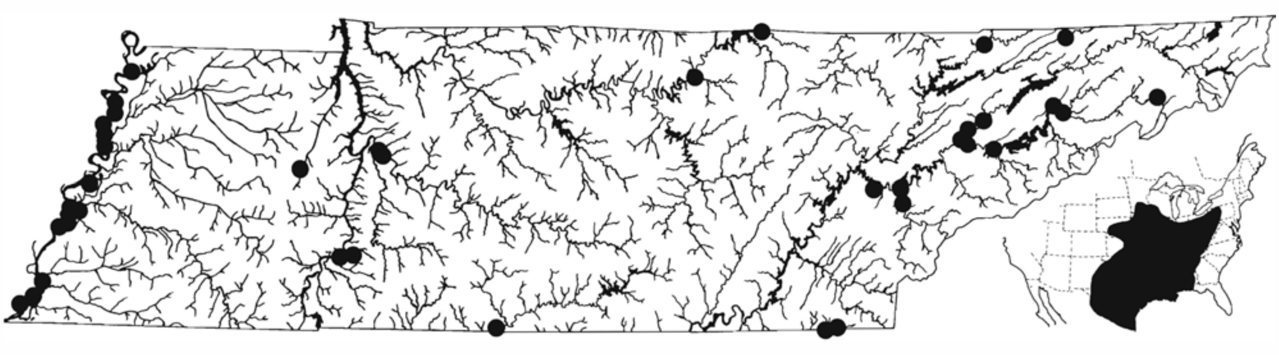
scattered dark spots. This widespread species is extremely variable throughout its range. Specimens from large, silty rivers have smaller eyes, less pigment, and fewer belly scales than do specimens from clear streams. Large uniserial nuptial tubercles develop on the dorsal surface of pectoral fin rays 2–10, and smaller tubercles may appear near the tips of dorsal, anal, and pelvic fin rays. We have not observed tubercles elsewhere. Published reports of nuptial tubercles for this species (Trautman, 1957; Pflieger, 1975) refer in part to the conspicuous taste buds that have an appearance similar to nuptial tubercles, appear to be more prominent on nuptial specimens, and develop on the head, ventral surface, and on the interradial membranes of the fins.

Biology: In the Mississippi River speckled chubs are abundant in moderate to swift current over sandy substrates. Elsewhere in the state they are associated with swift current over gravel substrates. Trautman (1981) noted an aversion to light and a preference for deeper water during daylight hours. They often remain stationary on the substrate when not foraging for food. Gut contents examined by us and by Starrett (1950) indicated a diet of aquatic insect larvae dominated by midges (Chironomidae). The spawning season is apparently quite long; we have noted tuberculate males in Tennessee collections from early May to mid August. According to Bottrell et al. (1964), spawning occurs near midday in flowing areas, and eggs drift a day or so until hatching. Juvenile chubs grow rapidly to about 40 mm TL by the first winter of life. Starrett (1951) reported a life span of only 1.5 years. The sensory systems of the speckled chub have been the objects of several studies (Branson, 1963, 1975; Davis and Miller, 1967; and Reno, 1969). Maximum total length about 76 mm (3 in).

Distribution and Status: Widespread in Mississippi River basin from southern Minnesota south, and in Gulf of Mexico drainages from Rio Grande drainage east to but not including Apalachicola drainage. Extremely common over sandy areas in the Mississippi River. Uncommon in the Conasauga River, and in the Tennessee River where it has likely been extirpated from large areas due to impoundments. Formerly occurred in Cumberland drainage in vicinity of Dale Hollow Reservoir, but apparently extirpated.

Similar Sympatric Species: The randomly scattered black spots on the sides and the long barbel make this one of our most distinctive cyprinids. Pallid juveniles from the Mississippi River might be confused with the sturgeon chub, which has slightly smaller scales, no randomly scattered black spots, ridges on dorsolateral scales, and a more distinctly bicolored lower lobe of the caudal fin.

Systematics: A published study of the systematics of this variable species throughout its range is badly needed. Hubbs and Ortenburger (1929) mention the six nominal taxa presently treated, with considerable reservation, as subspecies. We have at least three forms in Tennessee—a tiny, pallid, small-eyed form with a long barbel from the main channel of the Mississippi River; a short-snouted, heavily pigmented form from the Conasauga River that has a pinkish snout in life and 1,4-4,1 pharyngeal teeth; and a large, well-marked form with large eyes and a long snout from the Tennessee and (formerly) Cumberland drainages. The name *M. a. hyostomus* (Gilbert) is applicable to the Tennessee-Cumberland form. The undescribed Conasauga River form probably represents a valid species. In this case it seems likely that a positive taxonomic decision will be possible based on the likelihood that the two Mobile Basin forms occur (or occurred) in sympatry. The well-marked form with the short snout and 1,4-4,1 pharyngeal teeth, based on our holdings, occurs throughout the Conasauga River, the Etowah River above Allatoona



Range Map 58. *Macrhybopsis aestivalis*, speckled chub.

Reservoir, and the upper Tallapoosa River. Specimens from the Tombigbee and Cahaba rivers have weaker markings, longer snouts, and 4-4 pharyngeal teeth, and appear identical to specimens from the Pearl and Pascagoula systems. Our only two specimens from the lower Tallapoosa have long snouts and 4-4 pharyngeal teeth, but appear to be somewhat intermediate in pigmentation. This suggests that at least one area of potential sympatry within the Mobile Basin occurs in the Tallapoosa system. The complex is currently under study by Carter R. Gilbert, who (in litt.) adds to the above that the two Mobile Basin forms are also sympatric in the Cahaba River system, and certainly represent distinct species.

Etymology: *aestivalis* = of the summer.

Macrhybopsis gelida (Girard)

Sturgeon chub

Plate 60. *Macrhybopsis gelida*, sturgeon chub (preserved 1 week before photo), 45 mm SL, Missouri R., MO.

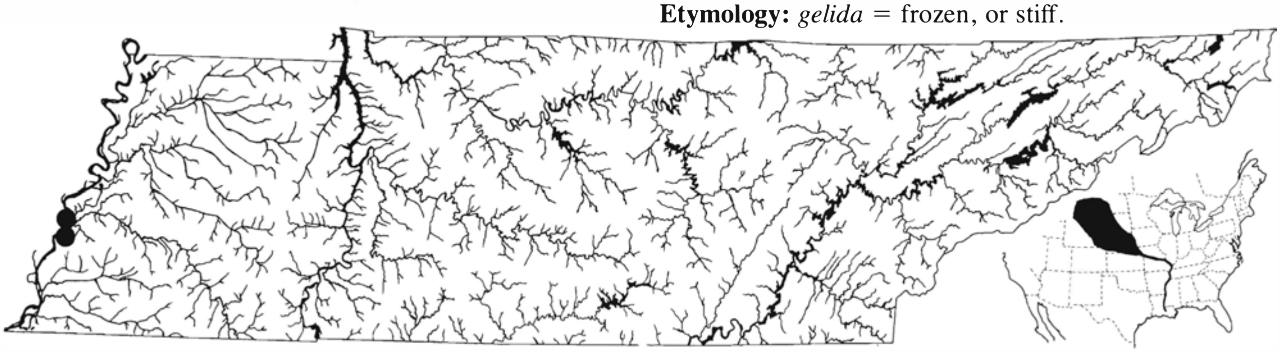
Characters: Lateral-line scales 39–45, predorsal scale rows 18–20 (10 specimens). Anal fin rays 8 (7–8). Pectoral fin rays 15–17 (13–17). Pelvic fin rays 8. Three to six blunt gill rakers on dorsal portion of arch. Pharyngeal teeth 1,4-4,1. Breast and belly naked. Scales with median keels, unique in native minnows. Bright colors and distinctive markings lacking. Lower lobe of caudal fin dark with a pale ventral border. Recorded as having 9 anal fin rays and 4-4 pharyngeal teeth by various authors. We suspect that these counts are erroneous.

Biology: The sturgeon chub is an obligate inhabitant of large, turbid rivers, and is virtually restricted to the main channels of the Missouri and Mississippi rivers and their larger tributaries. Its proliferation of cutaneous taste buds, tiny eye, keeled dorsolateral scales, and caudal fin coloration are all likely to be adaptations for this habitat. In the Missouri River we have collected them over broad sand bars with fast current. Habitat where sturgeon chubs were collected in the Mississippi River in Tennessee consisted of sand interspersed with some patches of fine gravel, moderate to swift current, and steeply sloping banks. These specimens, 22–28 mm long, are certainly in their first year. Pflieger (1975) indicated that lengths of 28–36 mm (1.1–1.4 in) are attained after 1 year's growth, with sexual maturity attained at about 43 mm. Gut content of a single adult we examined from the Yellowstone River contained about 6 chironomids and, surprisingly, about 20 baetid mayflies. Maximum total length 77 mm (3 in).

Distribution and Status: Widespread in Missouri River drainage, and taken rarely in the lower Mississippi River main channel south to Louisiana. In Tennessee known only from the Mississippi River near the mouth of the Hatchie River. Treated as a Species of Special Concern in Tennessee (Starnes and Etnier, 1980).

Similar Sympatric Species: See *M. aestivalis*. *Macrhybopsis meeki* and *Platygobio gracilis* are two additional barbeled minnows occurring in the Mississippi River that might be confused with *gelida*, especially when dealing with small specimens. Both have a falcate dorsal fin, with the tips of the anterior rays extending past the tips of the posterior rays when the fin is depressed (not so in *gelida*). In *Platygobio gracilis* the breast and belly are well scaled. None of these other Mississippi River barbeled minnows have keeled dorsolateral scales, and these are detectable even on small juveniles.

Etymology: *gelida* = frozen, or stiff.



Range Map 59. *Macrhybopsis gelida*, sturgeon chub.

Macrhybopsis meeki (Jordan and Evermann)

Sicklefin chub

Plate 61. *Macrhybopsis meeki,* sicklefin chub (preserved 1 week before photo), 45 mm SL, Missouri R., MO.

Characters: Lateral-line scales 43–50, predorsal scale rows 22–24. Anal fin rays 8. Pectoral fin rays 16–17. Pelvic fin rays 8. About 5 blunt gill rakers near dorsal portion of arch. Pharyngeal teeth 1,4-4,1. Breast and belly naked. Color silver, without distinctive markings. Lower lobe of caudal fin dark with white lower margin. The 4-4 tooth count attributed to this species by various authors is presumably an error.

Biology: The sicklefin chub is a big river cyprinid confined to the main channels of the Missouri and lower Mississippi rivers, where it occurs in swift currents over sand and gravel substrates. Pflieger (1975) implied a spring spawning season based on the appearance of young-of-year in July. Specimens we collected in the Missouri River on 24 May were 43–50 mm (1.75–2 in) long after presumably completing nearly 1 year of growth. Davis and Miller (1967) suggested, based on sensory morphology, that *M. meeki* is a taste feeder. Other aspects of its biology are not known. Maximum total length about 100 mm (4 in).

Distribution and Status: Not uncommon in the Missouri River, but rarely collected in the lower Mississippi River south to Louisiana. The single record in proximity to Tennessee, from the Mississippi River, is in the collection of the University of Michigan Museum of Zoology; it was taken on the Missouri side of the river at Cottonwood Point, Pemiscot County. Treated as a Species of Special Concern in Tennessee (Starnes and Etnier, 1980), but probably more common in the Mississippi River than records indicate.

Similar Sympatric Species: The extremely falcate fins, especially the pectorals, of this species are unlike those of other Mississippi River minnows. The tips of the pectorals extend well past the posterior base of the pelvic fins. *Platygobio gracilis* also has falcate fins, but the tips of the pectorals at most just barely extend to the anterior base of the pelvic fins.

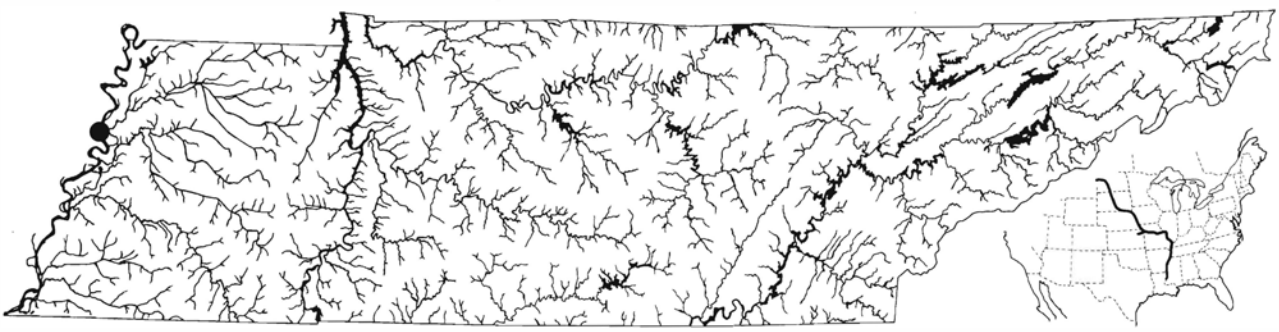
Etymology: Named in honor of Seth E. Meek, an early student of fishes of central North America.

Macrhybopsis storeriana (Kirtland)

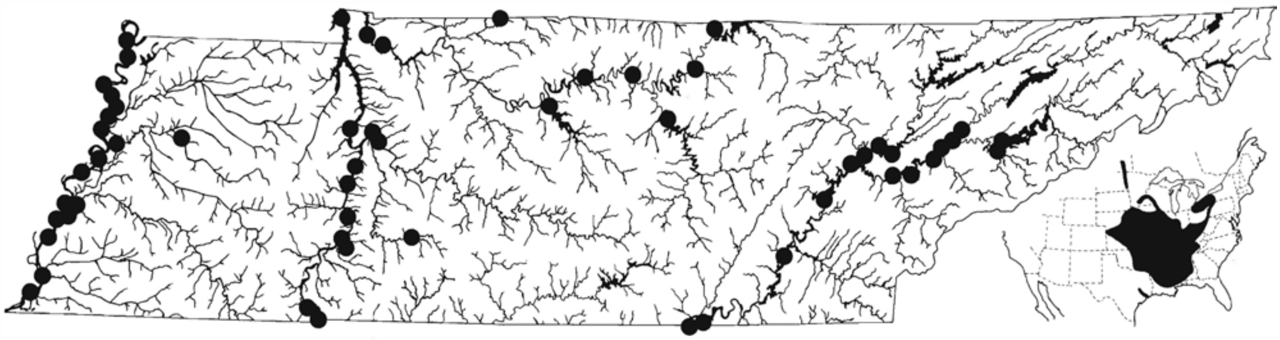
Silver chub

Plate 62. *Macrhybopsis storeriana*, silver chub, 105 mm SL, Tennessee R., TN.

Characters: Lateral-line scales 38–39 (35–41), predorsal scale rows 14–16. Anal fin rays 8 (7–8). Pectoral fin rays 17–18. Pelvic fin rays 8. Four to 6 blunt gill rakers. Pharyngeal teeth 1,4-4,1. Breast naked or occasionally scaled posteriad. Color silvery without distinctive dark markings. Lower lobe of caudal fin dark with pale ventral border. Adult males have large, uniserial tubercles on the dorsal surface of pectoral fin rays 2–



Range Map 60. *Macrhybopsis meeki*, sicklefin chub.



Range Map 61. *Macrhybopsis storeriana*, silver chub.

10, and barely detectable small granulations or pointed tubercles on the top and sides of the head. No other tubercles were in evidence.

Biology: The silver chub is a large, weakly pigmented minnow that occurs in big rivers throughout central United States and persists in some reservoirs. Although it may occur at considerable depth, most of our specimens have been taken in water about 1 meter deep with some current over sandy or silty sand substrates. Gut contents from Tennessee specimens included a variety of aquatic and terrestrial insect larvae, pupae, and adults; plant seeds; and large numbers of the introduced Asiatic clam, *Corbicula*. It is one of only a few Tennessee fishes that has adapted to this abundant but relatively new and unexploited food source, and this may in part explain its tolerance of reservoirs, where *Corbicula* is often abundant. Large adults are occasionally caught by anglers fishing with worms. Britt (1955) indicated extensive feeding on the burrowing mayfly, *Hexagenia*, in Lake Erie. Additional life history information is available in Starrett (1951), Kinney (1954), Williams (1963), and Becker (1983). Spawning occurs in June (probably May in our area). Spawning habitat is not entirely known. Growth estimates vary widely from about 80–130 mm TL at age 1 and 130–160 at age 2. Sexual maturity is apparently reached in 1 year. Life span is 4 years. Our collections contain a surprisingly large percentage of females. Maximum total length 231 mm (9.1 in).

Distribution and Status: Occurs throughout much of Mississippi River basin, and in the Lake Erie drainage and Red River of the North (Hudson Bay drainage). Also in Gulf of Mexico drainages from Brazos River drainage of Texas east through Mobile Basin. Common in lower Tennessee, Duck, and Mississippi rivers, with most large collections from late summer. Persistent but apparently uncommon in lower Cumberland River and main channel reservoirs of the upper Tennessee River.

Similar Sympatric Species: The large, dorsally placed eye, remoteness of the mouth from the eye, and the bluntly rounded snout give this species an appearance unique among our minnows. Juveniles are somewhat similar to the often sympatric *Notropis blennius*, *N. volucellus* and its allies, *N. shumardi*, and *Hybognathus nuchalis*, all of which lack a maxillary barbel; and to the less common big river chubs *Macrhybopsis meeki* and *Platygobio gracilis*, both of which have small eyes, very falcate fins, and 43 or more lateral-line scales.

Etymology: Named in honor of David H. Storer, an early North American naturalist and ichthyologist.

Genus *Nocomis* Girard
The River Chubs

The genus *Nocomis* consists of a group of seven closely related species which had long been included in the genus *Hybopsis*, primarily due to the presence of a barbel at the tip of the maxilla (Fig. 64b). Modern ichthyologists consider *Nocomis* as a group with full generic status, and with phylogenetic affinities with *Semotilus*, *Couesius*, or *Campostoma* (e.g., Mayden, 1989). They are robust, rather cylindrical fishes with orange-red fins; large scales that are not crowded anterior to the dorsal fin; complete lateral line with 37–44 scales, 7 anal fin rays, 8 dorsal fin rays, 8 pelvic fin rays, 15–19 pectoral fin rays, and large, horizontal, and slightly subterminal mouths. The small eyes are remote from the mouth and are situated near the dorsal border of the head. Both Tennessee species have 4-4 pharyngeal teeth, and breast squamation varies from naked to well scaled. Males develop large nuptial tubercles, primarily on the head, during the breeding season. Tubercles or their scars or primordia, extremely important characters for identifying species, are usually visible in adult females, subadult males, and non-nuptial males. Smaller uniserial tubercles develop on dorsal surfaces of pectoral fin rays 2–7 or 8. All species are nest builders, with males constructing and defending large, shallow depressions in gravel areas in the stream bed during late spring. Similar habits are found in the genera *Campostoma*, *Exoglossum*, and *Semotilus*. Nests are lined with pebbles carried to the site in the mouth of the male. *Nocomis* nests are frequently used as spawning sites by smaller stream cyprinids such as *Clinostomus funduloides*, *Notropis rubellus*, *N. leuciodus*, *Lythrurus ardens*, and species of *Phoxinus*. Adults feed primarily on aquatic invertebrates. *Nocomis leptocephalus*, a species of the Atlantic and Gulf coastal plains, is apparently a vegetarian (Lachner and Wiley, 1971). Males of all species grow to be considerably larger than females. In addition to the two species known to occur in Tennessee, *N. leptocephalus* is a possible future member of the state fauna since it occurs in the Bear Creek system, a southern tributary to Pickwick Reservoir (Tennessee River) in Mississippi and Alabama. It is abundant in the Coosawattee portion of the upper Coosa system but seems to avoid the Conasauga River portion which penetrates Tennessee, perhaps due to physiographic dissimilarities. Two additional species occur in the Atlantic Piedmont region (*N. raneyi* and *N. platyrhynchus*) and additional species occur in the Midwest (*N. bigutattus*) and in the Ozarks (*N. asper*). *Nocomis biguttatus* may have occurred in Tennessee during the Pleistocene based on possible remains found in a cave near the Duck River (Dickinson, 1986). Papers by Lachner and Jenkins (1967, 1971a, 1971b), Lachner and Wiley (1971), and Jenkins and Lachner (1971) provide a great deal of information concerning the systematics, zoogeography, and biology of the genus. Biochemical systematics was treated in part by Ferguson et al. (1981).

In fresh specimens the orange-red caudal fin will serve to separate this genus from other Tennessee cyprinids. Preserved specimens are somewhat similar to *Semotilus*, but *Nocomis* completely lack the black spot at the anterior base of the dorsal fin and have visibly larger scales (about 40 vs. about 50 in *Semotilus*). Small specimens might be confused with either *Campostoma* or *Rhinichthys atratulus*. The former lacks a barbel and has a black peritoneum; the latter has a non-protractile premaxilla.

The distribution of the two Tennessee species is of particular interest. Although there are no verified records of the species occurring together, each species has had ample opportunity to disperse into the range of the other. *Nocomis micropogon* occurs in the Big South Fork of the Cumberland River, while the Little South Fork, a tributary to Big South Fork, has only *N. effusus*. The mouth of Little South Fork is now inundated by Lake Cumberland and no longer offers suitable habitat for *Nocomis*, but the ranges of the two species may have overlapped near there prior to impoundment of Lake Cumberland. In middle Tennessee the Duck River contains only *N. effusus*, while its large tributary, the Buffalo River, has only *N. micropogon*. It would appear at first glance that the presence of one of the species of *Nocomis* precludes the establishment of a population of the other species and that competitive interactions are involved. But since the habitat preference of *micropogon* for larger streams and of *effusus* for smaller streams would imply the availability of additional unoccupied habitat for either species within the range of the other, competition, if occurring, does not provide an entirely satisfactory explanation. Virtual restriction of *effusus* to Highland Rim habitats which are only marginally occupied by *micropogon* suggests a powerful physiographic component to these distributions.

Etymology: *Nocomis* is an Indian name originally applied to this group of fishes.

KEY TO THE TENNESSEE SPECIES

1. Scale rows around caudal peduncle 17 or fewer (rarely 18 or 19); nuptial tubercles on head extend from tip of snout to interorbital area . . . . *N. micropogon* p.198

   Scale rows around caudal peduncle 19 or more (rarely 17 or 18); nuptial tubercles on head extend from internasal area to occiput . . . . *N. effusus*

Nocomis effusus Lachner and Jenkins

Redtail chub

Plate 63. *Nocomis effusus*, redtail chub, 75 mm SL, Cumberland R. system, TN.

Characters: Lateral-line scales 39–44, predorsal scale rows 18–22, body circumferential scales 34–39. Gill rakers 8–10, length of longest rakers 1–1.5 times their basal width. Vertebrae 40–42. Overall color olivaceous dorsally, yellowish ventrally. Fins bright orange to orange-red, especially in young. Adult males develop a red postorbital spot, nuptial tubercles from near the tip of the snout to the occiput, and single or paired tubercles on dorsolateral and midlateral scales. Nuptial males do not develop swollen heads characteristic of *N. micropogon*. Other characters included in generic account and key.

Biology: The redtail chub prefers relatively small, clear upland streams with predominantly gravel substrates. Adults are wary and difficult to collect with seines. Its biology has not been studied, but is presumably similar in many respects to that of the river chub. Based on nuptial specimens, spawning occurs in late spring. Maximum size 202 mm SL (about 245 mm [10 in] TL).

Distribution and Status: An uncommon species of primarily Highland Rim habitats in much of the Cumberland River drainage, Duck River system of the Tennessee drainage, and the Barren and Green river systems of the Ohio drainage. Apparently strongly tied to Mississippian gravel habitats of the Highland Rim. Rarity of adults in collections may be a collecting artifact, since juveniles are often fairly common. Additional comments included in generic account.

Similar Sympatric Species: See generic account for *Nocomis*.

Etymology: *effusus* refers to the proliferation of tubercles over the head and body. It is the most extensively tuberculate species of the genus.

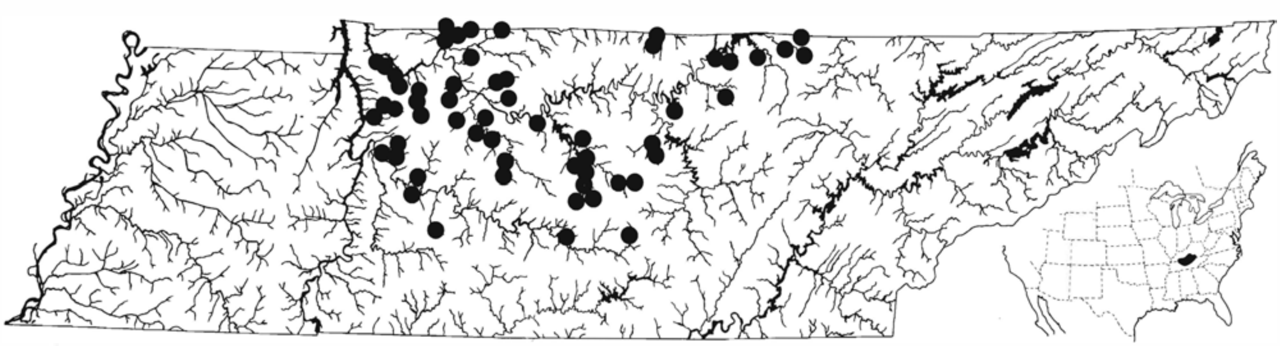
Nocomis micropogon (Cope)

River chub

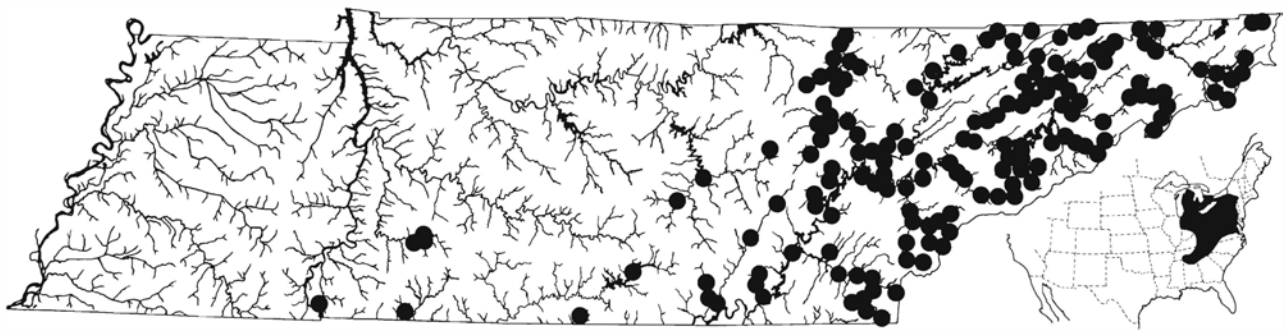
Plate 64a. *Nocomis micropogon*, river chub, juvenile, 42 mm SL, Little R., TN.

Plate 64b. *Nocomis micropogon*, river chub, breeding male, 160 mm SL, Nolichucky R. system, TN.

Characters: Lateral-line scales 37–43, predorsal scale rows 16–18, body circumferential scales 28–36. Gill rakers 7–8, length of longest rakers twice their basal width. Vertebrae 38–41. Color dark olivaceous above to dusky yellowish ventrally. Nuptial males develop swollen heads, pinkish-purple coloration on the body,



Range Map 62. *Nocomis effusus*, redtail chub.



Range Map 63. *Nocomis micropogon*, river chub.

and cephalic tubercles restricted to the area from the eyes to the snout tip. Other characters included in generic account and key.

Biology: The river chub is often taken by anglers, since the favored habitats include large creeks to small rivers with rapid current, cool waters, and rocky substrates. Like the stoneroller, tuberculate males are sometimes termed "hornyheads." In Tennessee, spawning occurs during late spring. The following biological information is from Lachner (1952) who studied New York populations. Fecundity of females probably ranges from 500 to 1,000 ova; presumably they spawn in the nests (see genus introduction) of several different males over a season. As might be expected for a communal spawner, hybrids are known, with species of *Clinostomus*, *Luxilus*, *Notropis*, and *Rhinichthys*. Young attain about 60 mm SL the first year and reach 95–110 mm and sexual maturity the second year. After sexual maturity males grow more rapidly than females and attain greater size, with their lengths averaging respectively about 140 and 120 at age 3 and 180 and 130 at age 4. Maximum life span is 5 years. Southern populations may grow more rapidly and be shorter lived. However, it seems likely that extremely large males represent age class 5 or even 6. Maximum size 270 mm SL (about 330 mm TL or 13 in) reported by Lachner and Jenkins (1971a).

Distribution and Status: Widespread in Great Lakes basin (except Lake Superior), upper and middle Ohio and Tennessee river drainages, upper Cumberland River drainage, and Atlantic Coast drainages from Susquehanna River south through James River. Also native in upper Savannah River drainage, and present (introduced?) in Santee River drainage and portions of Coosa River system of Mobile Basin. Abundant in Blue Ridge, Ridge and Valley, and Cumberland Plateau in Tennessee and Cumberland drainages. See further discussion under generic account.

Similar Sympatric Species: See *Nocomis* generic account.

Etymology: *micro* = tiny, *pogon* = beard, referring to the small barbel at the tip of the maxilla.

Genus *Notemigonus* Rafinesque

Notemigonus is a generalized cyprinid with no obvious close affinities with other North American cyprinids, and has been considered closely related to Eurasian minnows (Gill, 1907; Cavender and Coburn, 1989); however, Howes (1981) found no evidence of such a relationship. A single species comprises the genus.

Notemigonus crysoleucas (Mitchill)

Golden shiner

Characters: Lateral line decurved and complete with 45–55 scales, predorsal scale rows about 22–27. Dorsal fin rays 8. Anal fin rays 12–15 in Tennessee (8–19 throughout its range). Pectoral fin rays 15–18. Pelvic fin rays 9 (8–10). Gill rakers 17–22, length of longest rakers about 4 times their basal width. Pharyngeal teeth 5-5. Vertebrae 37–39. Breast scaled. Belly with sharp, naked keel between pelvic fin base and anus (Fig. 69). Adults silvery to golden. Juveniles with a broad, dark, lateral stripe, especially when taken from clear waters. The following tubercle description was provided by R. E. Jenkins: Nuptial males develop small, scattered tubercles on the top of the head from the internasal area to the occiput, on sides of the head, especially on posterior and ventral portions of opercles, and on lower jaw and branchiostegal rays. All lateral scales have several

Plate 65a. *Notemigonus crysoleucas*, golden shiner, 110 mm SL, Reelfoot L., TN.

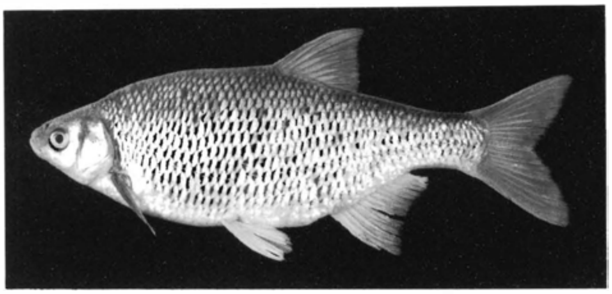


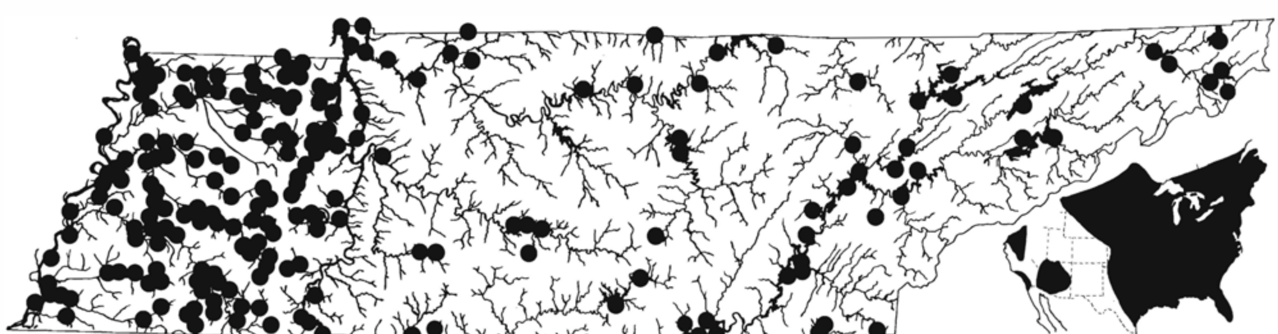
Plate 65b. *Notemigonus crysoleucas*, golden shiner, large preserved adult, 190 mm SL, Norris Res., TN.

tiny, marginal tubercles. Tiny tubercles occur on rays of all fins, including both dorsal and ventral surfaces of pectoral and pelvic fin rays.

Biology: The golden shiner is a popular bait minnow occurring in the quiet waters of natural lakes, swamps, oxbows, rivers, and large creeks, and is also quite tolerant of reservoir conditions. Biological information has been abstracted from McLane (1955), Scott and Crossman (1973), and Becker (1983). Spawning has been reported to occur from late spring through midsummer at water temperatures of 68–80 F, but McLane (1955) noted November and December spawning in Florida. The eggs are adhesive and are typically shed over submerged vegetation, but several workers have reported golden shiners spawning over centrarchid nests. During spawning, one or two males pursue a single female, often nudging her with their snouts and swimming in rapid circles. Sexual maturity is reached at lengths of 65–85 mm (2.5–3.5 in), usually after 2 years' growth. Life span may be as long as 8 years. Stomach contents reflect midwater feeding habits, and consist primarily of zooplankters (mostly cladocera) and midge pupae, with an assortment of terrestrial insects, aquatic insect larvae, filamentous algae, and gastropods. Large adults are occasionally taken by anglers. Techniques for propagation of these minnows as bait have been elaborated on by Prather et al. (1953) and Flickinger (1971). The golden shiner is not known to hybridize with any other North American minnow but is capable of hybridizing under artificial conditions with the Eurasian rudd, *Scardinius erythrophthalmus*, an introduced bait species which it may encounter in nature (Burkhead and Williams, 1991). Maximum total length 367 mm (14.5 in) reported by McLane (1955).

Distribution and Status: Widespread throughout central and eastern United States and southern Canada, and widely introduced in western United States. Most abundant on the Coastal Plain. Probably rare or absent from east and middle Tennessee prior to reservoir construction, but now established in larger waters of these areas as a result of bait bucket introductions or expansion of once-scattered populations.

Similar Sympatric Species: The deep-bodied, flat-sided form of the golden shiner is unique among our minnows, and is approached only by *Lythrurus umbratilis*, which has the dorsal fin origin far behind the origin of the pelvic fins, 2,4-4,2 pharyngeal teeth, 11 or fewer anal fin rays (rarely 12), 8 pelvic fin rays, an oblique rather than vertical mouth, and the region between the pelvic fin base and anus is rounded and covered with scales (naked and keeled in *Notemigonus*).



Range Map 64. *Notemigonus crysoleucas*, golden shiner (disjunct western populations represent introductions).

Large adults might be confused with our herring-like fishes, especially *Dorosoma* and *Hiodon*, all of which have adipose eyelids, 18 or more anal fin rays, silvery color, and midventral keels that are covered with scales.

Etymology: *Notemigonus* = angled back; *cryso* = gold, *leucas* = white.

Genus *Notropis* Rafinesque
The Shiners

Students of North American cyprinids have for many years been in agreement that the genera *Hybopsis* and *Notropis* of the past several decades were not natural (monophyletic) taxa. Both genera included species that were most closely related to species outside their genus (polyphyletic) and failed to include species that were closest relatives (paraphyletic). We treat former *Notropis* subgenera *Cyprinella*, *Luxilus*, and *Lythrurus* as genera. The resulting more restricted genus *Notropis* is hardly monophyletic, and additional lineages within *Notropis* are likely to be recognized as genera when reasonable confidence concerning their monophyly develops. Even with recognition of *Cyprinella*, *Luxilus*, and *Lythrurus*, *Notropis* is still a large genus of about 75 species. In all Tennessee *Notropis* except *N. maculatus* the lateral line is complete with 35–40 scales, dorsal fin rays 8, anal fin rays 7–12, premaxillae protractile, pharyngeal teeth 4-4 in the greater row, mouth not greatly modified and lacking barbels, intestine short and S-shaped, with a single loop. Most of our species have a silvery or speckled peritoneum (*boops* and *telescopus* are exceptions) and are silvery in life, with red and yellow breeding colors developing in many species.

Several additional species of *Notropis* may eventually be discovered in Tennessee with extensive collecting in the Mississippi River and its adjacent lowlands, as was the recently discovered *N. dorsalis*, a primarily upper Mississippi Valley species previously known only from southern Illinois and northward. Among such are *N. hudsonius*, which has been taken as far south as southern Illinois in the Mississippi River; *N. chalybaeus* and *N. hubbsi*, which occur in the Mississippi River lowlands to the north, south, and west of Tennessee; *N. candidus* and *N. edwardraneyi*, which will likely enter the Tennessee River from the Tombigbee River via the Tenn-Tom canal; and *N. baileyi*, known from the Bear Creek system, tributary to Pickwick Reservoir, Alabama and Mississippi.

The systematics of *Notropis* has been under study by Mayden (1989), Amemiya and Gold (1990), and M. M. Coburn and T. M. Cavender. Gilbert (1978) provided an important type catalog for the nominal species of *Notropis*, many since reallocated to other genera.

Etymology: *Notropis* = keeled back.

Following are current thoughts concerning relationships within this very diverse genus. We emphasize that the diagnoses of nominal and provisional subgenera are based on characters which, in some cases, do not conclusively indicate monophyly (common origin) for members of the various groups.

Subgenus *Alburnops* Girard

Characters (as here restricted) include 2,4-4,2 pharyngeal teeth, anal fin rays 8 or fewer, absence of bright breeding colors, non-elevated anterior lateral-line scales, about 14–16 predorsal scale rows, heavy and robust body form, big-river habitats, and tubercles small and typically on dorsal surface of head and dorsal surfaces of pectoral fin rays 1 or 2 through 7 to 9. Pectoral fin tubercles arranged in 2 rows (biserial), 2–4 tubercles per fin ray segment, continuing as single rows on each branch of fin ray. *Notropis blennius* is the type species, and the only Tennessee species included under present concepts. Additional species provisionally assigned to this subgenus include *edwardraneyi* of the Mobile drainage, and *bairdi*, *buccula*, *girardi*, *orca*, *potteri*, and *simus* of southwestern states (Mayden, 1989). *Alburnops* has traditionally been a catch-all subgenus for *Notropis* of uncertain affinities (Snelson, 1971). Whether additional species, such as *N. volucellus* and its allies, *N. stramineus*, *N. spectrunculus* and its allies, or the *N. longirostris* group, should be included remains problematic. Mayden (1989) hypothesized affinities of the latter group with *Hybopsis* and *Ericymba*. Coburn and Cavender (1987) hypothesized close relationships between *Alburnops* and members of the subgenus *Notropis* and genus *Hybognathus*. Pertinent references also include Suttkus and Clemmer (1968), Swift (1970), Chernoff et al. (1982), and papers listed under the subgenus *Notropis*.

Subgenus *Hydrophlox* Jordan

Characters include small maximum size, red or yellow breeding colors, 2,4-4,2 pharyngeal teeth (usually 1,4-4,1 in *leuciodus*), naked or weakly scaled breasts, and strictly uniserial (1 per fin ray segment) tubercles on pectoral fin rays. Studied species often spawn over the gravel nests of other fish species, usually during spring, and most species feed on both terrestrial and aquatic insects. Although many small, upland species of *Notropis* with 2,4-4,2 pharyngeal teeth have previously been placed in *Hydrophlox*, Swift's (1970) restriction of the subgenus appears to result in a natural grouping of related forms, although the inclusion of *rubellus* is in question (Mayden and Matson, 1988). Tennessee species include *chrosomus*, *leuciodus*, *rubellus*, and *rubricroceus*. Additional species include *chiliticus*, *chlorocephalus*, *lutipinnis*, and *baileyi* from Atlantic and Gulf coastal drainages, and *nubilus* (formerly placed in the genus *Dionda*) from the Ozarks and upper Midwest. Coburn and Cavender (1987) hypothesized *Hydrophlox* to be related to members of the *Notropis texanus*, *N. stramineus*, and *N. volucellus* species groups (roughly corroborated by Mayden, 1989) while Mayden and Matson (1988) hypothesized a closest relationship to members of *Notropis* s.s. and *Cyprinella*.

Subgenus *Notropis* Rafinesque

Characters include terminal and oblique jaws, anal fin rays usually 9 or more, pharyngeal teeth 2,4-4,2, absence of bright breeding colors, decurved lateral line with non-elevated anterior lateral-line scales, large-stream to large-river habitats, and tubercles small and typically covering entire head, forming a marginal row on body scales, and in 2–4 rows, 3–6 tubercles per row per fin ray segment, on dorsal surfaces of first 8–10 pectoral fin rays. Tubercles weak or absent on other fins. Form elongate, slender, and slab-sided with dorsal fin origin slightly to far behind pelvic fin insertion, adult size often large, breast usually naked, predorsal scale rows usually 15–20. These are considered to be the least derived species of the genus *Notropis*. Tennessee species include *ariommus*, *atherinoides*, *photogenis*, *shumardi*, *stilbius*, and *telescopus*. Additional species are *amabilis*, *jemezanus*, and *oxyrhynchus* of Gulf drainages in the Southwest; *amoenus*, *scabriceps*, *scepticus*, and *semperasper* of Atlantic drainages and the upper New (Kanawha) system; *candidus* of the Mobile Bay drainage; and probably the tiny and rather divergent *perpallidus* of the Ozark region. Limits of the subgenus are not distinct, and affinities with *Alburnops*, the *Notropis texanus* species group (Mayden, 1989), other unplaced *Notropis* species, and *Hybognathus* have been speculated. The above restriction of the subgenus may constitute a natural grouping (but see remark under genus *Lythrurus*), but other legitimate members may have been excluded. Pertinent references include Gilbert (1961a, 1969), Gilbert and Bailey (1962), Snelson (1968, 1971), Swift (1970), Suttkus (1980), Chernoff et al. (1982), Coburn (1982a), Coburn and Cavender (1987), Mayden (1989), and Mayden and Matson (1988).

The Tennessee fauna of 26 species currently assigned to the genus *Notropis* includes 11 species that can be assigned to the above subgenera with some confidence. Of the remaining 15 species, the closest relative of *maculatus* may be *Opsopoeodus emiliae*, as has been suggested by Gilbert and Bailey (1972), but the relationship is not well substantiated, and *Opsopoedus* is hypothesized to have affinities with *Pimephales* by other workers (Cavender and Coburn, 1985; Johnston and Page, 1988). The 14 remaining species ("palezone shiner," "sawfin shiner," *ammophilus*, *asperifrons*, *boops*, *buchanani*, *dorsalis*, *rupestris*, *spectrunculus*, *stramineus*, *texanus*, *volucellus*, *wickliffi*, and *xaenocephalus*) lack any thus far apparent shared specializations with any of the established subgenera, although some species groups among these and extralimital forms are evident based on such derivations (e.g., *spectrunculus-ozarcanus*-"sawfin shiner"; *volucellus-buchanani-cahabae-wickliffi*; *ammophilus-longirostris-sabinae*). Mayden (1989) included Atlantic slope species *alborus* and *bifrenatus*, plus *dorsalis* and *Ericymba buccata*, in the *N. longirostris* group. Mayden (1989) and Mayden and Kuhajda (1989) included *ozarcanus*, *spectrunculus*, *volucellus*, *wickliffi*, *cahabae*, *buchanani*, *rupestris*, *maculatus*, and *Opsopeodus emiliae* in the "*volucellus* species group." Coburn (1982a) and Mayden (1989) also recognized a *Notropis texanus* species group that contains the Tennessee species *boops*, *texanus*, and *xaenocephalus*, plus extralimital species *anogenus*, *altipinnis*, *chalybaeus*, *heterodon*, and *petersoni*. Only one currently recognized subgenus of *Notropis* is not represented in Tennessee, *Pteronotropis* Fowler (regarded as a genus by Mayden, 1989), whose members are restricted to the lower Coastal Plain from Mississippi to South Carolina.

KEY TO THE TENNESSEE SPECIES OF THE GENUS NOTROPIS

1. Anal fin rays modally 9 to 11; pharyngeal teeth 2,4–4,2 2
   Anal fin rays modally 7 or 8; pharyngeal teeth variable 8
2. Dorsal fin origin far behind origin of pelvic fins (Fig. 83a) 3
   Dorsal fin origin directly above origin of pelvic fins or nearly so (Fig. 83b) 4

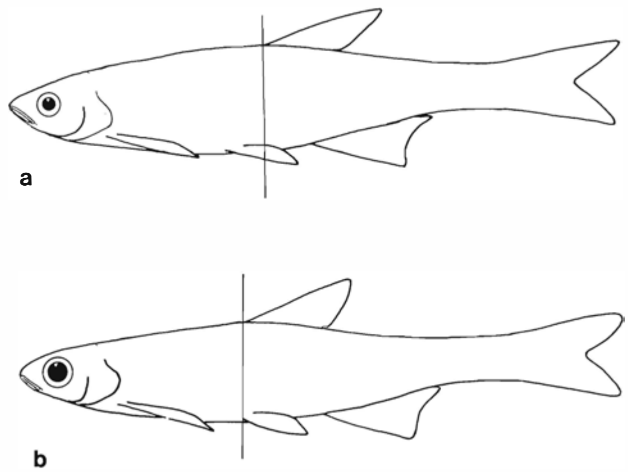


Figure 83. Dorsal fin positions of minnows: a) *Notropis atherinoides*; b) *N. telescopus*.

3. Anal fin with concave margin when expanded; dorsal fin pointed, with tip of anterior ray reaching well beyond tip of posterior ray when fin is depressed; lateral stripe pale anterior to dorsal fin where it is composed of small, discrete punctulations (Pl. 69); never develops red colors; big rivers and reservoirs .... *N. atherinoides* p.210
   Anal fin with margin straight when expanded; tips of anterior rays of dorsal fin do not quite reach tip of posterior ray when fin is depressed; lateral stripe fades anterior to dorsal fin but melanophores are more crowded, giving a shaded appearance (Pl. 78); nuptial males with red in life; large creeks and small rivers .... *N. rubellus* p.220
4. Modal number of anal fin rays 10 or more 5
   Modal number of anal fin rays 9 7
5. Predorsal scale rows 16 or fewer; each dorsolateral scale with a dark margin and anterior to this a pale area bordered anteriorly by another dark line (Fig. 84, Pl. 85) .... *N. telescopus* p.229

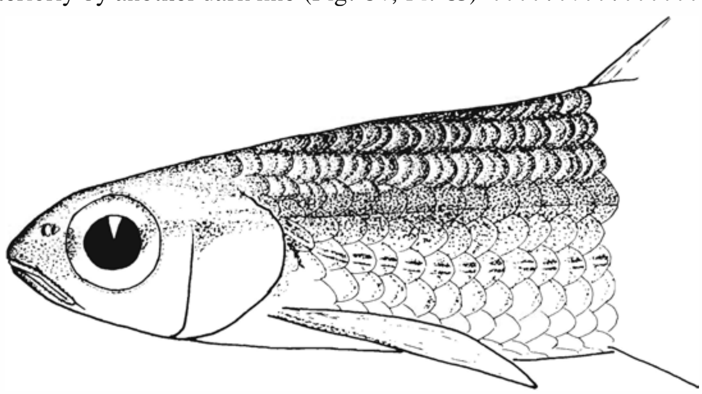


Figure 84. Pigmentation of scales in *Notropis telescopus*.

   Predorsal scale rows 17 or more; each dorsolateral scale pale with a single dark marginal concentration of melanophores 6

6. Pelvic fin rays 9; lateral stripe with anteriodorsal margin bluntly saw-toothed (Pl. 77); Cumberland, Tennessee, and Ohio river drainages . . . . *N. photogenis* p.219
Pelvic fin rays 8; dorsal margin of lateral stripe straight (Pl. 83); Mobile Basin . . . . *N. stilbius* p.227

7. Eye very large; its diameter about equal to the interorbital width, and longer than the snout (Pl. 67); pelvic fin rays 8; cast and middle Tennessee . . . . *N. ariommus* p.208
Eye diameter less than interorbital width and about equal to snout length (Pl. 81); pelvic fin rays often 9; Mississippi River proper, lower Cumberland River, and anticipated in lower Tennessee River (Hiwassee River *N. leuciodus* will key here) . . . . *N. shumardi* p.224

8. Anal fin rays modally 8 9
Anal fin rays modally 7 20

9. Anterior 3 to 5 lateral-line scales with exposed area much (2.5 to 4 times) deeper than wide, subrectangular in shape, and with posterior margin vertical (Fig. 85a); lateral stripe much darker on caudal peduncle, fading anteriad; pharyngeal teeth 4-4 10
Anterior 3 to 5 lateral-line scales with exposed area 1.5 to 2.5 times deeper than wide, with posterior edges of these scales rounded, and similar in shape (although may be slightly larger and deeper) to adjacent scales above and below (Fig. 85b); lateral stripe uniformly dark from head to base of caudal fin (except in *dorsalis*); pharyngeal teeth variable 14

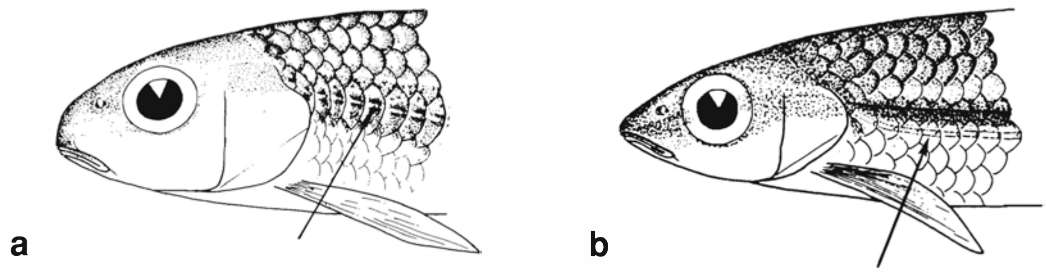


Figure 85. Shapes of anterior lateral-line scales in minnows: a) *Notropis volucellus*; b) *N. leuciodus*.

10. Coloration very pallid, with little trace of a lateral stripe, caudal spot, or dark edgings on dorsolateral scales (Pl. 72); peritoneum silvery; infraorbital canal absent or broadly interrupted under eye (Fig. 86a) . . . . *N. buchanani* p.214
Darker fishes with lateral stripe conspicuous on caudal peduncle, a triangular caudal spot, and dark-edged dorsolateral scales; peritoneum speckled with dark pigment; infraorbital canal complete (Fig. 86b) 11

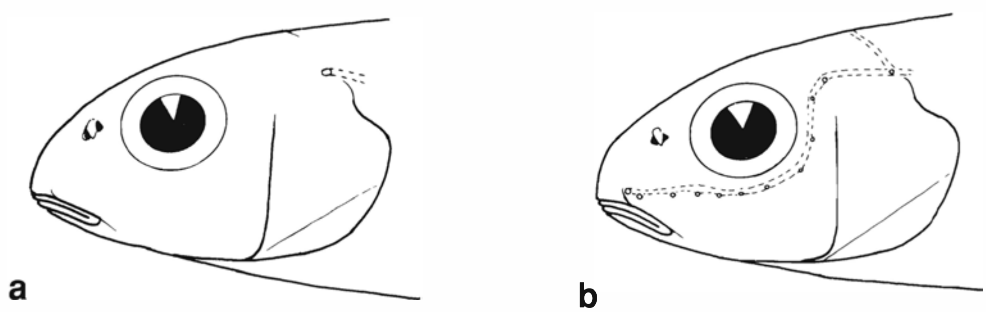


Figure 86. Infraorbital canals of minnows: a) *Notropis buchanani* (completely lacking in this specimen); b) *N. volucellus* (complete).

11. All dorsal fin rays outlined with melanophores (Fig. 87a) 12
Only the 4 anterior dorsal rays outlined with melanophores (Fig. 87b) . . *Notropis* sp., "sawfin shiner" p.236

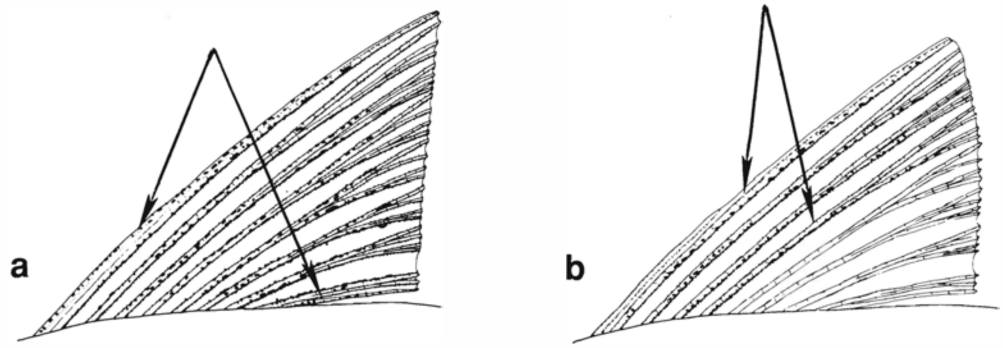


Figure 87. Pigmentation of dorsal fin rays in minnows: a) *Notropis volucellus*; b) *Notropis* sp. ("sawfin shiner").

12. Dorsal fin sharply pointed, the tips of the anterior rays extending past the tips of the posterior rays when fin is depressed; never with red on fins; snout somewhat angular in side view 13
Adults with dorsal fin rounded, the tips of the anterior rays not reaching past tips of posterior rays when fin is depressed (Pl. 82); adult males with red on fins in spring and summer; snout smoothly rounded in side view; Blue Ridge Province of east Tennessee . . . . *N. spectrunculus* p.226

13. Post dorsal dark streak absent or nearly so (Fig. 88a); breast with some scales posteriad where sympatric with *N. wickliffi*; widespread . . . . *N. volucellus* p.232
Post dorsal streak dark and continuous (Fig. 88b); breast and anterior belly naked; restricted to big rivers . . . . *N. wickliffi* p.233

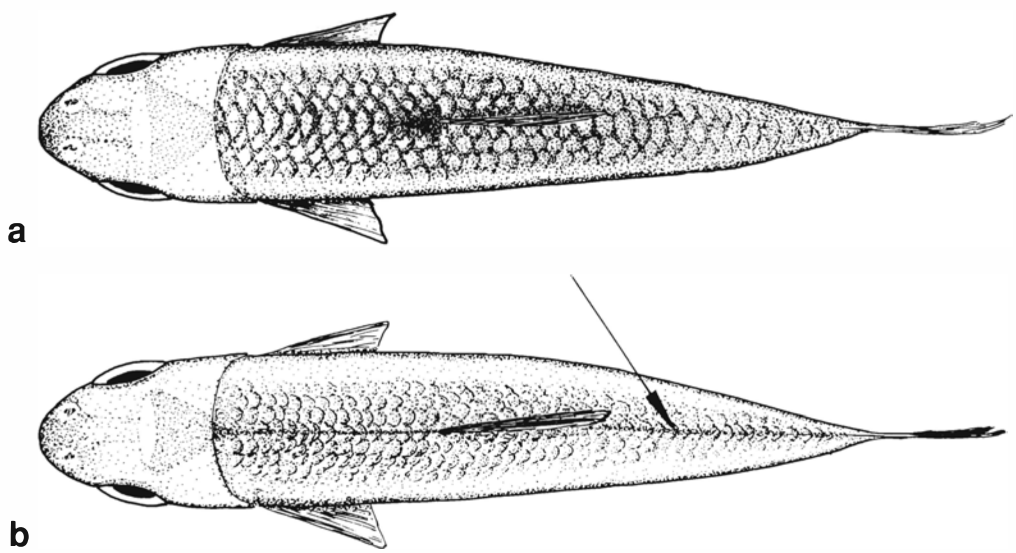


Figure 88. Postdorsal pigmentation of minnows: a) *Notropis volucellus*; b) *N. wickliffi*.

14. Lateral line very incomplete; large, black, round caudal spot distinctly deeper than lateral stripe, and with a smaller black triangle at dorsal and ventral origin of caudal fin (Pl. 76); west Tennessee . . . . *N. maculatus* p.218
Lateral line complete; caudal spot, if present, is rectangular and no deeper than lateral stripe 15

15. Lateral dark stripe prominent from head to caudal fin base, above this a pale stripe 16
Lateral dark stripe apparent only on caudal peduncle, no pale stripe above it (Pl. 74); known only from Bear Creek, Tipton County . . . . *N. dorsalis* p.216

16. Both lateral dark stripe and pale stripe above it of uniform width and intensity from head to caudal fin base (Pls. 73, 80) 17
Lateral dark stripe much deeper anterior to anal fin than on caudal peduncle; pale stripe above it deepest on caudal peduncle (Pls. 71, 75, 79) 18
17. Tip of snout overhangs horizontal mouth (Pl. 80); breast well covered with exposed scales; pharyngeal teeth 4–4; Nashville Basin of middle Tennessee . . . . . *N. rupestris* p.223
Mouth terminal and oblique (Pl. 73); breast mostly naked or with scales embedded; pharyngeal teeth 2,4–4,2; Mobile Basin . . . . . *N. chrosomus* p.215
18. Dark scale edgings apparent within lateral stripe in area anterior to pelvic fins, and with dark pigment extending at least a full scale row below lateral line (Pl. 79) . . . . . *N. rubricroceus* p.222
Dark scale edgings not apparent in anterior portion of lateral stripe, and little if any pigment below lateral-line scale row 19
19. Dorsal fin sharply pointed, with tips of anterior rays extending 1 scale or more past tips of posterior rays when fin is depressed; lateral stripe expands slightly at caudal base, but does not form a darker rectangular spot (Pl. 71) . . . . . *N. boops* p.213
Dorsal fin with vertical margin, tips of anterior rays even with tips of posterior rays when fin is depressed; lateral stripe terminates in a darker rectangular caudal spot (Pl. 75) . . . . . *N. leuciodus* p.217
20. Midlateral black stripe of uniform intensity extends from head to caudal fin base; above this a pale stripe . 23
Midlateral black stripe absent, weakly developed, or much darker on caudal peduncle; no pale stripe above dark stripe 21
21. Scales above lateral line and anterior to dorsal fin strongly edged with black and virtually lacking dark pigment elsewhere; mouth inferior and horizontal (Pls. 66, 84); pharyngeal teeth 4-4 22
Scales above lateral line and anterior to dorsal fin rather uniformly pigmented; mouth terminal and oblique (Pl. 70); pharyngeal teeth 2,4-4,2; big rivers . . . . . *N. blennius* p.211
22. Melanophores edging lateral scales in straight lines, forming diamond-shaped patterns; eye diameter more than 80% of caudal peduncle depth; no dark scale edgings on scales below lateral line on caudal peduncle (Pl. 84) . . . . . *N. stramineus* p.228
Melanophores edging lateral scales forming curved lines; eye diameter less than 70% of caudal peduncle depth; some scales below lateral line on caudal peduncle with dark edgings (Pl. 66); Hatchie River system of west Tennessee . . . . . *N. ammophilus* p.207
23. Very slender shiners, with maximum body depth contained 5 or more times in standard length; predorsal dark streak weak to absent and postdorsal dark streak absent 24
Maximum body depth contained fewer than 5 times in SL; both pre- and postdorsal dark streaks present . . 25
24. Caudal spot deeper than width of adjacent lateral stripe; scales in scale row below lateral line with dark edges (Pl. 68); Conasauga River . . . . . *N. asperifrons* p.209
Caudal spot not as deep as width of adjacent lateral stripe; scales in row below lateral line lacking dark edges (Pl. 90); Tennessee and Cumberland drainages . . . . . *Notropis* sp., "palezone shiner" p.235
25. Only posterior 2 or 3 anal fin rays margined with melanophores (Fig. 89); breast naked; Tennessee River drainage . . . . . *N. texanus* p.230

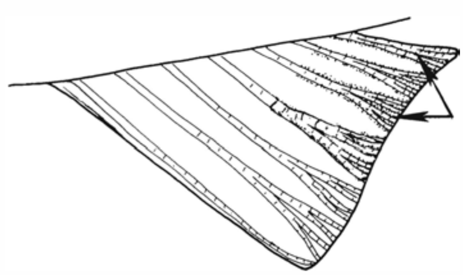


Figure 89. Pigmentation of anal fin rays of *Notropis texanus*.

Anterior and posterior anal fin rays with similar pigment; breast with some large scales; Conasauga River . . . . . *N. xaenocephalus* p.234

Notropis ammophilus Suttkus and Boschung

Orangefin shiner

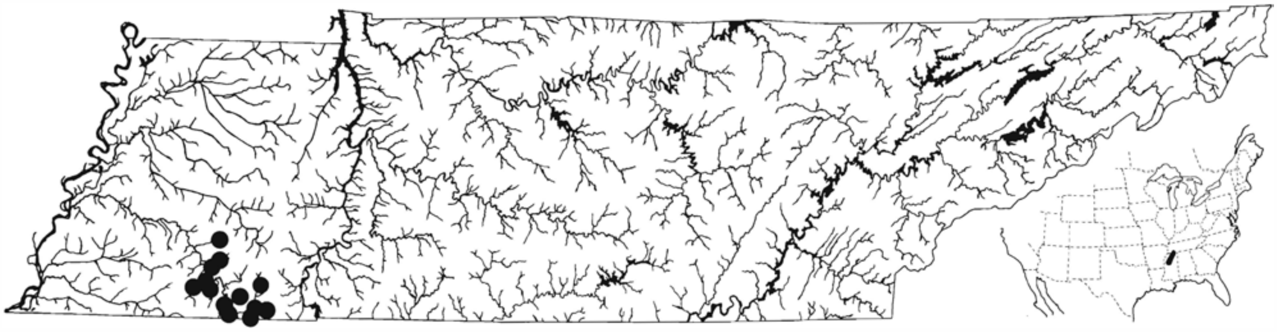
Plate 66a. *Notropis ammophilis*, orangefin shiner, 44 mm SL, Hatchie R. system, TN.

Plate 66b. *Notropis ammophilis*, orangefin shiner, breeding male, 42 mm SL, Hatchie R. system, TN.

Characters: Lateral-line scales 33–35 (32–36), predorsal scale rows 13–15 (12–16). Anal fin rays 7. Pectoral fin rays 13–15 (13–16). Pelvic fin rays 8. Gill rakers vestigial or reduced to about 7–10 rudiments. Pharyngeal teeth 4-4. Breast and anterior belly naked. Vertebrae 34–35. Pre- and postdorsal dark streaks well developed. Mouth large, ventral, and horizontal. Nuptial males are orange on the snout and lips and yellowish on top of the head and on preorbital areas. All fins are reddish orange with white leading edges. Nuptial tubercles are scattered over the top of the head, form a single row over the orbits, and are smaller and more dense on the snout. Smaller tubercles continue on margins of dorsal scales from the occiput to the dorsal fin. The first pectoral fin ray has scattered conical tubercles, and the dorsal surface of rays 2–7 has a dense shagreen of tiny tubercles concentrated near the middle of the rays. Distal to the branching of pectoral fin rays, tubercles occur in about 2 or 3 vague rows on the anterior branch, and usually as a single row with about 5 tubercles per ray segment on the posterior branch. Tubercles are conical, small, and usually 1 per ray segment on rays of other fins, and are more concentrated on the leading edges of the pelvic, dorsal, and anal fin rays, and on the dorsal and ventral margins of the caudal fin. Tubercles occasionally develop on the lower jaw of males, and females may have a few scattered tubercles, especially on the head and pectoral fins.

Biology: The orangefin shiner occurs in moderate current over sandy substrates, often in very shallow water, in creeks and rivers of the Coastal Plain where it is often the most abundant fish (Suttkus and Boschung, 1990). It typically forms large schools which alternately swim upstream and drift downward through shallow sandy runs, occasionally taking cover in depressions or behind snags. As has been noted for several species occupying these drastically fluctuating habitats, the spawning season extends over much of the warm season, occurring from April through September in this species (Heins et al., 1980). Biology otherwise unstudied but probably very similar to that of the closely related *N. longirostris* and *N. sabinae* as reported by Hubbs and Walker (1942), Heins and Clemmer (1975, 1976), and Heins (1981). In spawning season, males and females congregate over shallow, sandy areas with moderately swift current. Individual males court females by pursuing and contacting them with their snout and pectoral fins. During this time males defend the area around the female from other males. In the orangefin shiner, females produce about 100–325 eggs per year, and reproductive effort is concentrated in early and late-season spawning peaks, with young from the early peak maturing late the next summer after 1 year's growth at standard lengths of 23–30 mm; young from the later spawning peak apparently live through two winters and are sexually mature during the spring following their second winter (Heins et al., 1980). Life span is 1.5 to 2 years. Food of the related species is primarily midge larvae, which are typically one of the only food organisms abundant in sandy habitats. Maximum total length about 57 mm (2.25 in).

Distribution and Status: *Notropis ammophilus* is an abundant species that occurs primarily below the Fall Line in the Mobile Basin, the Hatchie River system of Mississippi and Tennessee, Yellow Creek (Tennessee River drainage) of northeastern Mississippi, and the upper Yazoo River system of Calhoun and Ponotoc counties, Mississippi (Suttkus and Boschung, 1990). The remainder of the Yazoo River system is occupied by a similar but undescribed species (pers. comm. R. D. Suttkus). Caldwell (1969) suggested that the Yellow Creek populations resulted from stream capture from the upper Tombigbee River system of the Mobile Basin. Additional closely related species are *N. sabinae*, which occurs primarily west of the Mississippi River, and *N. longirostris*, of eastern tributaries to the Mississippi River from the Big Black south, the Pearl and Pascagoula drainages (west of Mobile Bay), eastern tributaries to the lower Alabama River (where *ammophilus*



Range Map 65. *Notropis ammophilus*, orangefin shiner.

is absent), and from the Apalachicola through the Altamaha river drainages (east of Mobile Bay). *Notropis longirostris* also occurs in the Etowah River system of north Georgia (Mobile Basin), presumably as a result of stream capture from adjacent tributaries of the upper Apalachicola (Chattahoochee River) drainage along with several other species discussed in Bryant et al. (1979a).

Similar Sympatric Species: Occurs with *Hybopsis amnis*, which has 8 anal fin rays and is silvery rather than straw-colored in life.

Systematics: Among described species, most closely related to *N. longirostris* and *N. sabinae*, and perhaps also related to *N. texanus* and its allies (Swift, 1970). However, Titus and Wiley (1988), based on a biochemical study, hypothesized that the orangefin shiner and *longirostris* are closest relatives, with *sabinae* and the similar *N. dorsalis* of the Midwest their next closest relatives, respectively. Mayden (1989) allied these fishes with the *Hybopsis amblops* group and *Ericymba*. Suttkus and Boschung (1990) placed *ammophilus* in the *N. longirostris* species group along with *longirostris*, *sabinae*, and the recently described *rafinesquei* Suttkus (1991) from the Yazoo River system of Mississippi, but they felt that the immediate relationships of that group were still speculative.

Etymology: *ammos* = sand, *philo*, to love, or "lover of sand."

Plate 67a. *Notropis ariommus*, popeye shiner, 65 mm SL, Clinch R., TN.

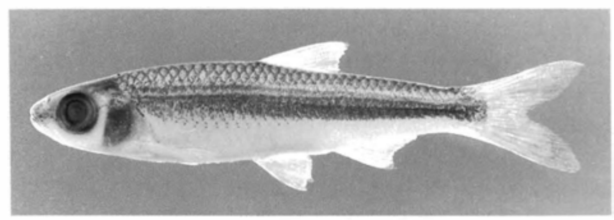


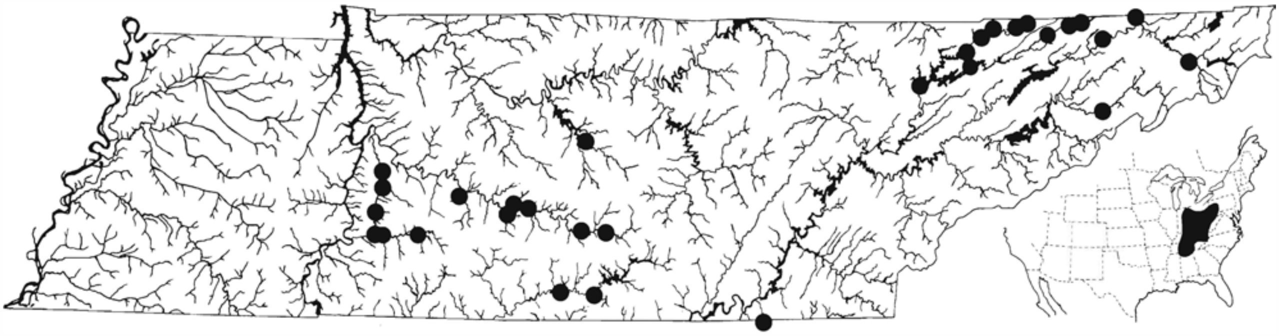
Plate 67b. *Notropis ariommus*, popeye shiner, preserved specimen showing pigmentation patterns, 64 mm SL, Clinch R., TN.

Notropis ariommus (Cope)

Popeye shiner

Characters: Lateral-line scales 35–39, predorsal scale rows 15–18. Anal fin rays 9 (8–10). Pectoral fin rays 14–16. Pelvic fin rays 8. Gill rakers 6–8, length of longest rakers 1–1.5 times their basal width. Pharyngeal teeth 2,4-4,2. Breast scaled. Vertebrae 37–39. Eye diameter more than 1.5 times snout length, and relatively larger than in any other Tennessee cyprinid. Life colors brilliant silver without distinctive markings. Bright breeding colors do not develop. Gilbert's (1969) description of nuptial tubercles agrees closely with our observations. Small tubercles cover the entire head (except the operculum) and anterior portion of the breast. Additional tubercles occur only on the dorsal surface of pectoral fin rays, with 1–2 poorly defined rows of small tubercles on the first ray. On rays 2–11 there are 1–2 rows basad, splitting into 3–4 well-defined rows beyond the fork of the ray. There are about 5 tubercles per row per fin ray segment, and a distinct hiatus occurs at each fin ray joint in the outer half of the fin.

Biology: The popeye shiner is a widespread but rare species that occurs in large streams and small rivers in



Range Map 66. *Notropis ariommus*, popeye shiner.

flowing pool areas with substrates of small gravel and depths of 1 m or deeper. June specimens we examined contained a wide variety of large adult insects including Coleoptera, Diptera, Hymenoptera, and Trichoptera; many midge pupae and adults, and several mayfly nymphs of the genus *Potamanthus*. A prenuptial female 70 mm total length contained about 275 well-developed eggs. Tuberculate males taken from early April through late June suggest a late-spring spawning peak. Maximum total length 100 mm (4 in.).

Distribution and Status: Widespread but with spotty distribution in tributaries to the Ohio River, and in Maumee River, a Lake Erie tributary, in Ohio. Associated with Ridge and Valley and Highland Rim in southern portion of its range. Gilbert (1969) suggested that its abundance is extremely variable from year to year, and that it was actually extremely low in numbers during the first half of this century, possibly due in part to its apparent intolerance of silt. We have found it to be very habitat restricted in the Clinch River, and normally take few if any specimens unless a concentrated effort is made to sample their specific and quite limited habitat. It's 50-year absence from fish collections might be associated with the chance failure of fish collectors of those times to adequately sample the proper habitat.

Similar Sympatric Species: The large, elongate, silvery adults resemble *Notropis atherinoides*, which has the dorsal fin origin posterior to the pelvic fin base. Juveniles are similar to *Luxilus chrysocephalus*, which in life have a yellowish cast to the caudal fin in contrast to the clear caudal of *ariommus*. Long confused with *N. telescopus*, which usually has ten anal fin rays and has both terminal and subterminal crescents of dark pigment on exposed portions of dorsolateral scales, this pigment forming curved lines between the scale rows in the form of elongate, pointed ellipses centered around the dorsal fin in dorsal view, and is less deep-bodied.

Systematics: The confused taxonomic history of this species has been thoroughly treated by Gilbert (1969). *Notropis ariommus* was apparently well known to ichthyologists near the turn of the century, but then was virtually unknown until about 1950. Its absence from collections for about 50 years apparently resulted in modern ichthyologists being completely unfamiliar with this distinctive fish, and it was, without explanation, treated as being conspecific with the very different *N. telescopus* until the situation was clarified by Gilbert.

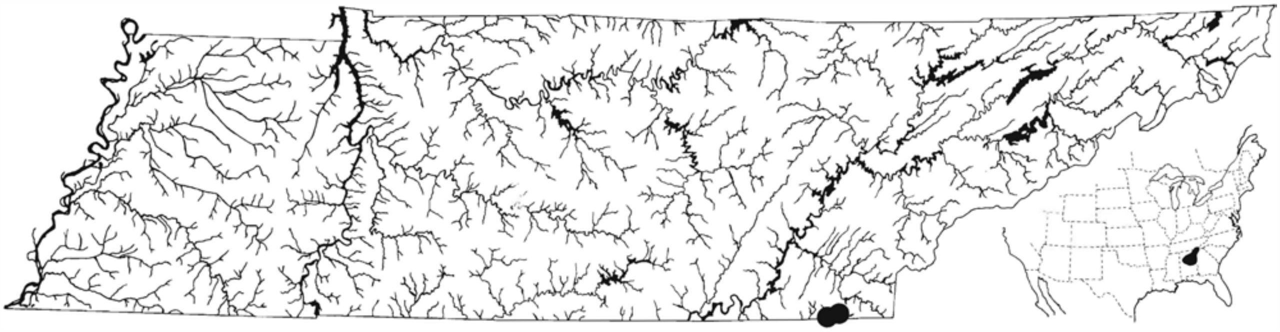
Etymology: *ariommus* = large eye.

Notropis asperifrons Suttkus and Raney

Burrhead shiner

Plate 68. *Notropis asperifrons*, burrhead shiner, 50 mm SL, Coosa R. system, AL.

Characters: Lateral-line scales 34–37, predorsal scale rows 14–16. Anal fin rays 7. Pectoral fin rays 12–14. Pelvic fin rays 8 (8–9). Gill rakers 10–12 blunt knobs. Pharyngeal teeth 2,4-4,2. Breast naked anteriad. Vertebrae 36–37. Silvery in life with prominent dark lateral stripe and no predorsal dark streak. Bright breeding colors do not develop. Tubercle pattern is described by Suttkus and Raney (1955) and Swift (1970). Except for the opercles, the head is covered with small tubercles that are largest on the snout, decrease in density toward the occiput, and extend onto the anterior portion of the breast. Minute tubercles may occur on anterodorsal scales. Fins lacking tubercles except for dorsal surfaces



Range Map 67. *Notropis asperifrons*, burrhead shiner.

of pectoral rays 2–8, which have a shagreen of very small and dense tubercles.

Biology: We have seined burrhead shiners from pools in small streams with sandy substrates, and have observed them in the Conasauga River in midwater areas where 1–2 m depths and scattered large boulders would make seining very unproductive. The biology of this minnow is unstudied. Spawning apparently occurs from April through June based on nuptial specimens. Maximum total length about 75 mm (2.9 in).

Distribution and Status: Occurs in Ridge and Valley and Cumberland Plateau portions of Mobile Basin. In Tennessee restricted to the Conasauga River system in Polk and Bradley counties, where it is uncommon. Most of our specimens have come from in or near the mouth of Minnewauga Creek in Polk County.

Similar Sympatric Species: *N. xaenocephalus* and *N. chrosomus* are quite similar, but both possess well-developed predorsal dark streaks, a character lacking in *asperifrons*. *N. xaenocephalus* has the breast well scaled and *N. chrosomus* has 8 anal fin rays.

Systematics: Relationships unclear, but perhaps related to *N. texanus* species group (Suttkus and Raney, 1955; Swift, 1970).

Etymology: *asper* = rough, *frons* = forehead, referring to the dense snout tubercles.

Notropis atherinoides Rafinesque

Emerald shiner

Characters: Lateral-line scales 35–43 (38–40 in Tennessee), predorsal scale rows 19–20 (18–21). Anal fin rays 10–13. Pectoral fin rays 14–16. Pelvic fin rays 8

Plate 69a. *Notropis atherinoides*, emerald shiner, 63 mm SL, Mississippi R., TN.

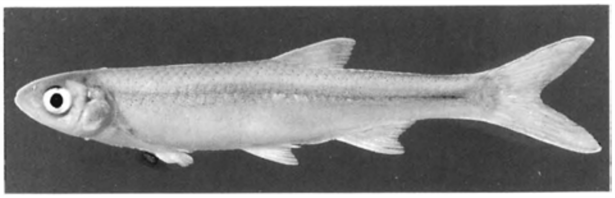
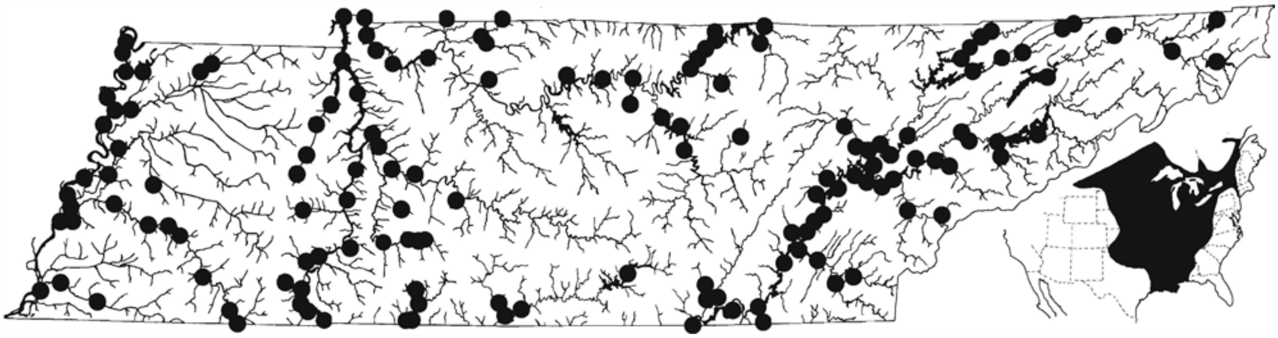


Plate 69b. *Notropis atherinoides*, emerald shiner, preserved specimen showing pigmentation patterns, 82 mm SL, lower Tennessee R., TN.

(8–9). Gill rakers 10–12, length of longest rakers 2–2.5 times their basal width. Pharyngeal teeth 2,4-4,2. Breast scaled. Vertebrae 39–40 (38–41). Slender, weakly pigmented minnows, bright silvery in life, with flat sides and the dorsal fin origin well behind pelvic fin base. No bright breeding colors develop. Nuptial males have tiny, virtually undetectable tubercles on the head, especially on the dorsal surface, and elsewhere only on the dorsal surface of the pectoral fin rays. First pectoral fin ray with scattered tubercles forming 2 poorly defined rows. Rays 2–10 have conspicuous tubercles that form a single row basad, continuing as a single row onto each branch of the ray, with 3–5 tubercles per ray segment and a hiatus at the joints.

Biology: The emerald shiner is a widespread and abundant species that is quite pelagic in its habitats and occurs in lakes, reservoirs, big rivers, and occasionally enters mouths of smaller creeks. Biological information is from our observations and summaries presented in



Range Map 68. *Notropis atherinoides*, emerald shiner (range extends off inset northwest to upper Mackenzie River drainage).

Carlander (1969), Scott and Crossman (1973), Mendelson (1975), and Becker (1983). Food consists primarily of zooplankton, midge larvae and pupae, algae, and adult insects (lakes and reservoirs), and adult aquatic and terrestrial insects and aquatic insect immatures in rivers. Spawning is reported to be at night, often in large schools, in 2–6 m depths over a variety of firm substrates, and occurs from late spring through mid August, but is concentrated between late May and early July in Tennessee. The 2,000–3,000 eggs produced by each female are reported to hatch in 24–32 hours. Sexual maturity is probably reached during the first year, and life span is 3 years. Widely used as a bait minnow, although difficult to keep alive in warm weather. Minnows pickled or salted for bait are often this species. An extremely important forage species in large midwestern lakes, and probably significant as such in our reservoirs and big rivers. Maximum total length 124 mm (4.9 in) reported in Becker (1983).

Distribution and Status: Widespread and abundant in larger streams of the Mississippi River basin, and extending north to the MacKenzie River drainage of Canada and east and west of the mouth of the Mississippi to Mobile Basin and Galveston Bay drainages. Largely avoids rivers of the Blue Ridge.

Similar Sympatric Species: *Notropis rubellus* is most similar, and juveniles can be difficult to separate. Little can be offered besides characters included in the key. In *atherinoides* pigment is consistently present on the chin and extends back between the mandibles on the gular area. In *rubellus* gular pigment is usually absent or consists of a few deep melanophores (see illustrations in Snelson, 1968). This pigment may be more extensive on large, darkly colored adults of *rubellus*. In *rubellus*, the jaws and snout are considerably longer than in *atherinoides*. Gill raker counts (10–12 in *atherinoides*, 7–9 in *rubellus*) appear to be a useful character. Also, see account for *N. rubellus*. Resembles members of the genus *Lythrurus* in body shape and the posterior position of the dorsal fin, but these species (*ardens*, *umbratilis*, *lirus*, *fumeus*), have more than 21 predorsal scale rows, and predorsal scales are much smaller than postdorsal scales.

Systematics: Type species of the genus *Notropis*. Snelson (1968) hypothesized *N. amoenus* of Atlantic slope drainages as closest relative. Relationships were further discussed by Coburn (1982a).

Etymology: *atherina* = silverside, *oides* = Greek suffix indicating resemblance (i.e., to the silversides, family Atherinidae).

Notropis blennius (Girard)

River shiner

Plate 70a. *Notropis blennius*, river shiner, 65 mm SL, Mississippi R., TN.

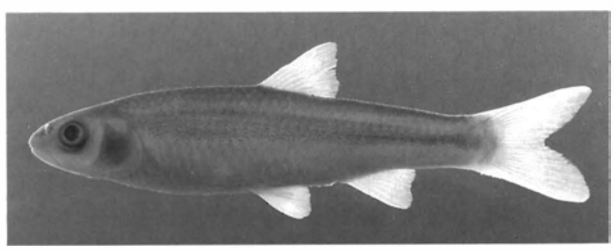


Plate 70b. *Notropis blennius*, river shiner, preserved specimen showing pigmentation patterns, 60 mm SL, Mississippi R., TN.

Characters: Lateral-line scales 34–37, predorsal scale rows 15–16 (14–18). Anal fin rays 7 (rarely 8 or 9). Pectoral fin rays 14–17. Pelvic fin rays 8 (7–9). Gill rakers 7–9, the longest slightly longer than their basal width. Pharyngeal teeth 2,4-4,2. Breast covered to partially covered with exposed or embedded scales. Vertebrae 36–37. A robust species lacking distinctive pigmentation. Bright breeding colors do not develop. Nuptial tubercles reported on snout and top of head, and leading edges of both dorsal and anal fins by Scott and Crossman (1973), in addition to those on the dorsal surface of the pectoral fin rays. First pectoral fin ray lacking tubercles or with a few very small ones in our highest males. Rays 2–7 with a single row of small tubercles basad, separating to form 2 rows near the branching of the ray, and continuing as a single row on each branch, with 2–4 tubercles per fin ray segment. Since we did not observe tubercles on the head or dorsal and anal fins, our specimens may not have displayed peak tuberculation.

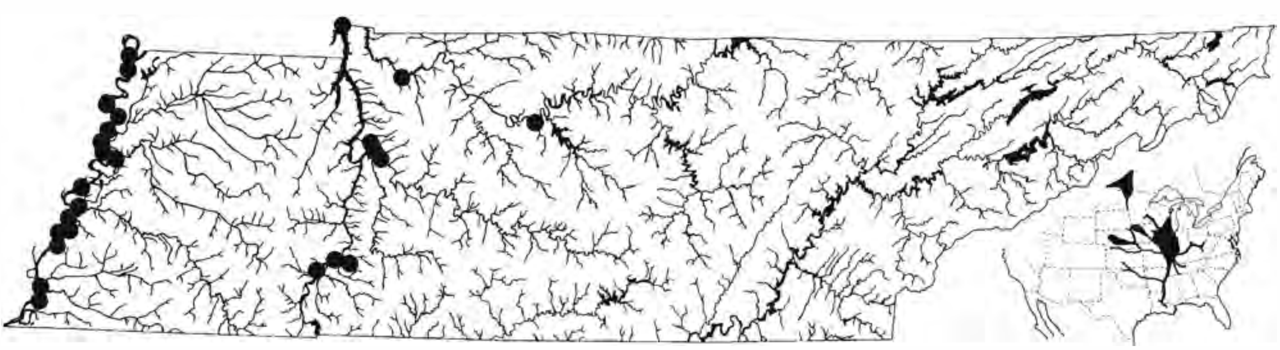
Biology: The river shiner is confined to large rivers where it is most often collected in moderate current over substrates ranging from silty sand to gravel. It feeds on cladocerans and a variety of immature aquatic insects (Becker, 1983). Published information suggests a late summer spawning peak in the northern portion of its range and that females produce 2,000–3,000 eggs per year; males mature at age 1, but mature females were mostly age 2 or older (Carlander, 1969; Trautman, 1957; Becker, 1983). Life span is 3 or 4 years. Tuberculate males occur in our collections from mid June to mid July. Maximum total length reported to be 132 mm (5.2 in) by Trautman (1957), but the largest specimens we have seen are only 99 mm (4 in).

Distribution and Status: Occurs in large rivers throughout the Mississippi River basin, and in the Hudson Bay drainage of southcentral Canada. Common in Tennessee in the Mississippi and lower Duck rivers, and flowing portions of upper Kentucky Reservoir (Tennessee River).

Similar Sympatric Species: Very similar to *Hybognathus nuchalis* in shape and pigmentation, but that species has a small mouth, black peritoneum, intensely coiled gut, and 8 anal fin rays. More robust than the somewhat similar *Notropis shumardi*, which has 9 anal fin rays and more sharply pointed dorsal and anal fins. If the highly similar *N. edwardraneyi* of the Mobile Basin negotiates the Tenn-Tom Waterway to the Tennessee River, as it surely will, it will be extremely difficult to distinguish from *N. blennius*, as would potential hybrids between the two. Eye size may be of help for non-hybrids; in *edwardraneyi* the orbit diameter exceeds the upper jaw length while the opposite is true in *blennius* (Suttkus and Clemmer, 1968).

Systematics: *Notropis blennius* is the type species of the subgenus *Alburnops*. Suttkus and Clemmer (1968) presumed it closest related to *N. edwardraneyi* of the Mobile Basin and less so to *N. potteri* of the Red River of Arkansas and Louisiana. Relationships among these three species were unresolved by Mayden (1989) in his analysis of *Alburnops*, but *potteri* was deemed closest related to southwestern species *bairdi* and *buccula*. Completion of the Tennessee-Tombigbee Waterway may result in eventual sympatry of *N. blennius* and its presumed closest relative, *N. edwardraneyi*. Whether or not they will be able to maintain reproductive isolation in sympatry will be of interest to systematists.

Etymology: *blennius* = blenny-like.



Range Map 69. *Notropis blennius*, river shiner (range extends off inset into central Saskatchewan and Alberta).

Notropis boops Gilbert

Bigeye shiner

Plate 71. *Notropis boops*, bigeye shiner, 56 mm SL, Tennessee R. system, TN.

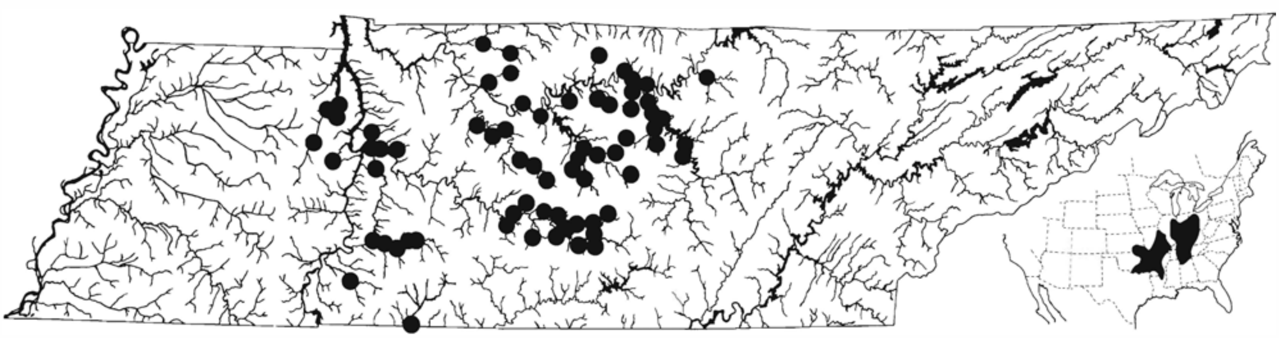
Characters: Lateral-line scales 35–38 (34–39), predorsal scale rows 12–15. Anal fin rays 8 (7–9). Pectoral fin rays 13–17. Pelvic fin rays 8. Gill rakers 8–11, the longest slightly longer than their basal width. Pharyngeal teeth 1,4-4,1. Breast fully scaled. Vertebrae 35–38. Peritoneum black (Burr and Dimmick, 1983). Deep-bodied, flat-sided fishes with a very large eye, and a prominent dark lateral stripe that passes through the head and onto snout and lower jaw, bordered above by pale area with very little pigment. Bright breeding colors absent. Males with maximum tuberculation have the entire head (except for the middle of the opercles) covered with moderately large tubercles that are largest on the snout and lower jaw. All body scales have a marginal row of 6–10 tubercles, and on anterior dorsolateral scales there are 1–3 basal tubercles. Breast scales have scattered tubercles. Small tubercles are dense on dorsal surface of pectoral fin rays 1–7 or 8, and occur in about 3 poorly defined rows on ray 1; on posterior rays there is a single row basad almost immediately splitting into 2 rows, and then into 3 poorly defined rows near the fork of the ray where there are about 10 tubercles per ray segment. A single row continues on each fork of the ray, with about 5 tubercles per ray segment on each fork. Tubercles occur on all other fins and are concentrated on the leading edges of the fin and scattered over the remainder of the rays as small tubercles, usually 1–4 tubercles per ray segment.

Biology: The bigeye shiner is an abundant species of pool areas in cool, clear, upland streams. Trautman (1957) indicated that it feeds mostly on surface insects, and occasionally leaps from the water to capture hovering insects. The spawning season extends from April through August, and breeding fish (39 mm SL or larger) were all in their second year or older (Lehtinen and Echelle, 1979). Smith (1979) indicated that sexual maturity might be reached after the end of 1 year's growth. Peak spawning in our area is in early July. Breeding behavior has not been reported. Trautman (1957) and Smith (1979) discussed its drastic decline in Ohio and Illinois as being associated with increased stream turbidity. Maximum total length 91 mm (3.6 in).

Distribution and Status: Widespread in the Ozark region and the Ohio, Cumberland, and Tennessee river drainages. Also known from Maumee River, Ohio (Lake Erie tributary) and the Illinois River, but presumably extirpated (Burr and Dimmick, 1983). Extremely abundant in the Ozarks and similar upland areas west of the Mississippi River where *N. boops* is often the dominant cyprinid. Less common in Tennessee where it is most abundant in the Nashville Basin and the west slope of the Highland Rim.

Similar Sympatric Species: *Notropis leuciodus*, *N. rupestris*, and *N. volucellus* are all more slender, have a silvery peritoneum, and lack the continuation of the lateral stripe onto the head and lower jaw. Both *rupestris* and *volucellus* have subterminal and more horizontal mouths.

Systematics: Related to *N. xaenocephalus* and *N. scabriceps* of the *N. texanus* species group, according to Swift (1970); considered sister species of



Range Map 70. *Notropis boops*, bigeye shiner.

xaenocephalus by Wiley and Mayden (1985) and Mayden (1989). Rangewide variation treated by Burr and Dimmick (1983).

Etymology: *bo* = ox, *ops* = eye, referring to the extremely large eye.

Notropis buchanani Meek

Ghost shiner

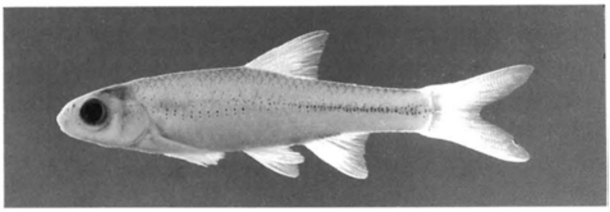


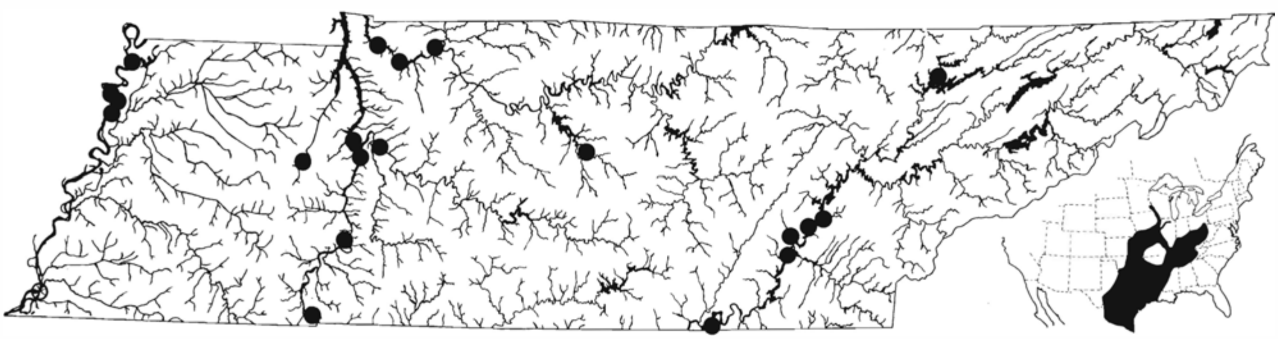
Plate 72. *Notropis buchanani*, ghost shiner, preserved specimen, 37 mm SL, lower Tennessee R., TN.

Characters: Lateral-line scales 30–35 with exposed portions of anterior scales more than three times as deep as long, predorsal scale rows 13–15. Anal fin rays 8. Pectoral fin rays 13–15. Pelvic fin rays 8. Seven to 9 short, thick, pointed gill rakers. Pharyngeal teeth 4-4. Peritoneum lacking dark pigment. Breast naked. Infraorbital canal incomplete (Fig. 86a). Vertebrae 34–35 (two specimens). Color silver, somewhat translucent, and virtually lacking dark markings. Nuptial males with head tubercles moderately large and most conspicuous on the snout. They continue to the occiput and also occur on the lower jaw, lachrymal area, dorsal portions of opercles, and lower cheeks. Nape scales are covered with up to 20 antrorse tubercles that are most abundant on the midline and extend about 2 scale rows below the midline. The first pectoral fin ray lacks tubercles. Pectoral fin rays 2–7 have antrorse tubercles on their dorsal surface that form a single row basad and continue as a double row on each ray branch, with about 3–5 tubercles per row per segment.

Biology: The ghost shiner is a poorly understood minnow usually associated with big river habitats. However, in the Southwest it occurs in some relatively small streams. Trautman (1957) indicated its preference for clear, quiet waters with sand or gravel substrates and some rooted aquatic vegetation. Our Tennessee collections range from relatively clear waters and firm substrates in the Tennessee River below Pickwick Dam to silt-covered gravel in pool areas in Stones River below the dam at Walter Hill, and turbid waters with silty sand substrates in the Mississippi River. Pflieger (1975) indicated that spawning occurred over sluggish sand or gravel riffles; most spawners were in their second year, and life span is 3 years. Its biology is otherwise unstudied. We have seen tuberculate specimens from late May collections, but spawning probably continues well into the summer. Maximum total length 66 mm (2.6 in).

Distribution and Status: Uncommon in larger stream habitats of eastern portions of the Mississippi River basin; more common west of the Mississippi to the Rio Grande. In Tennessee, ghost shiners occur in the Mississippi, Tennessee, and lower Cumberland rivers. Recent TVA cove rotenone samples from Chickamauga Reservoir downstream through Kentucky Lake often contain this species, but there are no recent records from the Tennessee River above Watts Bar Dam. We have a 1947 collection from lower Norris Reservoir that suggests that the preimpoundment distribution of the ghost shiner extended considerably farther up the Tennessee River. This population survived at least 10 years after construction of Norris Reservoir in 1937 but is apparently extirpated, as frequent sampling of Norris Reservoir by TVA biologists, some of whom are quite familiar with this species, has failed to produce any recent specimens.

Similar Sympatric Species: Often confused with *N. volucellus* and *N. wickliffi*, but differing from both in its



Range Map 71. *Notropis buchanani*, ghost shiner.

paler pigmentation, incomplete infraorbital canals, nuptial tubercle pattern, unpigmented peritoneum, deeper anterior lateral-line scales, longer pelvic fins (tips reach to or past anal fin origin), and deeper, more slab-sided body form.

Systematics: Although long associated with the *N. volucellus* species group (formerly considered a subspecies of *volucellus*), and sharing some characters with these species (e.g., Mayden, 1989), the drastic difference in nuptial tubercle pattern suggests that these affinities should be reevaluated.

Etymology: *buchanani* is a patronym for Dr. J. L. Buchanan, former president of Arkansas Industrial University.

Notropis chrosomus (Jordan)

Rainbow shiner

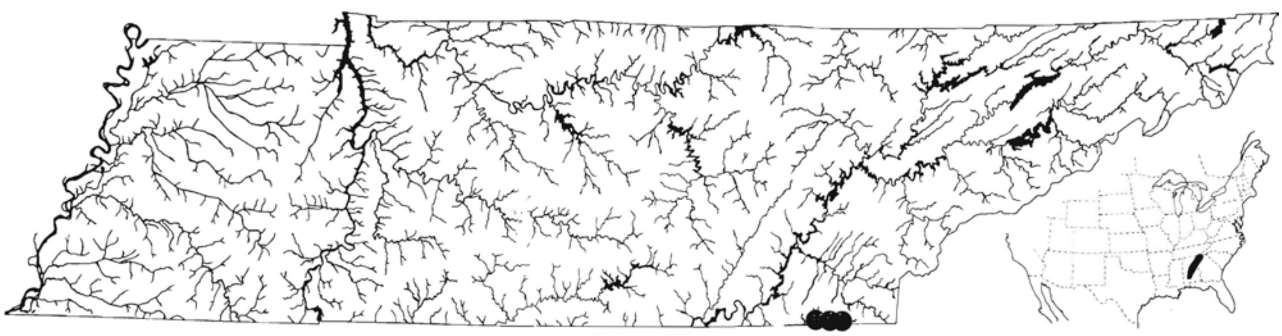
Plate 73. *Notropis chrosomus*, rainbow shiner, breeding male, 50 mm SL, Conasauga R. system, TN.

Characters: Lateral-line scales 36–37, predorsal scale rows 15–16. Anal fin rays 8. Pectoral fin rays 13–15. Pelvic fin rays 8. Gill rakers 7–8, about half as long as their basal width. Pharyngeal teeth 2,4-4,2. Breast naked on midline. Vertebrae 38. Females and young are silvery with the dark back and lateral stripe separated by a pale area. A narrow dark predorsal streak is present. Red, pink, and violet coloration is persistent on males during most of the year, intensifying in spring when the pale area above the dark lateral stripe is bright reddish purple; dorsal surface and pectoral and caudal fins are bright iridescent purple; lower sides are iridescent powder blue; and bright red occurs on snout, lips, pelvic fins, and above pectoral fin base (Swift, 1970). These colors fade quickly upon removal from the water. Nuptial tubercles (Swift, 1970) are large and uniserial (1 per fin ray segment) on dorsal surfaces of pectoral fin rays 2–7 or 8, small and uniserial on proximal two-thirds of caudal fin, anal fin, and dorsal surfaces of pelvic fin rays. Small tubercles cover the head, outer edge of mandibles, and margins of body scales.

Biology: A beautiful but uncommon shiner typically occurring in springs and small, clear streams over sand and gravel substrates with gentle to moderate currents. Spawning occurs in mid to late spring. Its biology has not been studied. Maximum total length 71 mm (2.8 in).

Distribution and Status: Majority of populations in Alabama River system of Mobile Basin, with some (possibly introduced) Black Warrior populations in Alabama. Also occurs in Tennessee River drainage in Town Creek near Fort Payne, Alabama. Most populations in Ridge and Valley region. In Tennessee confined to small, clear tributaries to the Conasauga River where it is not common.

Similar Sympatric Species: The prominent pale area above the dark lateral stripe is shared by *asperifrons*, *xaenocephalus*, and *Cyprinella caerulea*. Both *asperifrons* and *xaenocephalus* have 7 anal fin rays and lack bright colors. The former also lacks a predorsal dark streak, and the latter has melanophores along base of anal fin (none in *chrosomus*). In *C. caerulea* scale outlines are diamond-shaped (rounded in *chrosomus*), and this scale edging pattern continues through the lateral stripe area. In addition, *C. caerulea* has 1,4-4,1 pharyngeal teeth and 17–18 predorsal scale rows.



Range Map 72. *Notropis chrosomus*, rainbow shiner.

Systematics: Subgenus *Hydrophlox*, in species group with *N. leuciodus* and *N. nubilus* (Swift, 1970; Mayden, 1989). Matson et al. (1989) found biochemical but no morphological differences between populations within the Mobile Basin.

Etymology: *chrosomus* = colored body.

Notropis dorsalis (Agassiz)

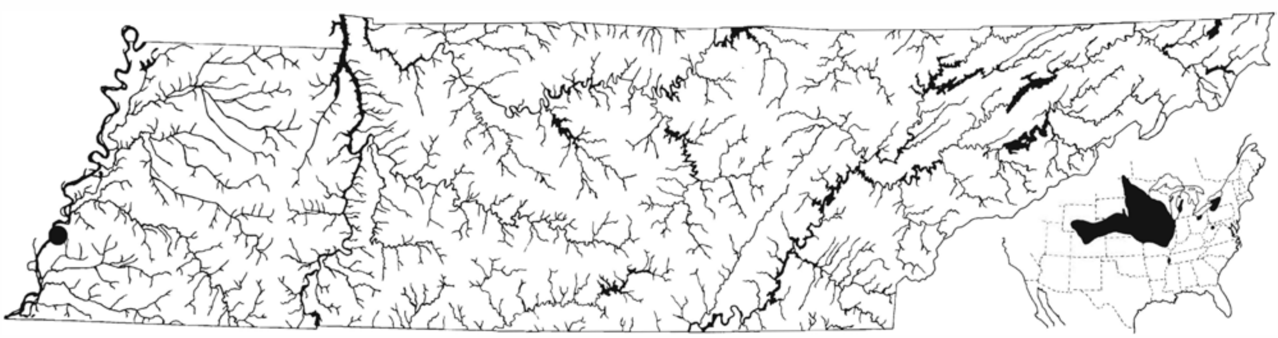
Bigmouth shiner

Plate 74. *Notropis dorsalis*, bigmouth shiner, 53 mm SL, Mississippi R. tributary, TN.

Characters: Lateral-line complete with 33–37 scales, predorsal scale rows 14–18. Anal fin rays 8 (7–9). Pelvic fin rays 8. Gill rakers reduced to about 7 knobs or conical protuberances. Pharyngeal teeth 1,4-4,1. Breast and anterior portion of belly naked or occasionally with tiny, embedded scales. Nape naked in western portion of range. Coloration silvery in life; in preservative a weak lateral stripe is present posteriad and the anterior lateral-line scales have distinctive X-shaped marks surrounding the pores. Dorsolateral scales have dark margins, pre- and postdorsal dark stripes are well developed, and there is little dark pigment below the lateral-line scale row. Nuptial males have tiny tubercles covering much of the top and sides of the head, and these continue but are less concentrated on the nape scales. A dense mat of small tubercles occurs on dorsal surfaces of pectoral fin rays 2 through 5 or so, and tubercles continue in decreasing numbers through rays 8, 9, or 10. Widely scattered small tubercles may occur on rays of the anal, dorsal, and pectoral fins.

Biology: *Notropis dorsalis* is an inhabitant of cool, low-gradient creeks where it occupies areas of moderate current over sand or fine gravel substrates, and is notably able to utilize unstable habitats of shifting sand and fluctuating water levels. The following biological information is summarized from Starrett (1950, 1951), Pflieger (1975), and Becker (1983). In Wisconsin, spawning was thought to occur from May into August. Two females (61 mm TL, 29 May, and 66 mm TL, 15 June) contained 1,000 and 1,275 eggs, respectively, that were about 1 mm in diameter. Additional eggs about .5 mm in diameter were also present in slightly higher numbers than the larger eggs, and these may have matured later that summer. Total lengths were estimated at about 45 and 64 mm at ages 1 and 2, and life span at 3 or 4 years. Sexual maturity may occur at age 1, but is likely delayed until age 2 in many individuals. Stomach contents of Wisconsin and Iowa specimens indicated a benthic diet consisting of immature midges, craneflies, and mayflies, plus occasional water mites and algae. Bigmouth shiners have been observed to ingest quantities of sand while feeding, which is then expulsed from mouth and gills while food items presumably remain to be swallowed. Maximum size 80 mm TL (3.1 in).

Distribution and Status: The bigmouth shiner is widespread in the upper Mississippi Basin, southern tributaries to the Great Lakes, and in the southern portion of the Hudson Bay drainage. We anticipated its occasional occurrence in the Mississippi River in Tennessee but were very surprised to find this the most abundant species in Bear Creek, Tipton County, Tennessee, on 10 June 1990. It appeared that two age groups, averaging about 50 and 66 mm TL, were present. In three previous large collections from this stream, 1967–1986, *Notropis dorsalis* was not collected, and was presum-



Range Map 73. *Notropis dorsalis*, bigmouth shiner.

ably not present, as the stream is very easy to sample. Becker (1983) noted the "pioneering" nature of this species and its ability to colonize unstable habitats. We suspect that adults moved downstream from farther up the Mississippi River, perhaps during drought conditions, and colonized Bear Creek subsequent to 1986; its long-term persistence in Tennessee is questionable.

Similar Sympatric Species: *Notropis stramineus* is sympatric at the only known Tennessee locality where *N. dorsalis* occurs, and members of the *N. volucellus* species group occur nearby in the Mississippi River; all of these are broadly sympatric in the Midwest. These differ from *dorsalis* in having smaller, less horizontal mouths, 4-4 pharyngeal teeth, and less well developed pre- and postdorsal dark stripes. In addition, members of the *volucellus* species group have greatly deepened anterior lateral-line scales (not so in *dorsalis*), and *stramineus* has only 7 anal fin rays, as does the somewhat similar *N. blennius*. *Ericymba buccata*, often sympatric with *N. dorsalis* in the Midwest, has only 12 or 13 predorsal scale rows (14 or more in *dorsalis*) in addition to having excessive development of the lateralis canals on the head.

Systematics: Hubbs and Lagler (1958) made brief mention of separate subspecies from the eastern Great Lakes and the Platte River, with *N. d. dorsalis* occupying the central portion of the range. Mayden (1989) considered *dorsalis* to be most closely related to *Notropis longirostris* and *N. sabinae*. Mayden also included *Ericymba buccata* as a closely related species, and the similarity between that species and *Notropis dorsalis* in head and body shape, tubercle pattern, and meristic characters is striking.

Etymology: *dorsalis* refers to the back.

Notropis leuciodus (Cope)

Tennessee shiner

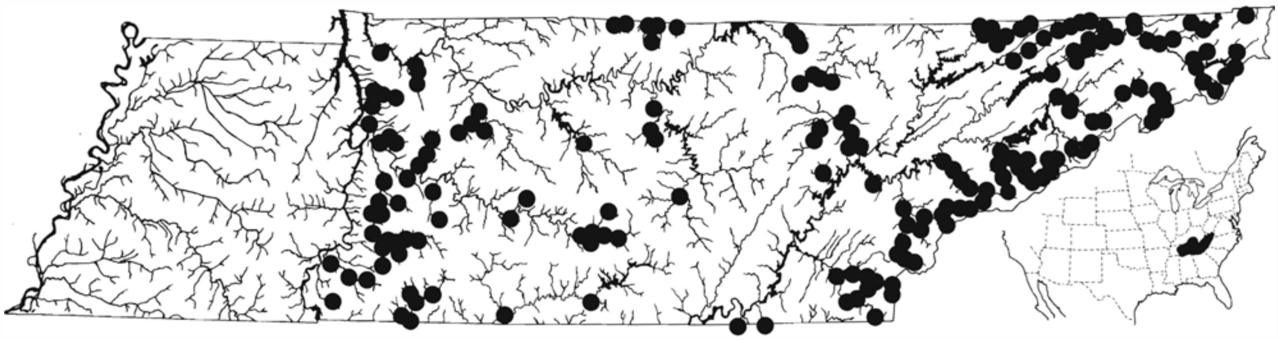
Characters: Lateral-line scales 37–38 (35–41), predorsal scale rows 15–17. Anal fin rays 8 (8–9), but 9 (8–11) in Hiwassee River system. Pectoral fin rays 14–16. Pelvic fin rays 8. Gill rakers 6–8, length of longest rakers equal to their basal width. Pharyngeal teeth 1,4-4,1 (not 2,4-4,2 as often reported). Breast naked. Vertebrae 38–40 (39–41). In life, dark gray dorsally with bright silver on sides often obscuring dark lateral stripe; lateral-line canal and rectangular black basicaudal spot always evident. Bright red nuptial colors of males are very transient (see Biology). Tuberculate males we have examined have a pattern typical for the subgenus *Hydrophlox*, with large uniserial tubercles developing on dorsal surfaces of pectoral rays 1–8 or 9 and most prominent on rays 2–5. The entire head, except the lower jaw where tubercles were not evident, is covered with small, blunt tubercles. Body scales except those on belly and above pectoral fins have a marginal row of 5–8 small tubercles, and small tubercles are often present on rays of pelvic, anal, and dorsal fins.

Plate 75a. *Notropis leuciodus*, Tennessee shiner, 53 mm SL, Clinch R., TN.

Plate 75b. *Notropis leuciodus*, Tennessee shiner, breeding male, 56 mm SL, Little R., TN.

Biology: The Tennessee shiner is an extremely common species of pool areas to rather swift waters flowing over gravel to boulder and bedrock substrates in macrohabitats ranging from small creeks to the largest remaining rivers within its range. It shows little tolerance for reservoirs. Outten (1961, 1962) observed spawning aggregations over *Nocomis micropogon* nests and reported red coloration on the head (particularly on snout and lower jaw), anterior body, pectoral fins, and bases of dorsal, pelvic, and caudal fins. We have observed them spawning over stoneroller nests. The stunning, completely red coloration of breeding males is apparently very ephemeral, and peak colors were present in only a few of the males in the several spawning aggregations we have seen. Spawning occurs during May and June. Its biology is otherwise unstudied. Maximum total length 88 mm (3.5 in).

Distribution and Status: An aptly named shiner, with most of its range in Tennessee. Common in Highland Rim, Blue Ridge, upper Ridge and Valley, and periph-



Range Map 74. *Notropis leuciodus*, Tennessee shiner.

ery of the Cumberland Plateau in Tennessee and Cumberland drainages, and the Barren (Ohio) River system. Also occurs in upper Savannah drainage (headwater piracy from Tennessee) and presumably introduced in New (Kanawha) system.

Similar Sympatric Species: Often confused with the usually sympatric but not closely related *N. telescopus*, which has 9 or more anal fin rays, a much larger eye, lacks a distinct caudal spot, and has pigment between dorsolateral scale rows forming irregular longitudinal dark lines coverging behind the dorsal fin. Juveniles and subadults of these species can be readily separated by noting pigmentation at dorsal fin base. In *telescopus* the predorsal dark streak continues uninterrupted under and posterior to the dorsal fin. In *leuciodus* this dark streak is interrupted under the anterior and posterior dorsal fin base, leaving an isolated dark mark under middle of fin base. Also similar to *N. rubricroceus*, which has a continuation of dark dorsolateral scale edgings through the lateral stripe area to well below the lateral line, whereas in *leuciodus* dorsolateral scale pattern stops at lateral stripe. In the somewhat similar *N. rubellus* there are 9 or more anal fin rays, a dark basicaudal spot is absent, and the dorsal origin is well behind the pelvic insertion.

Systematics: Subgenus *Hydrophlox*. Swift (1970) suggested close affinities with *N. chrosomus* and *N. nubilus*. Mayden (1987) considered *leuciodus* and *nubilus* to be a species pair with *chrosomus* as their sister species. Specimens examined by us and by Ramsey (1965) from the Hiwassee River system have a mode of 9 anal fin rays, a more triangular caudal spot, a mouth shape much like that of *N. rubricroceus*, and the snout flushed with red throughout much of the year. Matson and Mayden (1988) conducted a range-wide analysis of biochemical variation in *leuciodus* and found the Hiwassee form most distinctive and possibly warranting species status (R. L. Mayden, in litt.).

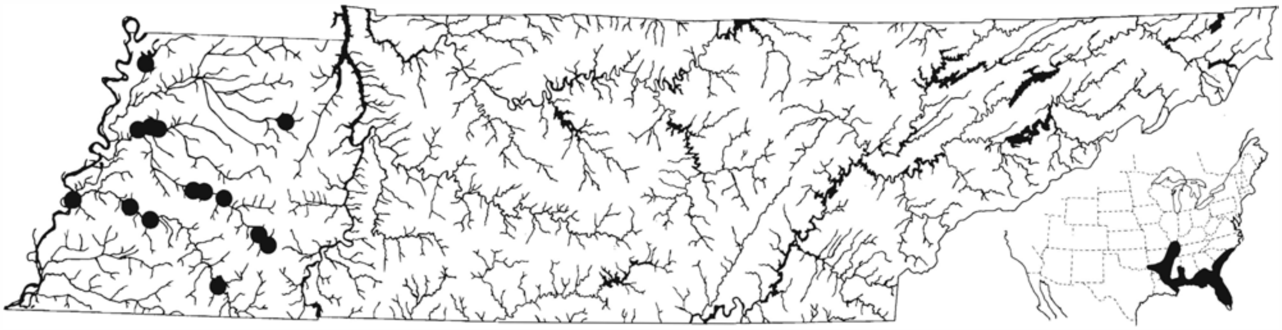
Etymology: *leucos* = white, *eiodus* = appearance.

Notropis maculatus (Hay)

Taillight shiner

Plate 76. *Notropis maculatus*, taillight shiner, breeding male, 53 mm SL, Forked Deer R. system, TN.

Characters: Lateral-line incomplete with about 15 pored scales and 35–37 (34–39) scales in lateral series, predorsal scale rows 15–17. Anal fin rays 8 (7–8). Pectoral fin rays 13–15. Pelvic fin rays 8. Gill rakers 0–5 short knobs. Pharyngeal teeth 4-4. Breast scaled. Vertebrae 37 (2 specimens). Translucent silvery in life, with caudal spot large and distinct. Nuptial males from Tennessee have a broad midlateral orange-red band on the body that continues on the head across dorsal portion of opercles and cheeks, dorsal portion of orbit and iris, and continuing and joining on snout. Brighter red pigment present on outer portions of all fins except pectorals. Posterior border of caudal fin, and both leading edges and posterior borders of other fins with black pigment. Nuptial tubercles of moderate size cover the entire head except for portions of snout and lachrymal area. Tubercles small, granular, crowded, and forming 2–3 poorly defined rows on first pectoral fin ray and its



Range Map 75. *Notropis maculatus*, taillight shiner.

anterior connective tissue pad. Tubercles sharper and somewhat larger on dorsal surfaces of rays 2–7 or 8, forming a single row basad and continuing as a single row on each major branch, with 3–5 tubercles per fin ray segment. Tiny tubercles may develop on rays of all other fins.

Biology: The tailight shiner is a Coastal Plain species that typically occurs in heavily vegetated oxbow lakes and cypress swamps where waters are clear and stained brown with humic acid. Such waters are typically acidic with pH readings of 6.1–6.9 (Robison, 1978). Life history studies by Beach (1974) and Cowell and Barnett (1974) on Florida populations indicated a diet composed of small food items such as microcrustaceans (chydorid cladocerans, cyclopoid copepods, ostracods), rotifers, unicellular algae (desmids and diatoms), and small dipteran larvae (Chironomidae and Ceratopogonidae). Life span is only slightly longer than 1 year, and sexual maturity is reached in 6–9 months. Females produce 100–250 eggs per year, and the breeding season extends from March through October. Burr and Page (1975) indicated up to 430 eggs per female and a March through May breeding season in western Kentucky populations. Breeding behavior has not been reported. Maximum total length 72 mm (2.8 in).

Distribution and Status: Occurs in Atlantic Coastal drainages from Cape Fear River south through Florida peninsula, and west in Gulf Coast drainages through Mississippi River. Extends north in Mississippi River basin to southern Illinois. Mostly confined to Coastal Plain areas and apparently uncommon, but its swampy habitats are seldom intensively sampled. Tennessee distribution restricted to direct eastern tributaries to Mississippi River. Channelization has probably extirpated several populations from west Tennessee.

Similar Sympatric Species: *Opsopoeodus emiliae* has a vertical rather than nearly horizontal mouth and 9 rather than 8 dorsal fin rays. Neither *Opsopoeodus* nor another swamp inhabitant, *Hybognathus hayi*, has a distinct caudal spot. *Pimephales notatus* and *P. vigilax* have large caudal spots, but have crowded predorsal scales (20 or more predorsal scale rows) and shorter, less pointed median fins.

Systematics: Relationships uncertain, but suspected of having affinities with *Opsopoeodus emiliae* by Gilbert and Bailey (1972) and Mayden (1989); see comments under that species.

Etymology: *maculatus* = spotted.

Notropis photogenis (Cope)

Silver shiner

Plate 77a. *Notropis photogenis*, silver shiner, 82 mm SL, Clinch R., TN.

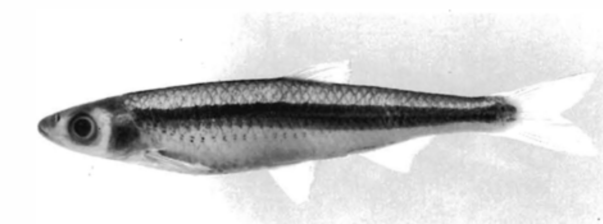


Plate 77b. *Notropis photogenis*, silver shiner, preserved specimen showing pigmentation patterns, 94 mm SL, Clinch R., TN.

Characters: Lateral-line scales 38–41, predorsal scale rows 17–20. Anal fin rays 10–11. Pectoral fin rays 15–18. Pelvic fin rays 9. Gill rakers 7–9, length of longest rakers about twice their basal width. Pharyngeal teeth 2,4-4,2. Breast scaled. In life, straw-colored on dorsum with bright silver of sides obscuring dark lateral stripe. Bright breeding colors do not develop. Small tubercles cover the entire head of nuptial males, except for an area on the cheeks just behind the eye. All body scales develop a single or occasionally double row of small marginal tubercles, 10–15 tubercles per row, and patches of small tubercles may develop near base of exposed portion of anterior scales. Pectoral fin rays 1–9 or 10 with moderate sized tubercles on dorsal surfaces, in single row basad, 3 rows with 10–20 per fin ray segment proximal to major branching, and continuing as single row, 3–5 per segment, on anterior branch, and 2 rows, 6–10 per segment, on posterior branch of ray. Small tubercles may develop on ventral surfaces of outer rays. Other fins with small tubercles, 1–2 per fin ray segment, mostly on outer half of rays. On caudal fin these virtually restricted to outer branched ray of both dorsal and ventral lobes. Dorsal fin also with tubercles directed laterad on anterior rudimentary ray, and pelvic fin may develop a few tubercles on ventral surfaces of rays.

Biology: The silver shiner is a large, slender species of large creeks to small rivers with firm substrates, where it is associated with clear waters and flowing pool habitats with moderate to swift currents. Schools feed near the surface, occasionally jumping from the water in pursuit of flying insects. Tuberculate males occur in our collection from late April through late May. Many of these are from smaller creeks, suggesting an upstream spawning movement. Trautman (1957) indicated that sexual maturity is reached in the second or third summer at lengths of 69 mm (2.7 in). Maximum total length 149 mm (5.9 in).

Distribution and Status: Occurs in Lake Erie tributaries south through Ohio, Cumberland, and Tennessee river drainages. Collection records suggest this to be an uncommon species, but the deeper waters inhabited (relative to other sympatric *Notropis*) probably contribute to this apparent rarity. In Tennessee it occurs in all physiographic provinces except the Coastal Plain.

Similar Sympatric Species: Both *N.* (*Notropis*) *atherinoides* and *N.* (*Hydrophlox*) *rubellus* are very similar to smaller specimens of *photogenis*, but have only 8 pelvic fin rays. In *photogenis* the dorsal margin of the lateral band is bluntly saw-toothed anteriad (even-edged in *atherinoides* and *rubellus*), jaws are larger, and a pair of dark crescents are present between nostrils of adults. The dorsal fin origin is only slightly behind the pelvic fin insertion in this species, whereas it is much farther back in both *atherinoides* and *rubellus*. Also similar to *N. telescopus*, which has a larger eye, usually 16 or fewer predorsal scale rows, and 8 pelvic fin rays.

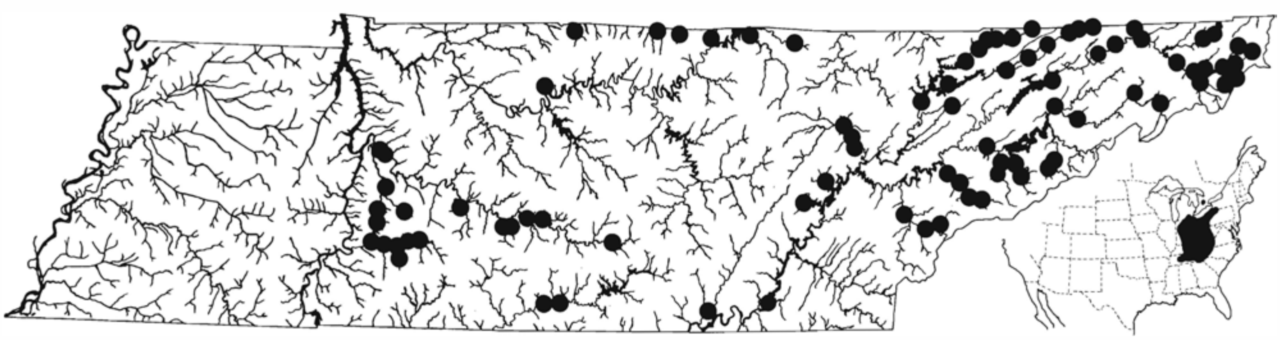
Systematics: Subgenus *Notropis*.

Etymology: *photo* = light, *gena* = cheek.

Notropis rubellus (Agassiz)

Rosyface shiner

Characters: Tennessee specimens have 36–39 (35–40) lateral-line scales and 18–21 predorsal scale rows. Anal fin rays 10 (9–11). Pectoral fin rays 13–14. Pelvic fin rays 8. Gill rakers 7–9, length of longest rakers equals their basal width. Pharyngeal teeth 2,4-4,2. Breast with embedded scales or naked. Vertebrae 39–41. In life gray on dorsum and bright silver on sides. Males develop diffuse orange-red pigment on lower sides, jaws, fin bases, and shoulder girdle only during the breeding season. Large uniserial tubercles occur on dorsal sur-



Range Map 76. *Notropis photogenis*, silver shiner.

Plate 78a. *Notropis rubellus*, rosyface shiner, 57 mm SL, Barren R. system, TN.

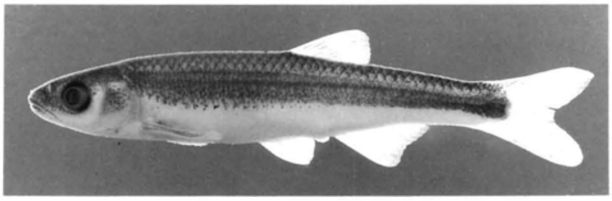


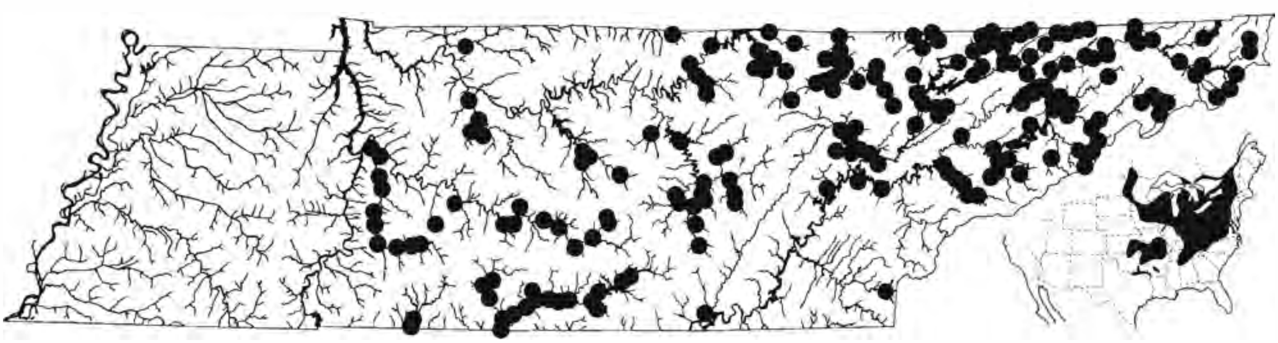
Plate 78b. *Notropis rubellus*, rosyface shiner, preserved specimen showing pigmentation patterns, 50 mm SL, upper Cumberland R. system, KY.

faces of pectoral fin rays 2–5 or 6, and smaller, less persistent tubercles may develop on dorsal surfaces of all pelvic fin rays and on rays of all median fins. Low, blunt tubercles occur everywhere on the head, but are sparse on middle portions of opercles. Body scales have a marginal row of 4–8 small tubercles that are most persistent on the nape.

Biology: The rosyface shiner is a common species of large creeks and small rivers with clear water and rubble, boulder, and bedrock substrates. Like other Tennessee members of the subgenus *Hydrophlox* (*chrosomus*, *leuciodus*, *rubricroceus*), *N. rubellus* often occurs in areas with considerable current. Reed (1957) reported a migration from the foot of riffles in the spring and summer to deeper pool areas in the fall and winter. Although numerous authors have mentioned its decrease in abundance in response to increased siltation, it is much more likely to be encountered in large silty rivers in Tennessee than are our other *Hydrophlox*. Adult diet consists of about equal proportions of surface insects and aquatic immatures, with the latter dominated by caddis larvae and mayfly nymphs (Starrett, 1950; Pfeiffer, 1955). Juveniles consume considerable quantities of algae and diatoms (Reed, 1957). Spawning occurs in late spring, usually over silt-free gravel of nests of a wide variety of other fish species. This behavior is presumably responsible for the rather common occurrence of hybrids between *rubellus* and *Luxilus cornutus* and *L. chrysocephalus*. It more rarely hybridizes with other species such as *N. volucellus* (Bailey and Gilbert, 1960). Pfeiffer (1955) found 450–1,500 eggs per mature female and indicated that newly hatched young burrowed into the gravel, where they remain for several days. Three adult *N. rubellus* from Ohio suggested the possibility of hermaphroditism, each containing both mature ovaries and testes (Reed, 1954). Maximum total length 76 mm (3 in) for the Tennessee form.

Distribution and Status: Widespread in Great Lakes and upper Mississippi drainages and in Red River system of Hudson Bay drainage north to southern Manitoba and Ontario. Also on Atlantic slope south through James River drainage, throughout Ohio, Cumberland, and Tennessee river drainages, and in Ozark region from lower Missouri drainage south through Red River system of southern Oklahoma. Usually common, and occurring in all upland physiographic provinces in Tennessee. The form occurring in the upper Cumberland may be on the verge of extirpation in Tennessee because of impacts of surface mining, and these populations are included on Tennessee's list of Species of Special Concern (Starnes and Etnier, 1980).

Similar Sympatric Species: Placement of the dorsal fin origin well behind the pelvic insertion, and the higher anal fin ray counts separate *rubellus* from sympatric *Hydrophlox* (*leuciodus* and *rubricroceus*). Most similar in



Range Map 77. *Notropis rubellus*, rosyface shiner.

appearance to *N.* (*Notropis*) *atherinoides*, which never develops red pigment, and has several tubercles per fin ray segment on pectoral fins. Juveniles and non-nuptial specimens can be very difficult to separate if taken from turbid water. From clear water, *rubellus* is a much more darkly pigmented species. In *atherinoides* anal fin rays are usually 11 or more (usually 10 in *rubellus*), pectoral fin rays are 14–16 vs. 13–14, gill rakers are 10–12 vs. 7–9, anterior lateral-line pores lack melanophores (bordered by melanophores in *rubellus*), dorsal fin is sharply pointed with anterior rays extending well past posterior rays when fin is depressed (not pointed and extending little if any past posterior rays when fin is depressed in *rubellus*), the expanded anal fin margin concave (straight in *rubellus*), and the gular area is pigmented (usually immaculate in *rubellus*).

Systematics: Presently included in subgenus *Hydrophlox*. Earlier workers had allied *rubellus* with *N. atherinoides* and its relatives (subgenus *Notropis*) based on slender body form, dorsal fin placement, and high anal fin ray counts. Snelson (1968) pointed out a possible relationship with *Hydrophlox* rather than with the subgenus *Notropis*, based on characters of nuptial color and tuberculation. Swift (1970) and Mayden (1989) also included *rubellus* in the subgenus *Hydrophlox*. However, questions may remain regarding the inclusion of *rubellus* in this group, since Mayden and Matson (1988) hypothesized it to be more closely related to *N. stilbius* of subgenus *Notropis* than to any species of *Hydrophlox*, based on biochemical evidence. The name *Notropis micropteryx* (Cope) has been used for populations occurring in the Tennessee and Cumberland river drainages. These differ from northern populations in having a shorter snout and a smaller maximum size. Tennessee specimens from tributaries to the Cumberland River above Cumberland Falls are typical of northern populations. Thus, two distinct forms that may warrant separate taxonomic status occur within Tennessee, and a thorough study of variation in *rubellus* throughout its range is needed.

Etymology: *rubellus* = reddish.

Notropis rubricroceus (Cope)

Saffron shiner

Characters: Lateral-line scales 37–40, predorsal scale rows 16–19. Anal fin rays 8 (7–9). Pectoral fin rays 13–15. Pelvic fin rays 8. Gill rakers 6–8, length of longest rakers 1–1.5 times their basal width. Pharyngeal teeth 2,4-4,2. Breast naked to covered with exposed scales. Vertebrae 39–40. Life color silver with prominent dark lateral stripe terminating in linear basicaudal spot, and with a broad predorsal dark streak. Red on snout, anterior sides, and fins is persistent on males throughout much of the year, and during the late April to mid July breeding season red intensifies, with peak males entirely flushed with bright red or reddish purple. Nuptial males have large uniserial tubercles on dorsal surfaces of pectoral fin rays 2–5, and smaller uniserial tubercles on dorsal and anal fin rays. Blunt tubercles or tubercle-like projections form a "crust" over the entire head. On the lower jaw, gular area, and breast these projections are very soft and may actually be neuromasts. It seems more likely that they are weakly cornified tubercles, or at least have a reproductive function, since they are best developed on nuptial specimens. All body scales have a marginal row of 4–8 tubercles that are erect and sharply pointed posterior to dorsal fin, but less erect and more blunt anteriad, giving edges of these scales a scalloped or saw-toothed appearance. In females, tubercles are conspicuous only on the head, but surprisingly those on snout and lower jaw are larger and sharper than those of males.

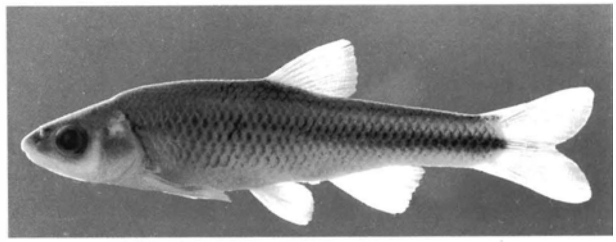
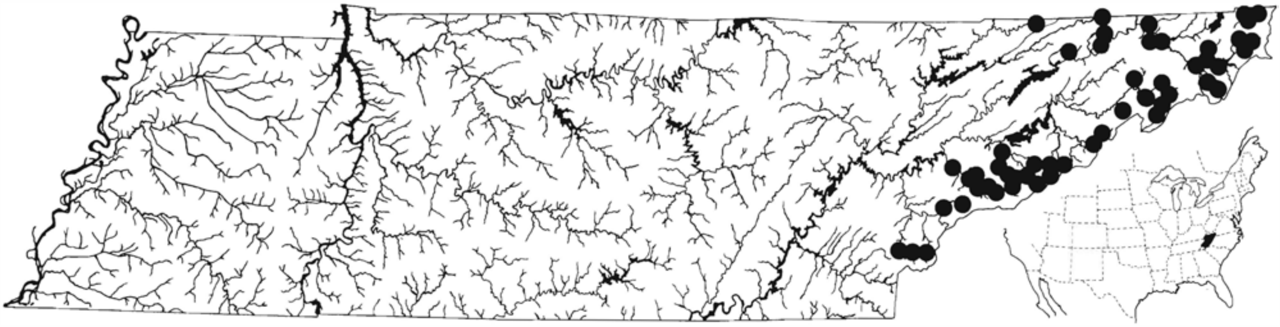


Plate 79a. *Notropis rubricroceus*, saffron shiner, preserved specimen showing pigmentation patterns, 55 mm SL, Little Pigeon R. system, TN.

Plate 79b. *Notropis rubricroceus*, saffron shiner, breeding male, 66 mm SL, Little Pigeon R. system, TN.

Biology: The saffron shiner, one of the most striking of our minnows when in breeding color, occurs in cool, clear streams of small to moderate size, with coarse substrates of rubble, boulder, and bedrock. It often occurs in trout streams. Although usually avoiding the



Range Map 78. *Notropis rubricroceus*, saffron shiner.

swiftest riffles, it is often found in moderate to swift currents. Outten (1958) reported a 5-year life span, found about 500–1,000 mature eggs per female, and observed spawning aggregations over *Nocomis micropogon* nests. Peak nuptial tuberculation occurs in mid June. Maximum total length 80 mm (3.2 in).

Distribution and Status: A common species mostly confined to Blue Ridge area of the Tennessee River drainage except for upper Clinch and Holston systems where it occurs in the Ridge and Valley. Tennessee River drainage distribution extends from Clinch and Powell river systems of Virginia (rarely penetrating into northern Tennessee) south through Little Tennessee River system. Populations in upper Savannah and Santee drainages are likely results of headwater piracy from the Tennessee, while upper New (Kanawha) populations are believed to result from introductions.

Similar Sympatric Species: *Notropis leuciodus* and *N. rubellus* are similar in size and appearance. In both of these the dark scapular bar of *rubricroceus* is absent and dorsolateral scale edgings do not extend through the lateral stripe. Further differing from *rubellus* in having the dorsal fin origin directly over the pelvic fin insertion (well behind insertion in *rubellus*). *Luxilus coccogenis* is our only other shiner with a persistent black scapular bar, but it is a much larger species with a scaled breast, persistent lower jaw tubercles, and the lateral stripe disappears anteriad (dark and narrow on peduncle, becoming broad and diffuse but remaining dark anteriad in *rubricroceus*).

Systematics: Type species of subgenus *Hydrophlox*. Closest affinities presumably with *N. chiliticus* of Atlantic drainages (Swift, 1970).

Etymology: *ruber* = red, *croceus* = saffron color.

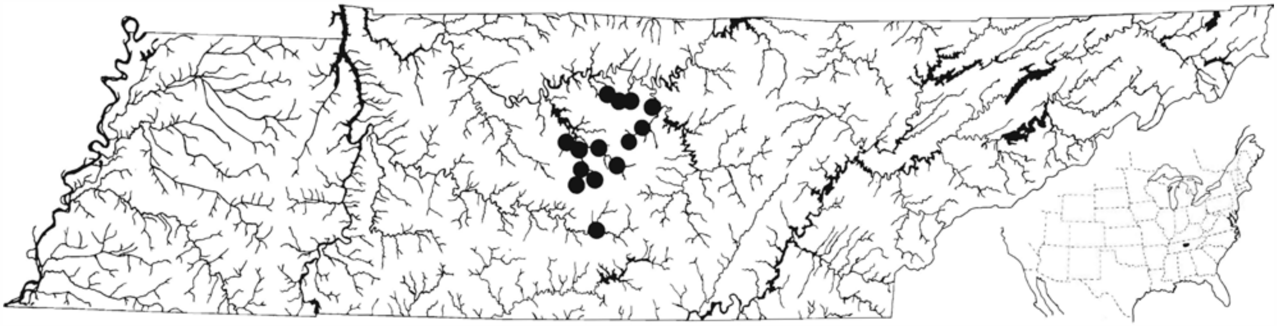
Notropis rupestris Page

Bedrock shiner

Plate 80. *Notropis rupestris*, bedrock shiner, 41 mm SL, Caney Fork R. system, TN.

Characters: Lateral-line scales 33–36 (31–37), predorsal scale rows 13–14. Anal fin rays 8 (rarely 7 or 9). Pectoral fin rays 12–14. Pelvic fin rays 8. Gill rakers 8–10 (5–11), length of longest rakers twice their basal width. Pharyngeal teeth 4-4. Breast scaled. Vertebrae 35 (two specimens). Translucent silvery to straw-colored in life with small black basicaudal spot and dark lateral stripe containing a darker vertical crescent on each scale; pale area above lateral stripe may show greenish tint (Page and Beckham, 1987). Bright breeding colors do not develop. Nuptial tubercles form a fine shagreen over dorsal surfaces of pectoral fin rays 1–6 or 8, and are best developed on rays 2–5, where 2–3 rows of tubercles are apparent at bases of rays, but distally rows are not evident, and 20 or more tubercles occur per fin ray segment. Tiny, sharp tubercles develop on top of head, opercles, cheeks, and anterior nape scales. A few small tubercles may appear on posterior rays of anal and dorsal fins.

Biology: The bedrock shiner is a common species in some low-gradient streams of the Nashville Basin, where it occurs in bedrock pools. Males are tuberculate throughout May, but females from these collections had not spawned, suggesting a late-May-through-June spawning peak, but we lack June-through-September



Range Map 79. *Notropis rupestris*, bedrock shiner.

collections. Age groups were not apparent based on length-frequency analysis, suggesting a prolonged breeding season. A 48-mm SL female contained about 300 mature ova, and a 39 mm SL female was sexually mature. The related *N. heterolepis* has a 2–3 year life span, with Michigan specimens 30–40 mm SL at age 1 (Emery and Wallace, 1974; Becker, 1983). Seven adults, taken in May and October, had eaten primarily midge larvae and chydorid cladocerans plus a few water mites, copepods, and small mayflies. Maximum total length 70 mm (2.75 in).

Distribution and Status: Restricted to the Nashville Basin in Tennessee, where it is known from the Stones and lower Caney Fork river systems and direct Cumberland River tributaries between these systems. Also, known from two collections from the Duck River (Tennessee River drainage) in Bedford County, but these may represent minnow bucket releases. Typically abundant, but because of its very restricted range it is included on Tennessee's list of Species of Special Concern (Starnes and Etnier, 1980, as *Notropis heterolepis*).

Similar Sympatric Species: Somewhat similar to *Pimephales notatus*, which has tiny predorsal scales, 7 anal fin rays, and a black peritoneum. Both *Notropis boops* and *N. volucellus* are somewhat similar. The former has a deeper body, a much larger eye, and a terminal rather than subterminal mouth. The latter has a naked breast, a lateral stripe that fades anteriad, and elevated anterior lateral-line scales.

Systematics: The bedrock shiner had previously been treated as a distinctive southern glacial relict of *Notropis heterolepis* (see Starnes and Etnier, 1986), but was recognized as a valid species by Page and Beckham (1987). In addition to its obvious affinity with *N. heterolepis*, it shares many characters with and is similar in appearance to *N. alborus* of the Atlantic slope. However, Mayden (1989) hypothesized *heterolepis* (and presumably *rupestris*) to be closest allied to *Notropis maculatus* and *N. emiliae* (=*Opsopeodus emiliae*) and placed *alborus* in a lineage with the *Notropis longirostris* and *Hybopsis amblops* groups.

Etymology: *rupestris* = to live among rocks.

Notropis shumardi (Girard)

Silverband shiner

Plate 81a. *Notropis shumardi*, silverband shiner, 45 mm SL, Mississippi R., TN.

Plate 81b. *Notropis shumardi*, silverband shiner, preserved specimen showing pigmentation patterns, 51 mm SL, Mississippi R., TN.

Characters: Lateral-line scales 34–37, predorsal scale rows 15–16 (14–17). Anal fin rays 9 (8–10) in Tennessee specimens. Pectoral fin rays 13–16. Pelvic fin rays modally 9 (8–9). Gill rakers 7–9, length of longest rakers 2–2.5 times their basal width. Pharyngeal teeth

2,4-4,2. Breast scaled. Vertebrae 36–39 (34–39 west of Mississippi River). Life color silver with straw-colored back, and lacking distinctive markings. Bright breeding colors do not develop. Nuptial males have a tubercle pattern typical for the subgenus *Notropis*, but tubercles are very reduced both in size and number. Tiny tubercles cover the entire head, but on body scales they are restricted to nape and breast regions in specimens we have examined. Pectoral fin rays 1–9 or 10 have small tubercles that form a single row basad and continue as a single row, 4–5 tubercles per fin ray segment, on both anterior and posterior branches of the rays. Tubercles were not seen on other fins.

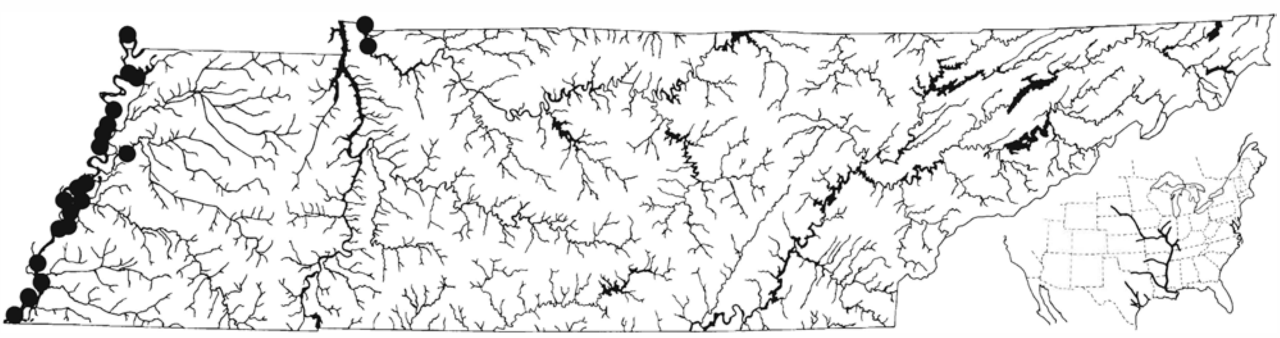
Biology: The silverband shiner is an inhabitant of large, silty rivers. Reproductive season is from late May through mid August. Other aspects of its biology are unreported. Suttkus (1980) provided some biological information for the closely related *N. candidus*. During warmer months adults inhabit deeper waters (about 1 m or deeper) and move into shallow areas at night. Breeding females were mostly one or 2 years old, with a few age 3. Males were smaller than females of the same age, were sexually mature at age 1, and did not reach age 3. Maximum total length 85 mm (3.4 in).

Distribution and Status: Occurs in larger rivers from the Mississippi westward into the Lavaca Bay drainage of Texas. In Tennessee, *N. shumardi* is virtually restricted to the main channel of the Mississippi River, where it is common.

Similar Sympatric Species: *Notropis blennius*, *N. wickliffi*, *Hybognathus nuchalis*, and *Notropis atherinoides* share the sharply pointed dorsal fin and pallid, silvery color. The first three above are robust and cylindrical rather than slab-sided species, have 7 or 8 anal fin rays, and mouths that are horizontal or subterminal rather than terminal and oblique. In *shumardi*, tip of depressed dorsal fin reaches far past anal fin origin, while in *H. nuchalis* (which also has a black peritoneum and intensely coiled gut) and *N. blennius* it merely reaches the anal fin origin. In *N. wickliffi* anterior lateral-line scales are elevated. Pigmentation is very similar to that of *N. atherinoides*, which has the dorsal fin placed far behind the pelvic insertion (barely behind in *shumardi*), and 10–13 anal fin rays. Hybrids between *N. atherinoides* and *N. volucellus* or *wickliffi*, occasionally encountered in the Ohio River (Mayhew, 1983) and to be anticipated elsewhere, are very similar to *N. shumardi* in appearance. These potentially confusing specimens differ from *shumardi* in having 0–1 lesser row pharyngeal teeth, a less pointed dorsal fin (tips of anterior rays barely extend past tips of posterior rays when fin is depressed), and a lateral stripe that is centered on the lateral line on the caudal peduncle (virtually restricted to the area above the lateral line in *shumardi*). The modal occurrence of 9 pelvic rays (8 in sympatric minnows) is diagnostic.

Systematics: The name formerly applied to this species was *N. illecebrosus* (Girard) (Gilbert and Bailey, 1962; Suttkus, 1980). We concur with Suttkus (1980) in placement of this species in or very closely related to the subgenus *Notropis*. Coburn (1982b) hypothesized a species group including this species plus *candidus* of the Mobile Basin and southwestern species *oxyrhynchus* and *jemezanus*, with *candidus* as the probable closest relative to *shumardi*.

Etymology: *shumardi* = patronym for George C. Shumard, naturalist on the Mexican Boundary Survey.



Range Map 80. *Notropis shumardi*, silverband shiner.

Notropis spectrunculus (Cope)

Mirror shiner

Plate 82a. *Notropis spectrunculus*, mirror shiner, 54 mm SL, Hiwassee R. system, TN.

Plate 82b. *Notropis spectrunculus*, mirror shiner, breeding male, 53 mm SL, Hiwassee R. system, TN.

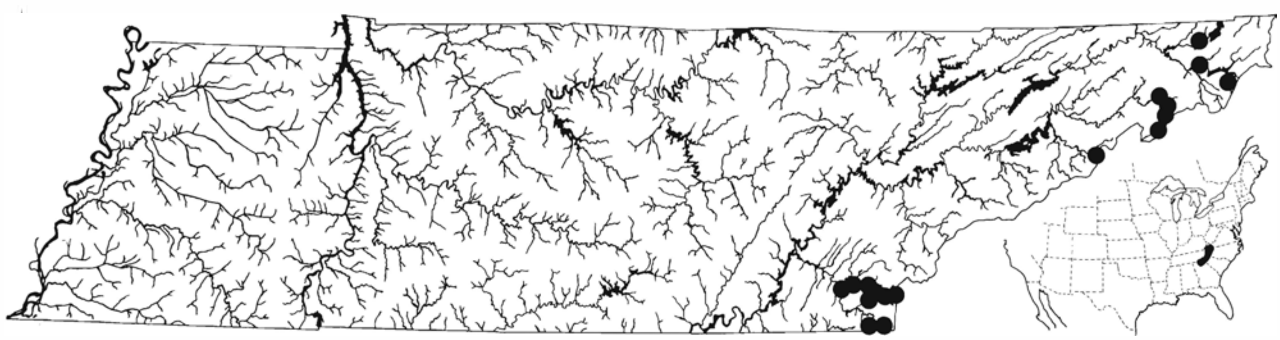
Characters: Lateral-line scales 37–39 (36–42), predorsal scale rows 16–18. Anal fin rays 8 (7–9). Pectoral fin rays 13–16. Pelvic fin rays 8. Gill rakers 5–7, length of longest rakers 1–1.5 times their basal width. Pharyngeal teeth 4-4. Breast naked. Vertebrae 39 (two specimens). Life color silver on sides, gray on back, and with prominent triangular black basicaudal spot. Nuptial males with red and black pigment on leading edge of pectoral fin (Little Tennessee and Hiwassee river races), pectoral, pelvic, and anal fins (more northerly races); and dorsal and caudal fins with centrally located reddish area (Ramsey, 1965; Outten, 1976). Males with small to moderate-sized nuptial tubercles on snout and lachrymal areas of head, and forming a single row along lower jaw and continuing onto lower margin of cheek. About 10–14 large anterodorsally directed tubercles occur on connective tissue pad anterior to first pectoral fin ray, adjacent to the row of slightly smaller, uniserial tubercles on dorsal surface of first ray. Smaller tubercles uniserial on dorsal surfaces of pectoral fin rays 2–4 or 5. Tubercles absent from other fins and body scales.

Biology: The mirror shiner is an inhabitant of mountain creeks and rivers where it occurs in rocky pools and runs. Peak tuberculation, and presumably reproductive activity, occurs from mid May through late June. We noted well-developed tubercles on a male 50 mm total length. Its biology is unreported. Maximum total length 82 mm (3.2 in).

Distribution and Status: Restricted mostly to Blue Ridge habitats of upper Tennessee River drainage from Clinch and Powell river systems of Virginia south through Hiwassee River system. Multiple headwater piracies have led to several distinct Atlantic slope populations in Savannah and Santee drainages that are more similar to populations from adjacent portions of the Tennessee than to each other (Ramsey, 1965). Locally abundant, but with spotty distribution in Tennessee.

Similar Sympatric Species: Very similar to the undescribed "sawfin shiner," which has only the first 4 or 5 dorsal fin rays outlined with melanophores (all outlined in *spectrunculus*). We are not aware of syntopic occurrence of these two species. Also similar to *N. volucellus*, which never develops red pigment, has a small or wanting caudal spot (large in *spectrunculus*), and concave dorsal and anal fin margins (straight edged or rounded in *spectrunculus*).

Systematics: As has been pointed out by Ramsey (1965), specimens from the Little Tennessee River system have a large portion of the nape naked, whereas populations both to the north and south have well-scaled napes. Although formerly included in the subgenus *Al-*



Range Map 81. *Notropis spectrunculus*, mirror shiner.

burnops, *spectrunculus* is certainly not a member of that group as herein restricted, and was included in the *volucellus* species group by Mayden (1989). The combination of red breeding colors, dark spot on anterior dorsal fin, 4-4 pharyngeal teeth, elevated anterior lateral-line scales, and a unique uniserial pattern of pectoral fin tuberculation unites *spectrunculus*, "sawfin shiner", and *N. ozarcanus* from the Ozarks.

Etymology: *spectrum* = an image, *spectrunculus* is a diminutive form.

Notropis stilbius (Jordan)

Silverstripe shiner

Plate 83a. *Notropis stilbius*, silverstripe shiner, 67 mm SL, Coosa R. system, AL.

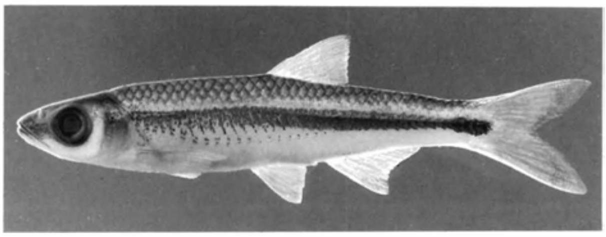
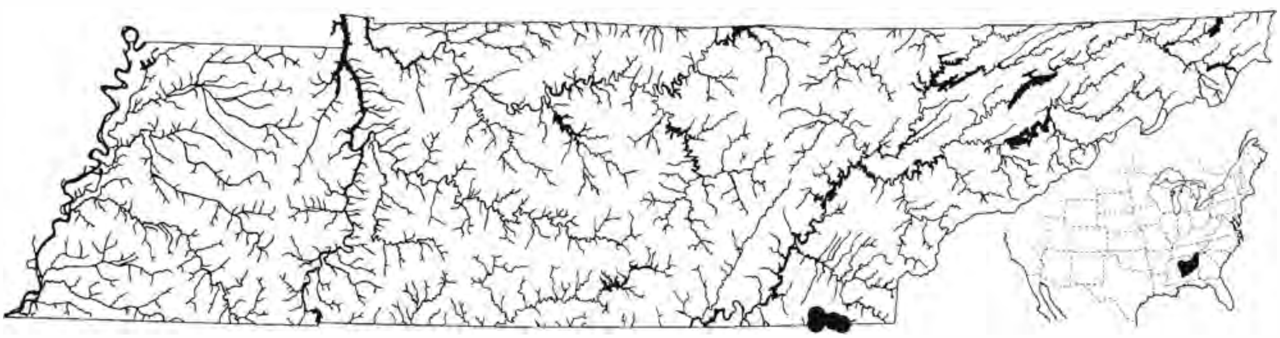


Plate 83b. *Notropis stilbius*, silverstripe shiner, preserved specimen showing pigmentation patterns, 64 mm SL, Coosa R. system, AL.

Characters: Lateral-line scales 36–37 (35–38), predorsal scale rows 17–18 (15–19). Anal fin rays 10–11 (9–12). Pectoral fin rays 14–16. Pelvic fin rays 8. Gill rakers 7–9, length of longest rakers 1–1.5 times their basal width. Pharyngeal teeth 2,4-4,2. Breast scaled. In life with elongate black basicaudal spot visible, but dark lateral stripe mostly obscured by silver; back gray with dark scale edgings apparent. Bright breeding colors lacking. Nuptial males with tiny tubercles covering the entire head. A marginal row of about 10 barely detectable tubercles occurs on all scales on anterior portion of body, and dorsal scales posterior to dorsal fin. These tubercles most conspicuous on nape scales. Pectoral fin rays 1–10 develop small tubercles on dorsal surfaces that form a single row basad, split to form 2–3 rows, 10–20 tubercles per fin ray segment, just before the branching of the ray, and continue usually as a single row, 2–3 per segment, on anterior branch, and 2–3 rows, 4–8 per segment, on posterior branch of fin ray. Tiny tubercles may also develop near margins of anal, dorsal, and dorsal surfaces of pelvic fin rays.

Biology: In Tennessee, the silverstripe shiner is confined to still or gently flowing pool areas in the Conasauga River and its larger tributaries. In more downstream portions of the Mobile Bay drainage it also occurs in large, silty rivers. Biology of the silverstripe shiner has not been studied. Conasauga River specimens have maximum tubercle development from late May through late June. Maximum total length 90 mm (3.5 in).

Distribution and Status: Occurs widely in the Mobile Bay drainage, mostly above the Fall Line, but common below Fall Line in Tombigbee River. The single Tennessee drainage specimen of *N. stilbius* (Bear Creek, northeast Mississippi, 1952) may represent a naturally occurring population due to stream capture, since additional species of Mobile Basin fishes occur in that creek (Wall, 1968). This minnow could potentially negotiate the Tenn-Tom Waterway and eventually appear in western Tennessee.



Range Map 82. *Notropis stilbius*, silverstripe shiner.

Similar Sympatric Species: *Lythrurus lirus* is the only sympatric cyprinid with 10 or more anal fin rays and the dorsal fin placed behind the pelvic insertion. It differs from *stilbius* in lacking a basicaudal spot, and in having 21 or more predorsal scale rows, lateral stripe pigment that extends down to the lateral line anteriad, and a much smaller adult size.

Systematics: Subgenus *Notropis*; relationships discussed by Coburn (1982a).

Etymology: *stilbius* = shining.

Notropis stramineus (Cope)

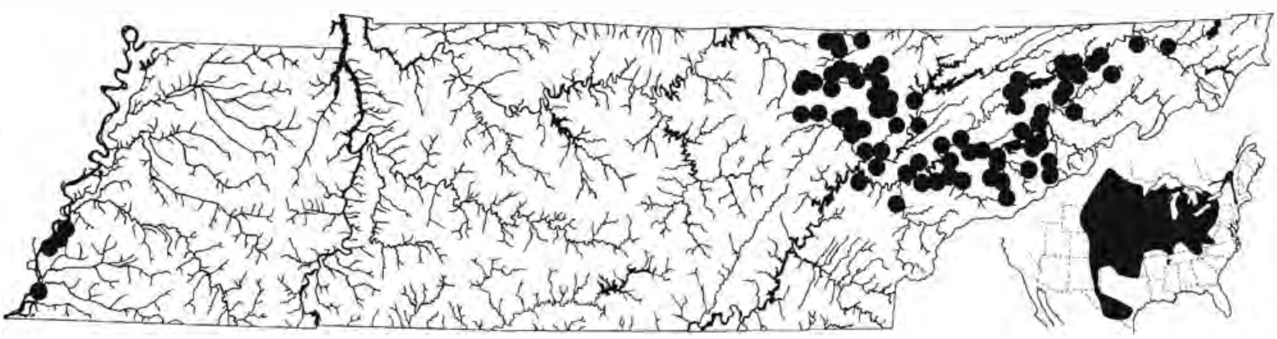
Sand shiner

Plate 84. *Notropis stramineus*, sand shiner, 47 mm SL, Big South Fork R. system, TN.

Characters: Lateral-line scales 33–35 and predorsal scale rows 14–15 in Tennessee specimens. Anal fin rays 7 (rarely 8). Pectoral fin rays 13–15. Pelvic fin rays 8. Gill rakers 7–9, length of longest rakers 1–1.5 times their basal width. Pharyngeal teeth 4-4. Breast naked to covered with embedded scales. Vertebrae 34–37. Translucent straw-colored in life with dark edgings of dorsal scales apparent. Bright breeding colors are not developed. Males with nuptial tubercles small on dorsal and lateral portions of head, most prevalent on dorsal surface posterior to nares. Pectoral fin rays 1–7 with dorsal surfaces covered with a shagreen of tiny tubercles, up to about 20 per fin ray segment, that do not form definite rows. Tiny tubercles also on nape scales and on anal and pelvic fins.

Biology: The preferred habitats of the sand shiner include quiet to flowing pools with rather clean sand or fine-gravel substrates in small to large stream environments. Its recent disappearance from numerous former habitats in upper Tennessee River tributaries may be related to large impoundments flooding the lower portions of many streams and eliminating its preferred habitat (Etnier et al., 1979). Biological studies (Starrett, 1950; Summerfelt and Minckley, 1969; Tanyolac, 1973; Mendelson, 1975) indicate that spawning extends from May or June through August. Fecundity varies from 150 to about 1,000 eggs per female per year. Sexual maturity is reached during the second summer at total lengths of about 35–40 mm. Few individuals live past their third summer. Food consists primarily of detritus, and small benthic and drifting invertebrates dominated by midge larvae and small mayfly nymphs. Gillen and Hart (1980) noted more surface-oriented feeding behavior (adult aquatic and terrestrial insects) in late summer. Maximum total length 82 mm (3.2 in), but usually not over 65 mm.

Distribution and Status: Occurs in Red River system of Hudson Bay drainage, Great Lakes drainage, and much of Mississippi River basin, but absent from most southern tributaries to Ohio River, lower and middle Cumberland and Tennessee river drainages, and most of lower Mississippi drainage below the Fall Line. Also present in western Gulf of Mexico drainages from Trinity River through the Rio Grande. Widespread and abundant throughout much of its range where sandy streams are available, but absent from Coastal Plain except for a few small Mississippi River tributaries in west Tennessee. Occasional specimens are taken in the Mississippi River proper. Common in Cumberland Plateau of Cumberland drainage above Cumberland



Range Map 83. *Notropis stramineus*, sand shiner.

Falls and in Big South Fork. Spotty in upper Tennessee drainage in Cumberland Plateau streams of Emory River system and in Ridge and Valley streams of Holston and French Broad systems where many former populations have apparently disappeared concurrent with reservoir construction (Etnier et al., 1979).

Similar Sympatric Species: Very similar to *N. wickliffi*, *N. volucellus*, and the "sawfin shiner," all of which have 8 anal fin rays and elevated (vertically elongate) anterior lateral-line scales. In *stramineus* a predorsal dark streak is conspicuous, and the postdorsal streak typically continues to the caudal fin base where it terminates in a slight intensification of pigment (predorsal dark streak absent or very faint in these similar species, postdorsal streak absent or not reaching caudal base in *volucellus* and "sawfin"). The "sawfin shiner" differs also in having only the first 4–5 dorsal fin rays outlined with melanophores (all dorsal rays outlined in *stramineus*). Certain identification of mixed series of these four species should still be based on anal fin ray counts and shape of anterior lateral-line scales, in addition to dorsal fin pigmentation. Relatively similar to the recently discovered (in Tennessee) *N. dorsalis* which co-occurs in at least one small Mississippi River tributary; *N. dorsalis* has modally 8 anal fin rays (vs. 7), a different shaped snout, which is longer (exceeds eye diameter vs. about equal or less in *stramineus*), more ventrally flattened head, and tends to have a moderately developed caudal spot broader than the lateral stripe on the caudal peduncle.

Systematics: Relationships uncertain (Mayden, 1989). Coburn and Cavender (1987) hypothesized affinities with *N. texanus*, *N. volucellus*, and members of *Hydrophlox* among other species. Snelson (1971) indicated that the closest relative of *stramineus* is *N. procne* of the Atlantic Piedmont area. Although the evidence is not compelling, some recent workers recognize a western subspecies, *N. s. missuriensis* (Cope), which differs from the nominate subspecies primarily in having smaller scales (Tanyolac, 1973). *Notropis deliciosus* (Girard) was the name formerly applied to this species. Suttkus (1958) discussed the confused nomenclature associated with this species, and of necessity relegated the name *deliciosus* to the synonymy of *N. texanus* (Girard) because of an unfortunate lectotype selection. An additional name change is pending, as Mayden and Gilbert (1989) indicated that *Cyprinella ludibunda* Girard, 1856, is an older available name for the same species. An appeal to conserve *Notropis stramineus* as the name for this species, in the interest of stability, has been submitted to the International Commission for Zoological Nomenclature (pers. comm. R. M. Bailey), and we maintain current usage until a decision is rendered by the commission.

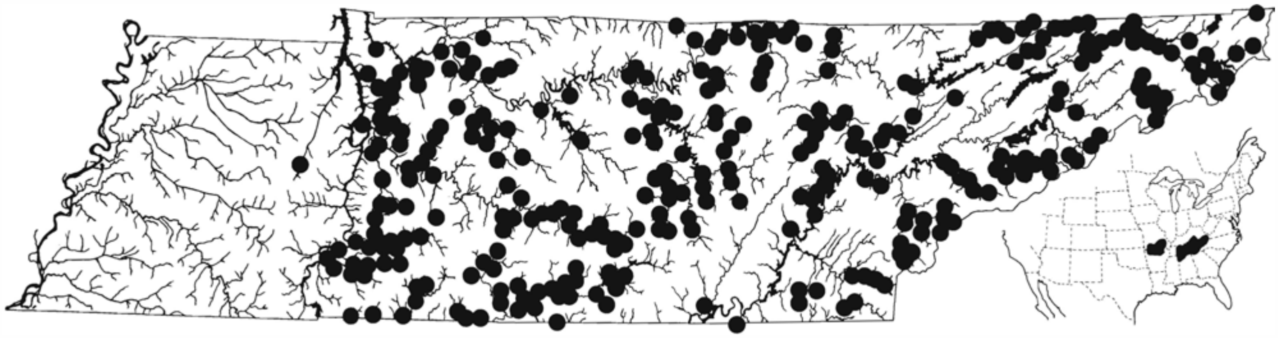
Etymology: *stramineus* = of straw, no doubt referring to the pale amber body color.

Notropis telescopus (Cope)

Telescope shiner

Plate 85. *Notropis telescopus*, telescope shiner, 68 mm SL, Caney Fork R. system, TN.

Characters: Lateral-line scales 36–39, predorsal scale rows 13–16. Anal fin rays 10 (9–11). Pectoral fin rays 14–16. Pelvic fin rays 8. Gill rakers 7–9, length of longest rakers equals their basal width. Pharyngeal teeth 2,4-4,2. Vertebrae 37–39. Breast scaled. In life silvery on sides with diagnostic dark edgings of scales on back conspicuous, no dark basicaudal spot. Bright breeding colors lacking. Peritoneum dark. Nuptial males have small, granular tubercles covering the entire head. Body scales have a marginal row of 4–20 small tubercles that are most prominent anteriad; some anterior scales also with tubercles near base of exposed field. Pectoral fin rays 1–8 or 9 with moderate-sized tubercles on dorsal surface forming single row basad, 2 rows with 2–6 tubercles per row per segment proximal to ray branching, continuing as 1–2 rows, 4–10 tubercles per segment, on posterior branch, and as a single row, 2–5 per segment, on anterior branch of ray. Smaller tubercles may develop on ventral surfaces of pectoral fin rays. Small tubercles, 1–2 per fin ray segment, also on anal, dorsal, outer branched ray of lower lobe of caudal, and both dorsal and ventral surfaces of anterior pelvic fin rays. As is the case with *L. coccogenis*, head tubercles (especially on snout and lower jaw) are persistent from April through October in both sexes, and occur on juveniles as small as 23 mm TL. Scale and pectoral fin tubercles are smaller and more abundant on Ozark and middle Tennessee specimens than on specimens from upper east Tennessee.



Range Map 84. *Notropis telescopus*, telescope shiner.

Biology: The telescope shiner is a common inhabitant of rocky streams and small rivers where it typically occurs in swift currents adjacent to riffle areas. Gut contents of the few spring and summer adults we examined contained about two-thirds terrestrial and surface insects, and one-third immature benthic insects (Trichoptera, Ephemeroptera, Plecoptera). Spawning occurs from mid April through mid June. Maximum total length 115 mm (4.5 in).

Distribution and Status: Common in all upland physiographic provinces of the Tennessee and Cumberland drainages except the Nashville Basin. We have a single specimen from the Coastal Plain from upper Big Sandy River, Henderson County, Tenn. Also common in Ozark uplands in Little, St. Francis, and White river systems of southern Missouri and northern Arkansas. Common, and presumably introduced in upper New (Kanawha) system.

Similar Sympatric Species: Often confused with *N. leuciodus*, which has 8 (8–9) anal fin rays, a distinct caudal spot, a smaller eye, and especially in juveniles, the middorsal streak is interrupted at anterior and posterior base of dorsal fin, leaving an isolated dark mark under middle of fin (middorsal streak continuous under dorsal fin in *telescopus*). In *telescopus*, anterior dorsolateral scales have both marginal and submarginal concentrations of dark pigment separated by a paler area, giving a "double exposure" effect (Fig. 84); and concentrations of dark pigment between horizontal scale rows form two irregular horizontal lines on each side of and converging behind dorsal fin. These lines best seen in dorsal view. In *leuciodus* and the also similar *ariommus*, *photogenis*, and *rubellus*, these scales usually have a single marginal concentration of dark pigment, and scale rows never form dark horizontal lines. Similar but more numerous dark lines also present on *Luxilus chrysocephalus*, which has greatly deepened anterior lateral-line scales, a yellowish caudal fin, and lacks dark pigment concentrations surrounding lateral-line canal (dark spot above and below canal on each lateral-line scale in *telescopus*). The persistent snout and loweı jaw tubercles of females and juveniles are shared only by *Luxilus coccogenis*.

Systematics: Included in subgenus *Notropis* (Coburn, 1982a). Until recently unjustly considered a subspecies of *N. ariommus*. See comments under that species, and Gilbert (1969).

Etymology: *telescopus* = far-seeing, referring to the large eye.

Notropis texanus (Girard)

Weed shiner

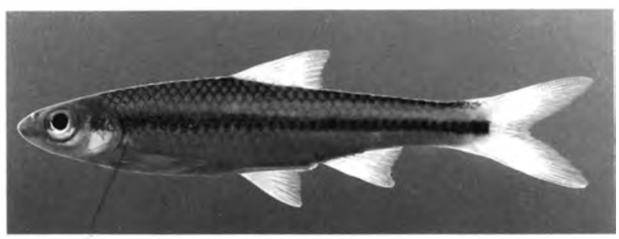


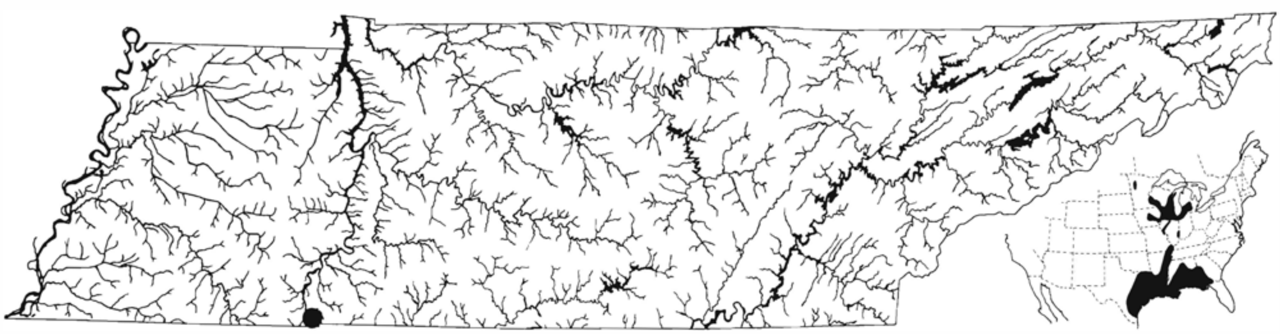
Plate 86. *Notropis texanus*, weed shiner, preserved specimen, 55 mm SL, Leaf R. system, MS.

Characters: Lateral-line scales 34–38, predorsal scale rows 14–16. Anal fin rays 7 (6–8). Pectoral fin rays 12–16. Pelvic fin rays modally 8. Gill rakers 7–9, the longest rakers about twice their basal width. Pharyngeal teeth usually 2,4-4,2. Breast naked. Vertebrae 36–37 (35–38). Coloration in life is silvery, often with yellowish tints dorsally, and with a dark midlateral stripe and basicaudal spot. Nuptial males are mentioned as having rosy or reddish orange colors on the median and pectoral fins, the pale area above the lateral stripe, the top of the head, and the snout (Jordan and Evermann 1896–1900, as *Notropis roseus*; Swift, 1970). These colors are apparently very ephemeral, as neither of us nor a number of our colleagues who are very familiar with this fish have noticed red or rosy nuptial coloration. In preservative the lateral dark stripe, about 1 scale deep and narrowing and darkening slightly on the caudal peduncle, is conspicuous. The stripe is continuous with a darker basicaudal spot of about equal depth, and anteriad continues on the head (weak on preoperculum) to the snout and tip of the lower jaw. An area about 1.5 scale rows deep above the lateral stripe is conspicuously paler than the lateral stripe or the dorsum, and scales in this area on the caudal peduncle virtually lack dark pigment. The predorsal dark streak is prominent, and enlarges to form a wider blotch at the dorsal fin origin. The postdorsal dark streak is narrow and inconspicuous. A diagnostic character of this species is the darkly margined posterior (but not anterior) rays of the anal fin (Fig. 89). Nuptial males have large tubercles on the lower jaw, snout tip, lachrymal area, and dorsal margin of the orbits. Tubercles are slightly smaller on the gill cover and top of the head, and continue along the midline to the dorsal fin. Anterior dorsal body scales have a marginal row of small tubercles, and a dense shagreen of sharply pointed tubercles is present on the second through about the eighth or ninth pectoral fin ray.

Biology: The common name of weed shiner is reasonably appropriate in the Midwest, but in the southern portion of its range *Notropis texanus* inhabits creeks and small rivers with clear water and sandy substrates, with vegetation often lacking and rarely conspicuous. Heins and Rabito (1988) compared reproductive traits of two Gulf Coastal Plain populations. The breeding season extended from March through August, and some breeding may have occurred from February to October. Both sexes were mature at age 1, at sizes as small as 30 mm SL. Females produced several clutches of eggs during the spawning season, with early clutches averaging about 500–700 eggs. Mature ovarian eggs averaged .81 and .97 mm in diameter. The southeastern Mississippi population matured at smaller sizes, had smaller maximum size, and produced more but smaller eggs per clutch than the population from the Florida Panhandle area. The authors attributed these differences in reproductive strategies to different selective regimes caused by differences in run-off rates in the two areas. Bresnick and Heins (1977) reported on growth of the same southeastern Mississippi population mentioned above. Mean standard lengths of 37, 44, and 54 mm were reached at ages 1, 2, and 3, and life span was 3 years. Becker (1983) indicated that a significant portion of the diet was composed of filamentous algae and detritus, in addition to the expected small invertebrates. Maximum total length 82 mm (3.2 in).

Distribution and Status: Occurs from the Suwannee River drainage of Florida west through the Neuces River drainage of central Texas, mostly below the Fall Line, and extends northward through Arkansas and Missouri into the lower Wabash River system, the Illinois River system, the upper Mississippi River drainage, the central Great Lakes drainage, and the southern portion of the Hudson Bay drainage in northwestern Minnesota. The weed shiner is a new addition to our fauna, apparently having entered Tennessee via the Tenn-Tom Waterway. At this writing the only known population is in Robinson Creek in Hardin County.

Similar Sympatric Species: Other *Notropis* in the Hardin County area with only 7 anal fin rays are *blennius* and possibly *edwardraneyi*, a Mobile Basin species which may also traverse the Tenn-Tom. Both of these lack a dark lateral stripe and caudal spot and are restricted to large rivers. Even modest expansion of the range of the weed shiner in Tennessee would bring it into potential contact with the very similar *Notropis*



Range Map 85. *Notropis texanus*, weed shiner.

boops and the rather less similar *N. leuciodus* and *N. volucellus*. All of these have 8 anal fin rays, and none of them has 2,4-4,2 pharyngeal teeth.

Systematics: Suttkus (1958) discussed the circumstances that necessitated the name change from *Notropis roseus* (Jordan). Swift (1970), Coburn (1982a), and Mayden (1989) all considered the *Notropis texanus* species group to contain that species plus *chalybaeus* and *petersoni*. Swift also included *asperifrons* and *hypsilepis* in the *texanus* group, and Coburn and Mayden both omitted these species and added *anogenus*, *altipinnis*, *boops*, *heterodon*, and *xaenocephalus*.

Etymology: *texanus* = of Texas, the type locality.

Notropis volucellus (Cope)

Mimic shiner

Plate 87a. *Notropis volucellus*, mimic shiner, 42 mm SL, Stones R. system, TN.

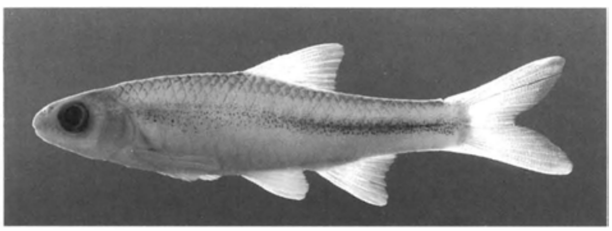


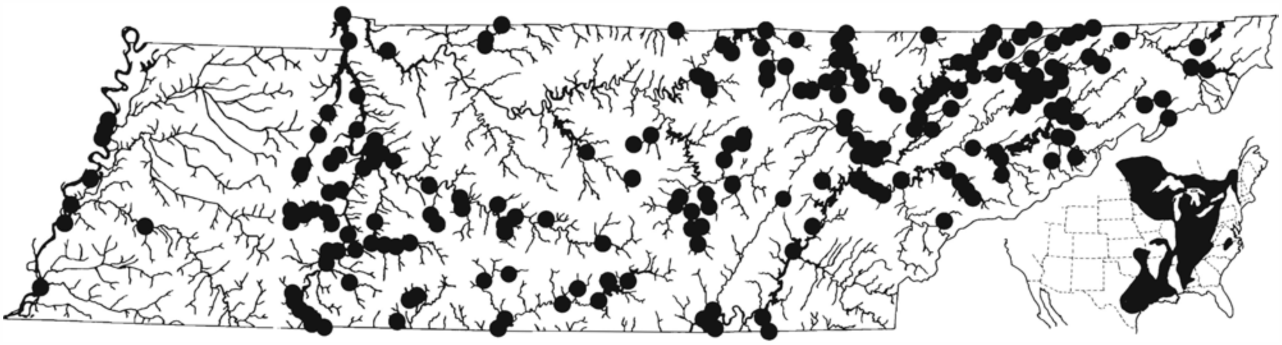
Plate 87b. *Notropis volucellus*, mimic shiner, preserved specimen showing pigmentation patterns; 42 mm SL, lower Tennessee R., TN.

Characters: Lateral-line scales 33–36, predorsal scale rows 13–15. Anterior lateral-line scales 2–3 times deeper than long. Anal fin rays 8. Pectoral fin rays 13–17. Pelvic fin rays 8. Gill rakers 5–10, length of longest rakers 0.5–1 times their basal width. Pharyngeal teeth 4-4. Breast naked or (rarely) fully scaled. Vertebrae 35–37 (ten specimens). Color in life translucent silver on sides to gray or faintly amber on back; dark edgings conspicuous on dorsolateral scales, and tiny, triangular basicaudal spot often evident. Bright breeding colors lacking. In nuptial males tubercles cover the top and sides of the head and lower jaws, and are largest on the snout and lachrymal areas. Tubercles are generally absent from fins except the dorsal surface of the pectorals, where there are about 2 poorly defined rows on ray 1, and on rays 2–6 or 7 there is a single row basad that branches into 2 rows near the branching of the ray, each row continuing on one of the ray branches, with 2–3 tubercles per fin ray segment. Small tubercles are occasionally present on scales on and near the dorsal midline, and on anterior dorsal fin rays.

Biology: The only aquatic habitats consistently avoided by the widespread mimic shiner are small creeks and marshy or swampy areas. The mimic shiner is very common in glacial lakes in the Midwest and in clear small rivers and large creeks in our area. It has considerable tolerance for reservoirs and rivers as large as the Mississippi and lower Duck in Tennessee. Biological investigations (Black, 1945; Moyle, 1973) have dealt primarily with midwestern populations, where diets have consisted of microcrustacea, midge larvae and pupae, and some terrestrial insects. Life span is suspected to be 3 years, with sexual maturity probably attained in the first year in Tennessee populations. Diurnal migrations to and from inshore areas have been noted for this species and its relatives. Both above studies indicated night movement away from shore in midwestern lakes. Tubercles appear on males from late May through early October in our area, indicating an extensive spawning period throughout the warmer months. Maximum total length 65 mm (2.6 in) in Tennessee forms, but reported to reach slightly larger sizes elsewhere.

Distribution and Status: Widespread in southern Hudson Bay drainage, Great Lakes drainage, and throughout much of Mississippi River basin except for northern Great Plains. Also occurs in Atlantic Coast drainages in Connecticut and Housatonic rivers (introduced) and in James, Roanoke, Neuse, and Tar rivers of Virginia and North Carolina. Gulf of Mexico distribution extends from Mobile Bay west through Neuces River drainage of Texas. Common in a wide range of habitats and physiographic provinces throughout its range. Strangely absent from broad areas of Tennessee, such as the Coastal Plain, where it occurs in the Mississippi River but is virtually absent from its direct tributaries.

Similar Sympatric Species: See comments under *N. buchanani* and *N. wickliffi*. *Notropis stramineus*, in addition to having only 7 anal fin rays, has well developed pre- and postdorsal streaks and a pale area under the dorsal fin origin followed by a distinct dark dash under



Range Map 86. *Notropis volucellus*, mimic shiner.

the remainder of the fin. The undescribed "sawfin shiner" has only the first 4–5 dorsal fin rays margined with dark pigment (all rays margined in *volucellus*). *Notropis spectrunculus* has rounded or straight-edged rather than pointed and falcate dorsal and anal fins. The last two species considered develop red breeding colors on the fins.

Systematics: The vernacular name "mimic shiner" is very appropriate for this taxonomically confusing species. Even with removal of *buchanani* and *wickliffi* from the synonymy of *volucellus*, description of *Notropis cahabae* by Mayden and Kuhajda (1989), and recognition of the as yet undescribed "sawfin shiner" as distinct species sympatric with *volucellus* (J. S. Ramsey, pers. comm.), *Notropis volucellus* is still likely to be a complex of several cryptic species. In Tennessee, nontypical forms occur in the Nolichucky River, the Caney Fork River, and in portions of Norris Reservoir. Specimens from south central and southwestern U.S. also show considerable divergence from Tennessee and Midwest specimens. The affinities of the *volucellus* species group with other recognized subgenera or species groups are still unclear, but they are most commonly associated with the *Notropis texanus* species group, though Coburn and Cavender (1987) hypothesized affinities with *N. stramineus* and other species, and Mayden (1989) erected a "*volucellus* species group" to include species mentioned above and *N. tropicus* of Mexico, as well as *spectrunculus*, *ozarcanus*, and the "sawfin shiner." Also included as more primitive in the group were *N. heterolepis* (and presumably *rupestris*), *N. maculatus*, and *Opsopoeodus emiliae*. An understanding of the phylogeny of this group and the number of species or subspecies involved is seen as one of the most interesting, needed, and difficult problems remaining in the systematics of North American freshwater fishes.

Etymology: *volucellus* = winged or swift.

Notropis wickliffi Trautman

Channel shiner

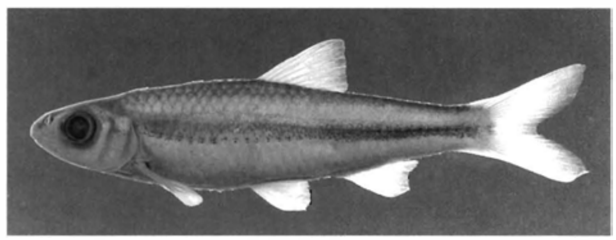
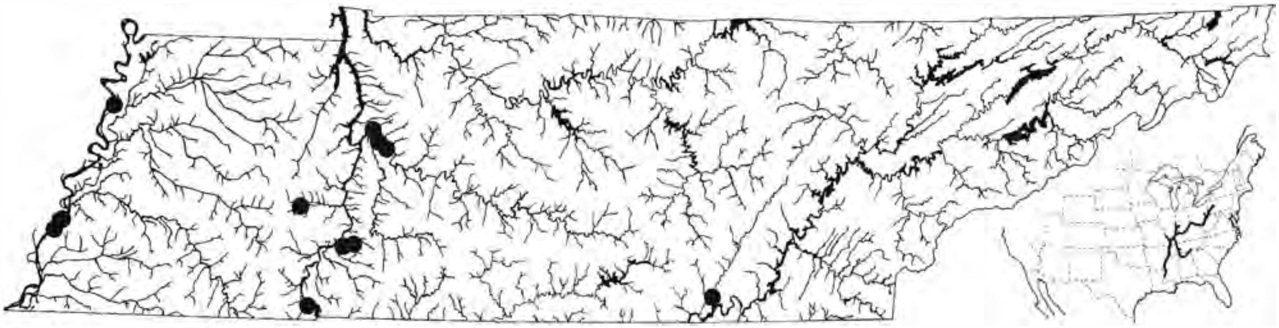


Plate 88. *Notropis wickliffi*, channel shiner, preserved specimen, 54 mm SL, Sequatchie R., TN.

Characters: Lateral-line scales 33–36, predorsal scale rows 13–15. Anterior lateral-line scales elevated. Anal fin rays 8. Pectoral fin rays 14–16. Pelvic fin rays 8. Gill rakers 6–9, length of longest rakers 1–1.5 times their basal width. Pharyngeal teeth 4-4. Breast naked. Life colors translucent silvery on sides to gray on back; dark edgings of dorsolateral scales faintly visible. Bright breeding colors lacking. Nuptial tubercles are essentially identical with those of *N. volucellus*, except that snout tubercles are not well developed, and are less distinct than those on the interorbital area. We have not observed tubercles on specimens smaller than 50 mm TL, whereas male *N. volucellus* as small as 40 mm are frequently tuberculate.

Biology: The channel shiner is, as the name implies, apparently restricted to big-river habitats, where it occurs in quiet water to moderate current over substrates ranging from silt to gravel. Trautman (1957) reported spawning from June to August, and this agrees well with the distribution of tuberculate specimens in our collection. The biology of *wickliffi* is otherwise unstudied. Maximum total length 78 mm (3.1 in).



Range Map 87. *Notropis wickliffi*, channel shiner (range in Mississippi Basin probably more extensive than shown).

Distribution and Status: Because of confusion with *N. volucellus*, the distribution of this species is poorly understood, but certainly includes the Ohio River and its larger tributaries, the Mississippi River, and the Tennessee River and its larger tributaries.

Similar Sympatric Species: Adults differ from sympatric *N. volucellus* in having a larger eye, bigger mouth, deeper caudal peduncle, and less deepened body (Trautman, 1931). In addition, we have noted that *wickliffi* has a less-arched back, a very weak or wanting predorsal blotch (conspicuous in *volucellus*), a continuous postdorsal dark streak (absent or not continuous in sympatric *volucellus*), and melanophores more evenly distributed over dorsolateral scales (concentrated near margins in *volucellus*). In *N. volucellus* nuptial males, tubercles on the snout and lachrymal areas are much more prominent than those on top of the head, while in *wickliffi* the reverse is true. Also, see comments under *N. buchanani*.

Systematics: Trautman (1931) described *wickliffi* as a subspecies of *N. volucellus* that was more prevalent in large rivers than typical *volucellus*. He noted many "intergrades" in areas of sympatry. While sorting through fish collections from the lower Duck River in Tennessee, David L. Nieland noted that "*N. volucellus*" specimens were easily separated into two distinct forms, without apparent intergrades. This pattern has persisted where the two forms are sympatric in Tennessee rivers and in specimens we have seen from throughout the Ohio River. Although so similar in appearance that juveniles are virtually inseparable, the consistent differences in adult body form, pigmentation, tuberculation, and maximum size strongly suggest that two species are involved. The Tennessee form to which we, with little reservation, apply the name *wickliffi*, agrees perfectly with Trautman's (1931) description of *N. volucellus wickliffi* from big rivers of the Midwest, and with recently collected topotypic specimens. It is interesting to note that *N. buchanani* was also considered a subspecies of *N. volucellus* in this paper. More recent studies of Ohio River populations (Cavender, pers. comm.) have also tended to support species status for *wickliffi*. Furthermore, Mayden and Kuhajda (1989) hypothesized it to be the sister species to the newly described *N. cahabae* of the Cahaba River in Alabama.

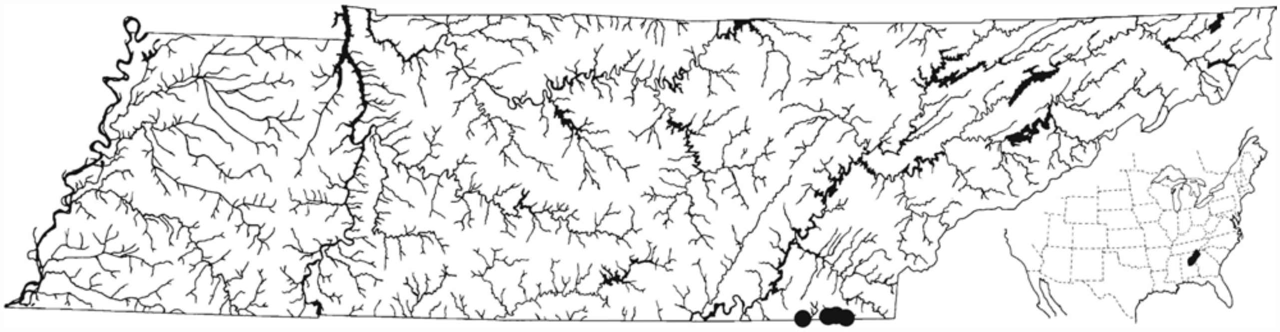
Etymology: *wickliffi* is a patronym for Edward L. Wickliff, an early student of Ohio fishes and colleague of M. B. Trautman.

Notropis xaenocephalus (Jordan)

Coosa shiner

Plate 89. *Notropis xaenocephalus*, Coosa shiner, 60 mm SL, Conasauga R. system, TN.

Characters: Lateral-line scales 35–37, predorsal scale rows 15–16. Anal fin rays 7 (7–8). Pectoral fin rays 13–15. Pelvic fin rays 8. Gill rakers 6–8, length of longest rakers 1.5–2 times their basal width. Pharyngeal teeth 2,4-4,2. Breast scaled. Vertebrae 36–37 (38). In life, silvery on sides with prominent dark lateral stripe terminating in quadrate basicaudal spot; dark edgings of dorsolateral scales prominent, and dark pre- and postdorsal streak present. Bright breeding colors lacking. In nuptial males, small tubercles cover the dor-



Range Map 88. *Notropis xaenocephalus*, Coosa shiner.

sal surface of the head and occur on body scales anterior to dorsal fin base and down to 2–3 rows below lateral line. Tubercles on dorsal surfaces of pectoral fin rays 1–8 form a single row basad, with a row continuing onto each major branch of the ray, and 3–4 tubercles per fin ray segment.

Biology: The Coosa shiner occurs in pool areas with firm substrates, and inhabits small creeks and rivers. It's biology has not been studied. Swift (1970) indicated a June-to-July breeding season, but our early April specimens have well-developed tubercles. Maximum total length 75 mm (3 in).

Distribution and Status: Endemic to the upper Alabama River portion of the Mobile Basin where it is common in small to medium streams above the Fall Line. In Tennessee confined to the Conasauga River and its tributaries in Polk and Bradley counties.

Similar Sympatric Species: Other small Conasauga River *Notropis* with low anal fin ray counts are *asperifrons* and *chrosomus*. In the former there is no dark predorsal streak, the breast is mostly naked, and the body is very slender. In *chrosomus* red breeding colors are often present, a dark postanal streak and melanophores along the anal fin base are lacking, and there are 8 anal fin rays.

Systematics: Swift (1970) indicated that *N. scabriceps* (a New River, Va. and W. Va. endemic) and *N. boops* are closest relatives of *xaenocephalus*, and that these three species have their affinities either with the subgenera *Alburnops* or *Notropis*. Mayden (1989) considered *xaenocephalus* and *boops* to be sister species within the *N. texanus* species group.

Etymology: *xaeno* = to scratch, *cephalus* = head, referring to head tuberculation of nuptial males.

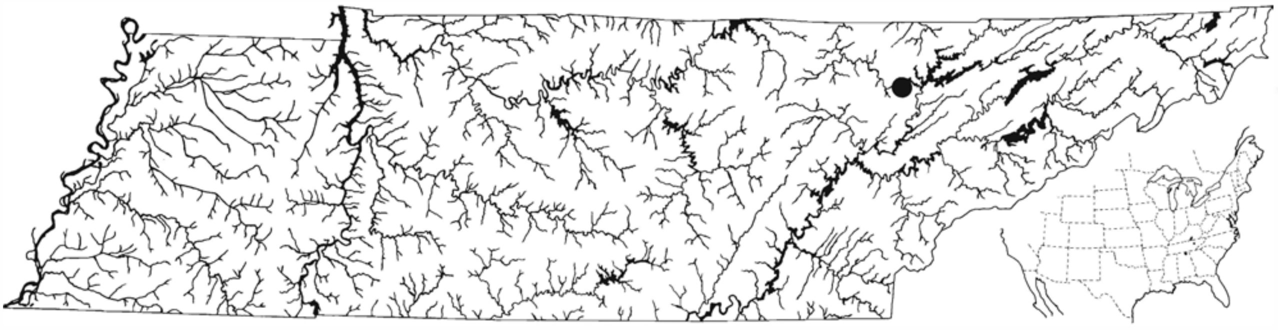
Notropis sp

"Palezone shiner"

Plate 90. *Notropis* sp., "palezone shiner", 58 mm SL, Little South Fork R., KY.

Characters: Lateral-line scales 35–39, predorsal scale rows 15–17. Anal fin rays 7. Pectoral fin rays 13–16. Pelvic fin rays 8 (8–9). Gill rakers 7–9, length of longest rakers 1.5–2 times their basal width. Pharyngeal teeth 4-4. Breast nearly naked to almost fully scaled. Vertebrae 38 (one specimen). An extremely slender species with a dark lateral stripe bordered above and below by non-pigmented areas. Nuptial males with sharply pointed tubercles of moderate size covering the entire head except for the anterior portion of the snout and the lower opercles. Tubercles on the dorsal surface of the pectoral fin rays are tiny, occupy the first 8–9 rays, and form a shagreen over the basal portions of the rays; they continue as a single row with about 5 tubercles per ray segment on the anterior branches of the rays and as a double row on the posterior branch. Small tubercles are also present on the branchiostegal rays, but were not apparent on body scales or other fins. Bright breeding colors do not develop. Characters were discussed by Branson (1983).

Biology: The "palezone shiner" occurs in quiet waters and flowing pools in shallow to moderate depths over gravel substrates. The only known extant populations occur in small upland rivers, the Little South Fork of the Cumberland River in southeast Kentucky and Paint



Range Map 89. *Notropis* sp., "palezone shiner."

Rock River in Alabama. Both of these streams have exceptional water quality, diverse aquatic faunas, and provide refugia for other jeopardized fishes and invertebrates. Our only tuberculate specimens are from 23 May and 17 June, with the June specimens probably close to peak spawning condition. At least two size classes occur in our collections, indicating a life span of 2 to 3 years. Maximum total length 62 mm (2.5 in).

Distribution and Status: In addition to Little South Fork and Paint Rock rivers where it is locally restricted and occasionally common (Warren and Burr, 1990), the only other locality where this species has been collected is Cove Creek, tributary to Clinch River in Campbell County, Tenn., where it was extirpated by impoundment of Cove Lake and Norris Reservoir or by siltation from coal mining. In years of high abundance it might penetrate the headwaters of the Little South Fork in eastern Pickett County, Tenn., but marked changes in habitat several kilometers downstream from the state line suggest that it probably does not. All three localities are on the periphery of the Cumberland Plateau. It is included in Tennessee's list of Species in Need of Management (believed to be extirpated from Tennessee), and is certainly a candidate for future federal listing as a Threatened Species.

Similar Sympatric Species: *Pimephales notatus* is generally similar, but is more robust, has more than 20 predorsal scale rows, and has a black peritoneum. *Notropis volucellus* lacks the virtually unpigmented area above its less intense lateral stripe, is deeper bodied, has eight anal fin rays, and has the anterior lateral-line scales elevated.

Systematics: According to R. E. Jenkins affinities of the palezone shiner may be with *N. procne* of the Atlantic Piedmont and Coastal Plain, and *N. stramineus*. Those two species were of unresolved status in Mayden's (1989) analysis of cyprinid relationships. It is being described by B. M. Burr and M. L. Warren, Jr.

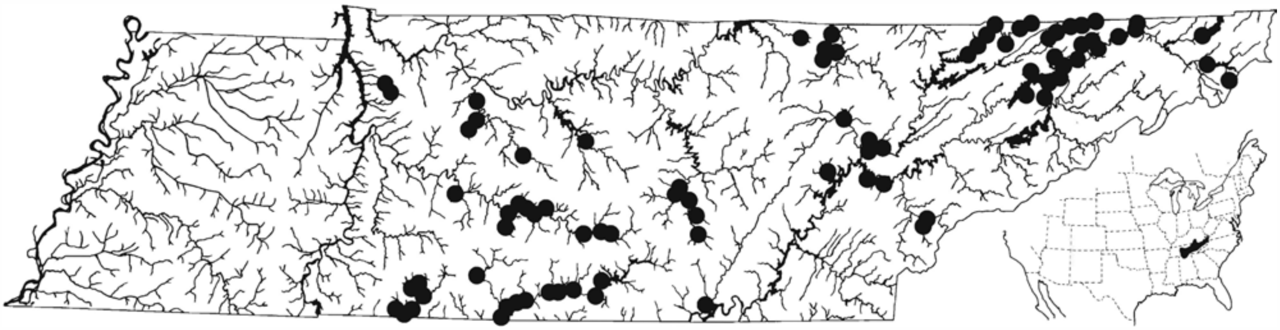
Notropis sp

"Sawfin shiner"

Plate 91a. *Notropis* sp., "sawfin shiner", 50 mm SL, Clinch R., TN.

Plate 91b. *Notropis* sp., "sawfin shiner", breeding male, 43 mm SL, Clinch R., TN.

Characters: Lateral-line scales 34–37, predorsal scale rows 16–17 (15–18). Anal fin rays 8 (7–9). Pectoral fin rays 13–16. Pelvic fin rays 8 (7–9). Gill rakers 7–8, length of longest rakers half their basal width. Pharyngeal teeth 4-4. Breast usually with exposed or embedded scales. Vertebrae 38–39 (two specimens). Translucent silvery gray in life with prominent dark edging on dorsolateral scales. Males develop red on anterior portions of dorsal, anal, pectoral, and pelvic fins. Pectoral fin tuberculation identical to that of *N. spectrunculus*, except that tubercles are slightly smaller. Other fins and body scales lacking tubercles. Head lacking conspicuous tubercles in our specimens, but in a collection from Clinch River, 20 June, the entire head



Range Map 90. *Notropis* sp., "sawfin shiner."

of both sexes was covered with tiny, slender, bluntly pointed projections that may represent tubercles, or free neuromasts associated with the breeding season. It is also possible that the visibility of these structures is a preservation artifact. Characters discussed by Branson (1983).

Biology: The "sawfin shiner" is a locally abundant species of clear streams and rivers of the Tennessee and Cumberland river drainages, where it occurs in quiet or gently flowing pools. Its biology is unstudied. Tuberculate males occur in collections from mid May through mid July, but red breeding colors are persistent over a longer period. A male only 40 mm TL was fully tuberculate and apparently sexually mature. Maximum TL 68 mm (2.7 in).

Distribution and Status: Of sporadic occurrence but locally common in Highland Rim and Ridge and Valley in Cumberland and Tennessee drainages. It is replaced by the closely related *N. spectrunculus* in Blue Ridge of Tennessee drainage.

Similar Sympatric Species: Nonchromatic specimens are very similar to both *N. volucellus* and *N. stramineus*, both of which have all dorsal fin rays outlined with melanophores (only first 4–5 in "sawfin"). Neither of these species has a scaled breast, and *stramineus* has only 7 anal fin rays. Not known to be sympatric with the closely related *N. spectrunculus*, which has rounded or straight rather than concave dorsal and anal fin margins, and all dorsal fin rays outlined with melanophores.

Systematics: Long confused with its close relative, *N. spectrunculus*, and many earlier records for that species, especially those not from Blue Ridge areas, were probably based on the "sawfin shiner." Also related to *N. ozarcanus* (see *spectrunculus* account).

Genus *Opsopoeodus* Hay

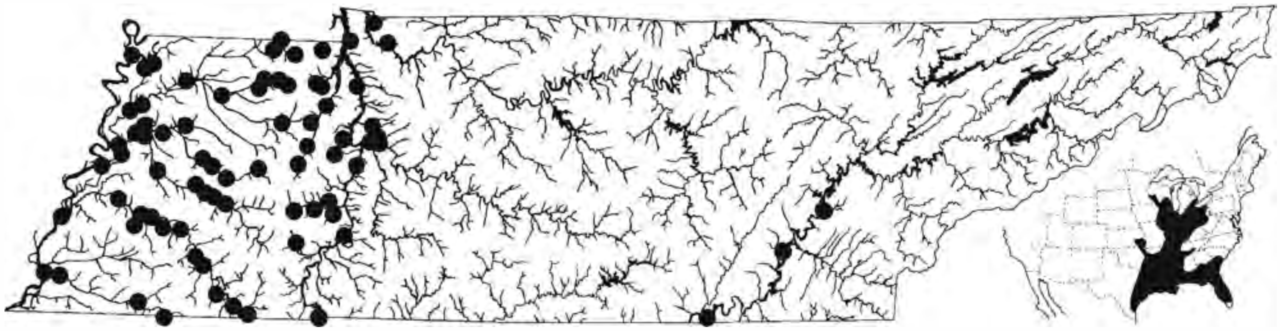
The genus consists of a single species, discussed below.

Opsopoeodus emiliae Hay

Pugnose minnow

Plate 92. *Opsopoeodus emiliae*, pugnose minnow, 45 mm SL, Hatchie R., TN.

Characters: Lateral-line scales 36–39, lateral line occasionally incomplete on caudal peduncle, predorsal scale rows 16–20. Anal fin rays 8. Dorsal fin rays 9 as opposed to 8 in other native Tennessee cyprinids. Pectoral fin rays 14–15 (13–16). Pelvic fin rays 8. Gill rakers 8–11, length of longest rakers 0.5–1 times their basal width. Pharyngeal teeth 5-5. Breast naked. Small maxillary barbel occasionally present. Vertebrae 37–38. Translucent silvery on lower sides to straw-colored on back, with dark edgings of dorsolateral scales apparent. A dark, narrow lateral stripe and separate diffuse basicaudal spot are usually evident. Except for nuptial males, the first 4 and last 3 dorsal fin rays are outlined with melanophores, but rays 5 and 6 lack dark pigment (Fig. 70). Fins, especially the caudal and anal, may develop pink or red breeding colors (Gilbert and Bailey, 1972), and males also develop dark pigment on anterior and posterior membranes of dorsal fin. At peak breeding color, tips of the paired fins are white, the dorsal fin



Range Map 91. *Opsopoeodus emiliae*, pugnose minnow.

may be entirely blackened, and (Page and Johnston, 1990b) white spots tip the 3 anterior dorsal fin rays. In males, nuptial tubercles on the head are in a curved band on the anterior snout adjacent to the upper lip, anterior to the nares, and bounded laterally by the lachrymal area. An additional dense patch of tubercles occupies the gular area, extending from the lower lip to slightly behind the jaw angle. Pectoral fin rays 2–6 or 7 have moderate-sized tubercles on their dorsal surfaces that form a single row basad, 2 rows with about 3 tubercles per row per fin ray segment medially, and extend a short distance past major branching of ray as a single row on each branch. The first pectoral fin ray has a poorly defined single row of smaller tubercles. Tubercles absent elsewhere.

Biology: The pugnose minnow is a characteristic inhabitant of vegetated slack-water areas in the Coastal Plain of west Tennessee; it also occurs in pools in large creeks and rivers in that area. Its biology is poorly studied. Food consists of insect larvae, filamentous algae, and microcrustacea (McLane, 1955), which, judging from its nearly vertical mouth, are taken in midwater areas or on the surface. Spawning time, based on occurrence of tuberculate males, is in late spring and early summer. As in *Pimephales*, eggs are deposited on the underside of a flat object by the partially inverted female, and presumably the eggs and nest site are defended by the male (Johnston and Page, 1988, from aquarium spawning). Maximum total length 66 mm (2.6 in).

Distribution and Status: Coastal Plain from Edisto drainage of South Carolina through Neuces drainage of Texas, the Mississippi Valley north to southeastern Minnesota, and the Lake Erie drainage. In Tennessee it occurs sporadically on the Coastal Plain and adjacent larger waters of the Tennessee drainage, and in the extreme lower Cumberland drainage.

Similar Sympatric Species: *Notemigonus crysoleucas* also has a distinctly upturned mouth, but differs in having the lateral stripe broad or absent (narrow in *Opsopoeodus*), and in having 12 or more anal fin rays. The diamond-shaped dorsolateral scale pattern is shared by *Hybognathus hayi*, *Pimephales notatus*, *P. vigilax*, and the genus *Cyprinella*, all of which have horizontal or moderately oblique mouths and 8 dorsal fin rays. None of these share the unique dorsal fin pigmentation of *Opsopoeodus*.

Systematics: Gilbert and Bailey (1972) proposed the inclusion of *Opsopoeodus* under the synonymy of *Notropis*, arguing that the diagnostic characters of *Opsopoedus* all have their counterparts in various *Notropis*, a proposal followed by Robins et al. (1980). Dimmick (1987) noted that *emiliae* was genetically more similar to *Notropis maculatus* than to any other species of the small sample of minnows he examined, and Mayden (1989) regarded these as sister species with *N. heterolepis* as next closest relative within the *N. volucellus* species group. Campos and Hubbs (1973) indicated that *emiliae* differs from current members of *Notropis* in having 48 rather than 50 chromosomes in diploid cells, but Gold (1984) found 50 chromosomes in *emiliae*. Amemiya and Gold (1990) also reported a diploid chromosome count of 50 in *Opsopoeodus* and found that chromosome morphology did not support a close relationship with *Notropis maculatus* but rather with members of *Cyprinella* and *Pimephales*. Cavender and Coburn (1985) hypothesized that closest affinities of *Opsopoeodus* are with *Pimephales*, and the specialized *Pimephales*-like reproductive behavior (Johnston and Page, 1988; Page and Johnston, 1990b) lends support to that view. We feel that the combination of 9 dorsal fin rays, 5–5 pharyngeal teeth, and a vertical mouth in this species, features of undetermined significance with regard to relationships, combined with uncertainty of phylogenetic position with regard to the probably polyphyletic genus *Notropis*, warrants its retention as a distinct genus for the present. Other currently recognized genera (*Ericymba*, *Hybognathus*) might be synonymized with *Notropis* using similar justification and uncertainty concerning relationships. In addition, the nuptial tubercle pattern is unique.

A distinctive subspecies, *O. e. peninsularis* Gilbert and Bailey (1972), occurs in peninsular Florida and differs from the nominate subspecies in snout tubercle pattern, 5-4 pharyngeal tooth count, and absence of a strikingly bicolored dorsal fin in nuptial males.

Etymology: *Opsopoeodus* = approximately "teeth for dainty feeding" (Greek); *emiliae* = matronym for Mrs. Emily Hay, wife of the author of the species, Dr. O. P. Hay.

Genus *Phenacobius* Cope
The Suckermouth Minnows

Four of the five species in the distinctive genus *Phenacobius* occur in Tennessee. The remaining species, *P. teretulus* Cope, occurs in the New River system of North Carolina, Virginia, and West Virginia. All species are slender, silvery fishes with sucker-like mouths, 4-4 pharyngeal teeth, small scales, naked breasts, deeply embedded scales on anterior belly, complete lateral lines, 7 anal fin rays, 8 pelvic fin rays, gill rakers about as long as their basal width, and gill membranes broadly joined to the isthmus. The four eastern species are typically found in swift currents over gravel substrates in medium-sized rivers. The central species, *P. mirabilis*, is frequently found in rather quiet waters, tolerates habitats from creeks to big rivers, and is also capable of inhabiting torrential currents. Biology of the genus has received little attention, and reproductive habits are unknown. Food studies on *P. mirabilis* by Starrett (1950) and *P. teretulus* by Hambrick et al. (1975) indicated these species to prey on aquatic insect immatures, especially blackflies and midges (Diptera), mayflies, and hydropsychid caddisflies. Relationships of *Phenacobius* to other groups are controversial. Although similar in appearance and ecology to *Erimystax* chubs, and sharing with that genus a nuptial pad on the lower cheek of breeding males (Harris, 1986), marked skeletal differences (W. C. Dickinson, pers. comm.) suggest that relationships between the two groups may be distant. However, Mayden (1989) regarded *Erimystax* and *Phenacobius* as sister groups with *Macrhybopsis aestivalis* as next closest relative. Cavender and Coburn (1985) suggested relationships with the cutlips minnows of the genus *Exoglossum* (upper Ohio, eastern Great Lakes, and central Atlantic coastal drainages). However, species of *Phenacobius* apparently do not engage in gravel nest-building behavior shared by *Exoglossum*, *Nocomis*, *Semotilus*, and *Campostoma*. Species relationships within *Phenacobius* were hypothesized by Mayden (1989), who regarded *crassilabrum* and *uranops* as sister species with *catostomus* as next closest relative; *teretulus* is sister to this group and *mirabilis* sister to the lineage containing all these species.

Etymology: *Phenacobius* = deceptive life, possibly alluding to its insectivorous diet in spite of its herbivorous appearance (Jordan and Evermann, 1896).

KEY TO THE TENNESSEE SPECIES

1. Lateral-line scales 50 or fewer; caudal spot separated from and distinctly darker than lateral stripe; west Tennessee and Duck and Buffalo rivers . . . . *P. mirabilis* p.241
   Lateral-line scales 52 or more; caudal spot usually indistinct; east and middle Tennessee 2
2. Scale rows around caudal peduncle 19–20 . . . . *P. crassilabrum* p.240
   Scale rows around caudal peduncle 17 or fewer (rarely 18–19 in *P. catostomus*, which is confined to the Alabama River drainage) 3
3. Lateral stripe narrow, occupying 1.5 to 2 scale rows anteriad; Tennessee and Cumberland river drainages . . . . *P. uranops* p.242
   Lateral stripe occupying 2.5 to 3.5 scale rows anteriad; Alabama river . . . . *P. catostomus*

Phenacobius catostomus Jordan

Riffle minnow

Plate 93. *Phenacobius catostomus*, riffle minnow, 73 mm SL, Conasauga R., TN.

Characters: Lateral-line scales 59–69, predorsal scale rows 25–27. Pectoral fin rays 15–18. Gill rakers 4–7. Vertebrae 40–42. Fresh specimens silver on sides and gray on back, usually showing some diffuse orange on the snout and paired fins. There is a very broad middorsal dark stripe that is about 10 scale rows wide at the occiput. Below this is a paler area about 2 scale rows wide that is sharply separated from both the middorsal and lateral stripes. In nuptial males, tubercles on dorsal surface of pectoral fin rays 2–8 are large and essentially uniserial, with posterior branches of each ray often bearing 2 tubercles per segment arranged side by side. Smaller and more transient tubercles, about 2 per fin ray segment, occur on pelvic fin rays 2–5 and on rays of other fins. Tiny, sharply pointed tubercles cover the top of the head posterior to the nostrils and extend onto the sides of the head where they become more granular and are difficult to differentiate from the numerous taste buds in these areas. Dorsal and lateral body scales have a marginal row of about 3–5 tubercles. Additional characters typical for genus or included in key.

Biology: As the common name implies, the riffle minnow occurs in swift riffle areas, typically in large creek and river habitats. Maximum tubercle development in *P. catostomus*, and presumably peak breeding activity, occurs from mid April through late May. Although usually associated with excellent water quality, it is apparently very plastic in its requirements, occurring in tailwaters with erratic flow regimes and seasonally low dissolved oxygen concentrations, and in heavily silted habitats. Other aspects of its biology are unstudied. Maximum total length 115 mm (4.5 in).

Distribution and Status: Mobile Basin above the Fall Line. In Tennessee restricted to the Conasauga River, where it is not common.

Similar Sympatric Species: The ubiquitous stoneroller is a somewhat similar species, but differs in having scattered dark scales, a dark peritoneum, and an entirely different mouth structure.

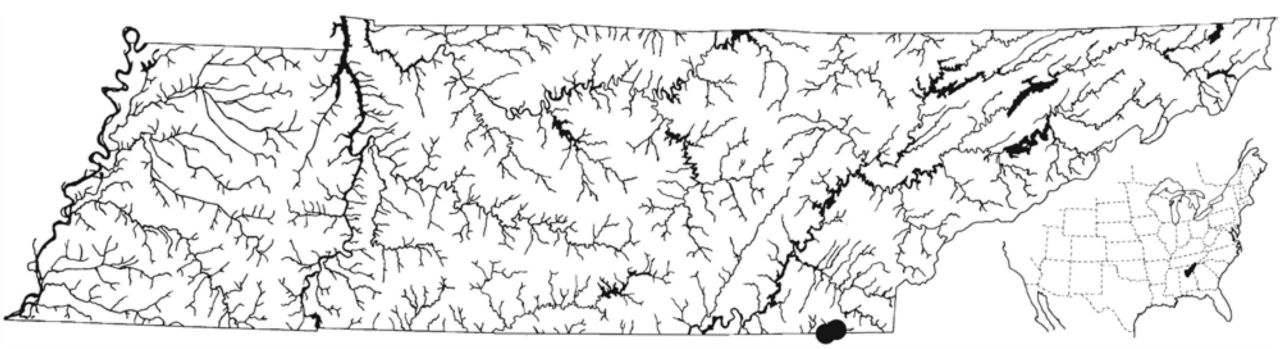
Etymology: *catostomus* = inferior mouth.

Phenacobius crassilabrum Minckley and Craddock

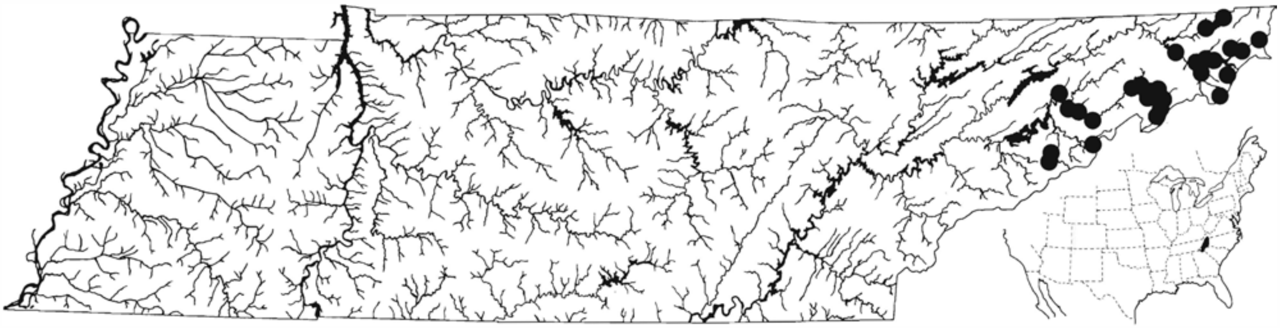
Fatlips minnow

Plate 94. *Phenacobius crassilabrum*, fatlips minnow (preserved several hours before photo), 78 mm SL, Nolichucky R. system, NC.

Characters: Lateral-line scales 56–65 (54–68), predorsal scale rows 25–29 (24–30). Pectoral fin rays 14–16. Gill rakers 8–11. Vertebrae 41–43. Life colors as in *P. catostomus*, but lacking orange on snout or paired fins. Nuptial tubercles are as described for *P. catostomus*, except that head tubercles extend forward over the entire snout. Other characters typical for genus or included in key.



Range Map 92. *Phenacobius catostomus*, riffle minnow.



Range Map 93. *Phenacobius crassilabrum*, fatlips minnow.

Biology: The fatlips minnow is an upland species that occupies riffle areas in small to medium rivers, often in waters sufficiently cold to support trout. Maximum tubercle development, and presumably breeding, occurs in April and May in Tennessee. Jenkins and Burkhead (in press) indicated a May–June spawning period in western Virginia. Sexual maturity occurred at age 1 in specimens larger than 62 mm SL; all 2-year-olds were sexually mature, and few survived to age 3; food in Virginia populations was dominated by midge larvae and cranefly larvae of the genus *Antocha*. Maximum total length 112 mm (4.4 in).

Distribution and Status: Occurs only in upper Tennessee River drainage from South Fork Holston River through Little Tennessee River, but not known from Little or Little Pigeon rivers, or Little Tennessee River in Tennessee. Virtually restricted to the Blue Ridge and often common.

Similar Sympatric Species: See comments under *P. uranops*.

Systematics: Until its description (Minckley and Craddock, 1962), this species had not been distinguished from the very similar *P. catostomus* of the Mobile Basin.

Etymology: *crassi* = fat, *labrum* = lip.

Phenacobius mirabilis (Girard)

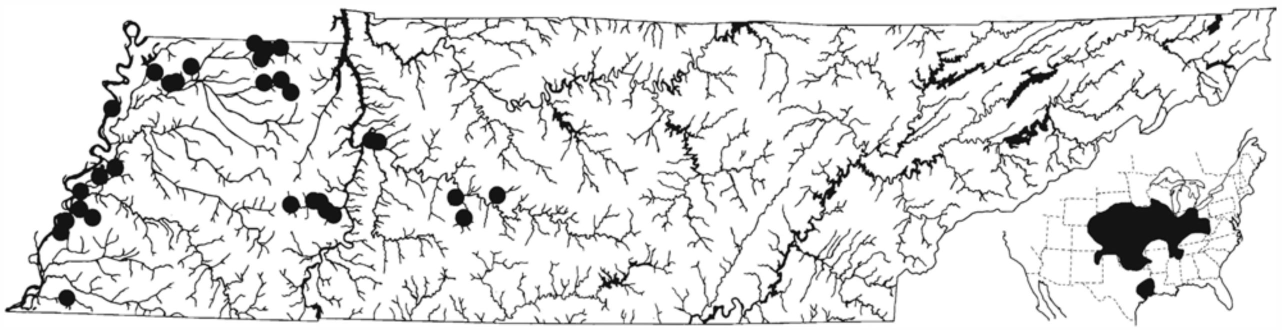
Suckermouth minnow

Characters: Lateral-line scales 41–51, predorsal scale rows 18–21. Pectoral fin rays 13–16. Gill rakers 3–6 plus additional ventral rudiments. Silvery, with distinct black caudal spot and lateral stripe. Nuptial tubercles are as described for *P. catostomus*, except tubercles on dorsum of head are larger, more widely spaced, and extend over the snout. Other characters typical for genus or included in key.

Plate 95. *Phenacobius mirabilis*, suckermouth minnow, 48 mm SL, Obion R. system, TN.

Biology: The suckermouth minnow differs from its congeners most markedly in its wide habitat tolerance. It occurs in tiny creeks as well as large rivers, is quite tolerant of silt, and is not necessarily restricted to swift currents. Trautman (1981) discussed its apparent eastward range extension in recent years in response to increased siltation in streams. Nuptial tubercles are present on males from May through June in our collections. Becker (1983) summarized biological information for Midwest populations. Spawning may occur from April through August. Sexual maturity occurs at age 2. Fecundity is high, with a 90 mm TL female from Wisconsin containing an estimated 1,640 mature ova. Suckermouth minnows feed by probing the substrate, and stomachs contained primarily midge and caddis larvae. Average total lengths at ages 1–3 were 36, 61, and 85 mm in Wisconsin, and life span is apparently 4–5 years. Maximum total length 120 mm (4.8 in).

Distribution and Status: Occurs in Lake Erie tributaries and in upper and central portion of Mississippi River basin north to southern Minnesota and South Dakota. Also present in western Gulf of Mexico drainages of Sabine, Trinity, Colorado, and upper Rio Grande rivers. Mostly avoids the Coastal Plain, but oc-



Range Map 94. *Phenacobius mirabilis*, suckermouth minnow.

curs in some of the swifter streams of the northern Mississippi River Embayment. In Tennessee it is uncommon, occurring primarily in the Mississippi River proper, small tributaries to the river along the bluff bordering the floodplain, North Fork of the Obion River, in Coastal Plain streams of the lower Tennessee drainage, and in the lower Duck and Buffalo rivers (western Highland Rim).

Similar Sympatric Species: Superficially similar to *Pimephales vigilax*, which has a nearly terminal mouth; and *Erimystax dissimilis*, *E. insignis*, and *Phenacobius uranops*, all of which lack a distinct caudal spot.

Etymology: *mirabilis* = wonderful.

Phenacobius uranops Cope

Stargazing minnow

Plate 96. *Phenacobius uranops*, stargazing minnow, 58 mm SL, Powell R., TN.

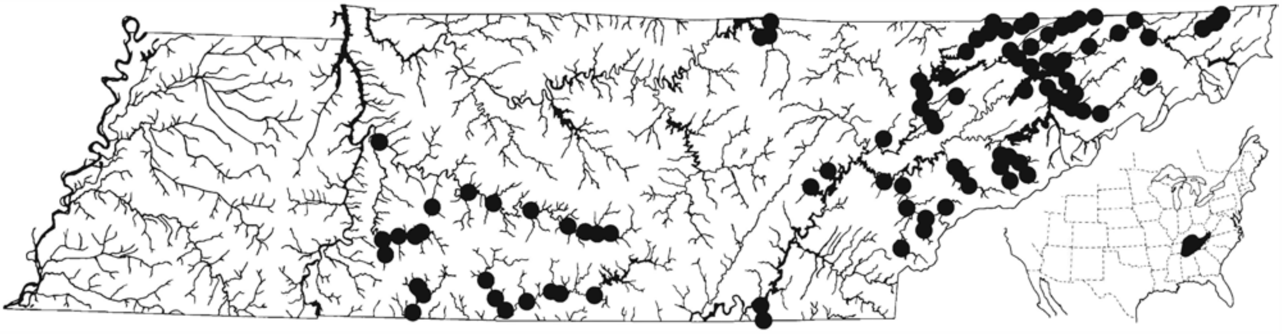
Characters: Lateral-line scales 51–59 (46–61), predorsal scale rows 21–25 (20–27). Pectoral fin rays 15–16. Gill rakers 4–10. Vertebrae 41–43. Color in life silvery with dark olivaceous back; black lateral stripe usually apparent. Bright colors lacking. Nuptial tubercles are as described for *P. catostomus*, except body scales have 2–4 tubercles situated near the center of the exposed field instead of on the margins. Other characters typical for genus or included in key.

Biology: The stargazing minnow is a fairly common inhabitant of riffle areas in small to medium rivers. Jenkins and Burkhead (in press) indicated an April-through-June spawning period. Sexual maturity occurs at age 1, and life span is typically less than 3 years. Adults were observed feeding in groups of 10–20, often with *Erimystax dissimilis*, and food was primarily dipteran and caddis larvae. Maximum total length 119 mm (4.7 in).

Distribution and Status: Occurs in the Tennessee and Cumberland drainages, and the Barren-Green system of the Ohio drainage, in Highland Rim and Ridge and Valley regions. Most common in upper Tennessee drainage.

Similar Sympatric Species: The more upland and finer scaled *P. crassilabrum* is a very similar and occasionally sympatric species in which the entire venter is virtually immaculate (some pigment below lateral stripe in *uranops*). In addition, *P. crassilabrum* is a deeper-bodied species, with the following depths (expressed as thousandths of standard length, mean followed by range in parentheses, *P. uranops* listed first) as tabulated in Minckley and Craddock (1962): head depth at nape 120 (110–139) vs. 139 (127–149); body depth at dorsal fin origin 146 (127–163) vs. 179 (147–213); minimum caudal peduncle depth 71 (65–77) vs. 87 (77–96). The three Tennessee species of the genus *Erimystax* are often sympatric and are quite similar. Both *E. insignis* and (usually) *E. dissimilis* have well-defined lateral blotches that are totally lacking in *P. uranops*. *Erimystax cahni* is very similar in appearance, but has a barbel, a longer and more flattened snout, and a more distinctly patterned caudal fin.

Etymology: *uranops* = star-gazing.



Range Map 95. *Phenacobius uranops*, stargazing minnow.

Genus *Phoxinus* Rafinesque
The Redbelly Daces

The genus *Phoxinus* contains several North American cyprinids commonly named daces. As construed by Banarescu (1964), Mahy (1975), Gasowska (1979), Joswiak (1980), and Howes (1985), the genus is comprised of both North American and Eurasian forms, making it the only cyprinid genus occurring naturally in both the Old and New worlds. Issue has been taken with this view by several authors (McPhail and Lindsey, 1970; Scott and Crossman, 1973; Eddy and Underhill, 1974) who felt that inadequate evidence had been cited for this grouping and therefore retained usage of the nominal genera *Chrosomus* Rafinesque and *Pfrille* Hubbs for North American species. Morphological and genetic investigations currently underway by W. C. Starnes, R. E. Jenkins, and G. R. Joswiak indicate a close relationship of the forms in question. While well differentiated, they appear to form a monophyletic (natural) group. *Phoxinus phoxinus* is the Eurasian representative of the genus; our preliminary studies and those of Howes (1985) indicate that other Eurasian forms sometimes referred to this genus (*P. percnurus*, *P. steindachneri*, and others) are not congeners. The affinities of *Phoxinus* perhaps lie with the North American genera *Margariscus* and *Semotilus* (Cavender and Coburn, 1987). Legendre (1970) even suggested inclusion of *Margariscus* (the northerly distributed pearl dace) in *Phoxinus* based on hybrid evidence. Howes (1985) postulated that the northern North American genus *Couesius* may be the sister group to *Phoxinus*. North American *Phoxinus* species include the northern glacial region species *P. neogaeus* and *P. eos*, *P. oreas* of central Atlantic slope and New River drainages, and at least three more southerly members all of which occur in Tennessee.

Northern species of *Phoxinus* are known to have evolved complicated reproductive strategies in some populations in which "unisexual hybrid species" persist by clonal reproduction (Dawley et al., 1987). This is accomplished by the process of gynogenesis in which hybrids reproduce by having ova development stimulated by the sperm of one parental species, but incorporate no genetic information from that sperm, thus resulting in an exact genetic copy (clone) of the mother. Many diploid and triploid hybrid populations of *eos* × *neogaeus* are known to exist (Legendre, 1970; Joswiak et al., 1985; Dawley et al., 1987). There are no indications that southern *Phoxinus* species, which are largely allopatric from one another, engage in such aberrant reproductive strategies.

Members of *Phoxinus* all share brilliant nuptial coloration, including scarlet bellies, and they are certainly among our most beautiful native fishes. Our three species are morphologically similar, having incomplete lateral lines, tiny scales, scaled breasts, gill membranes joined to the isthmus, conical gill rakers with length of longest rakers 2–3 times their basal width, 8 pelvic fin rays, 8 anal fin rays, 5-5 pharyngeal teeth, and similar patterns of tuberculation. Red coloration can be extremely ephemeral, changing moment to moment with the "mood" of the fish (e.g., fright), and appears to be under neural-hormonal control. Habitats for *Phoxinus* species range from small to medium creeks and bog areas in the north to pools of smaller creeks and spring-fed ponds in our area. All species adapt well to aquaria. In addition to the three native Tennessee species, *P. oreas* has apparently been locally introduced from time to time in the upper Tennessee drainage in Virginia

(Starnes and Jenkins, 1988). It is often seined for bait by fishermen in adjacent Virginia, and introductions might be expected in the upper East Tennessee area.

Etymology: *Phoxinus* = tapering, and is an old vernacular name for the European minnow, *Phoxinus phoxinus*.

KEY TO THE TENNESSEE SPECIES

1. Adults with a single wide dusky to intense black lateral stripe; subadults with two dusky lateral stripes convergent on caudal peduncle; upper Cumberland drainage .... *P. cumberlandensis*
   Adults and juveniles with two parallel dark lateral stripes, the upper sometimes represented by a broken line, the lower continuous or broken above pelvic fins 2
2. Lower (midlateral) dark stripe uninterrupted and straight throughout .... *P. erythrogaster* p.245
   Lower lateral stripe interrupted above pelvic fins with anterior portion ventrally deflected (Pl. 99), extending to anal fin base in some larger specimens; upper Tennessee drainage (potentially introduced specimens of *P. oreas* would key here) .... *P. tennesseensis* p.247

Phoxinus cumberlandensis Starnes and Starnes

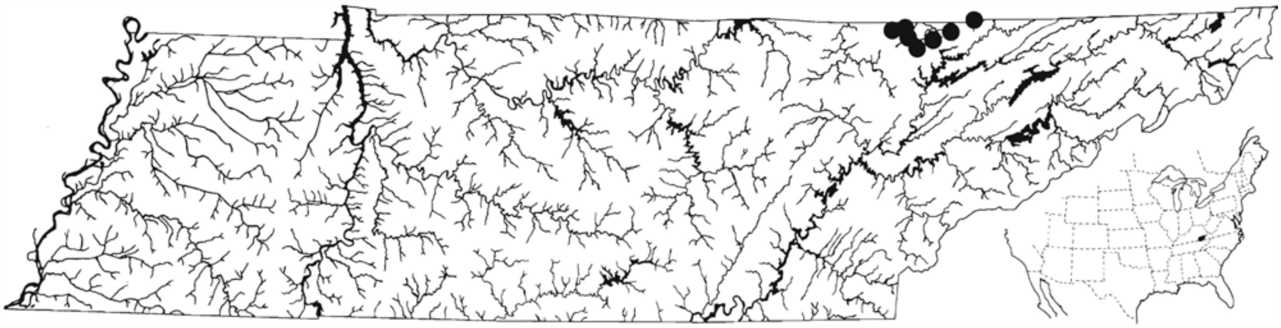
Blackside dace

Plate 97a. *Phoxinus cumberlandensis*, blackside dace, 39 mm SL, upper Cumberland R. system, KY.

Plate 97b. *Phoxinus cumberlandensis*, blackside dace, breeding male (preserved several hours before photo), 55 mm SL, upper Cumberland R. system, KY.

Characters: Scales in lateral series 66–81, lateral line incomplete with 0–62 pores. Anal fin rays 8 (8–9). Pectoral fin rays 14–16. Gill rakers 11–13, length of longest rakers about twice their basal width (9 arches counted). Vertebrae 39–40. Peritoneum dark, gut long and repeatedly looped (3.5 × SL in adults). Olivaceous dorsally with fine speckles; a single wide lateral stripe present or two stripes converging on caudal peduncle, becoming intense black in breeding adults; pale ventrally. Scarlet coloration on the belly, ventral portion of head, nape, and in base of dorsal fin may be present any time of year but is most pronounced in late spring. Yellowish fins seem much more closely associated with the breeding season. At the peak of breeding, males have a golden dorsum. Metallic silvery spots are present on the lower preopercle, origin of dorsal fin, and bases of pectoral and pelvic fins. Females have red coloration, but lack yellow or gold. Nuptial males have dense breeding tubercles covering the entire head and the entire body except the midventral region. Tubercles are especially well developed on the margins of the opercles and on the caudal peduncle. Eight or 9 rows of characteristic comb-like tubercles occur on the breast. Uniserial tubercles occur on rays of all fins except the caudal. Strong tubercles occur on the dorsal surfaces of pectoral fin rays 2–5. Females develop weak tuberculation but lack the strongly developed pectoral fin tubercles of males.

Biology: The blackside dace inhabits small upland tributaries to the upper Cumberland River drainage, mostly above Cumberland Falls. These streams have sand, sandstone, and shale substrates; generally lie beneath a canopy of hemlock, mountain laurel, and deciduous trees; and remain relatively cool throughout the year. Dace are secretive and remain in pools near the cover of undercut banks, brush, or large rubble. Starnes and Starnes (1981) reported on biology. The blackside dace feeds on attached algal growth which it grazes from objects on the stream bottom and perhaps beneath banks. Diatoms and other algal cells are often ruptured during their passage through the long gut by the abrasive action of the numerous sand grains which are coincidentally ingested. This may be an important aid to digestion, since the walls of plant cells are resistant to



Range Map 96. *Phoxinus cumberlandensis*, blackside dace.

digestive enzymes of fishes. Additional nutrition is probably obtained from root hairs and bacteria associated with algal growths. Aquatic insect immatures are consumed in winter when other fare is in limited supply. Spawning commences in April and extends into July, with females expending an average of 1,540 eggs over the season. Similar patterns of tuberculation and observations suggest that all members of *Phoxinus* spawn approximately as described in the next account for *P. erythrogaster*. Exceedingly brilliant coloration is displayed by males and females during spawning. Blackside dace were observed spawning over the silt-free gravel of a stoneroller nest, but presumably utilize gravel riffle areas when such nests are not available. A life span of 3 years is indicated with young growing to about 30 mm SL by the first fall of life and reaching sexual maturity by the following spring; total lengths average 50 mm and 65 mm at the end of the second and third summers. Maximum total length 76 mm (3 in).

Distribution and Status: Blackside dace are restricted to the Cumberland Plateau portion of upper Cumberland drainage, both above and below Cumberland Falls in Kentucky and Tennessee. This region is seriously altered by surface coal-mining, and many populations were probably extirpated before they could be discovered (Starnes and Starnes, 1978a, 1978b). Following thorough survey work (Starnes, 1981; O'Bara, 1985), only six small populations are currently known in Tennessee. These are all very localized and vulnerable to extirpation by mining activities. A few larger populations with perhaps brighter futures occur in the Daniel Boone National Forest areas in Kentucky. The blackside dace is considered an endangered species in Tennessee (Starnes and Etnier, 1980), has been listed as Threatened by the U.S. Fish and Wildlife Service, and a recovery plan has been drafted (Biggins, 1987).

Similar Sympatric Species: The southern redbelly dace, *P. erythrogaster*, is occasionally syntopic. It is distinguished by pigmentation (see key) and by the shape of the opercular bone (Starnes and Starnes, 1978a), which has the posteroventral angle produced rather than rounded as in *P. cumberlandensis*. Young *Phoxinus* are easily confused with juvenile creek chubs (*Semotilus atromaculatus*) and blacknose dace (*Rhinichthys atratulus*). The former is more robust and has only 51–64 scales in lateral series. The bridge of skin connecting the snout to the upper lip (frenum) in *Rhinichthys* is unique among Tennessee minnow genera.

Etymology: *cumberlandensis* = of the Cumberland, in reference to the Cumberland River drainage.

Phoxinus erythrogaster (Rafinesque)

Southern redbelly dace

Characters: Lateral line incomplete, scales in lateral series 70–95. Pectoral fin rays 15–17. Gill rakers 9–13, the longest about twice as long as their basal width. Peritoneum dark, gut long and looped. Small dark spots may be present on the greenish dorsum, often forming two rows, and a narrow middorsal streak is present. Two parallel lateral stripes are present, the upper often interrupted posteriorly. Seasonal trends in chromatic coloration are similar to those of *P. cumberlandensis*. Males may have some red on the belly throughout the year, with color intensifying in spring when red extends from the lower caudal fin base forward over most of the belly and lower head, and along the posterior edge of the gill cover. The dorsal fin base has a red spot, and the pectoral, pelvic, and anal fins and the urogenital area are bright yellow. Silver spots are present generally as described in *P. cumberlandensis*; patterns of breeding tuberculation are as described in that species.

Plate 98a. *Phoxinus erythrogaster*, southern redbelly dace, 40 mm SL, Cumberland R. system, TN.

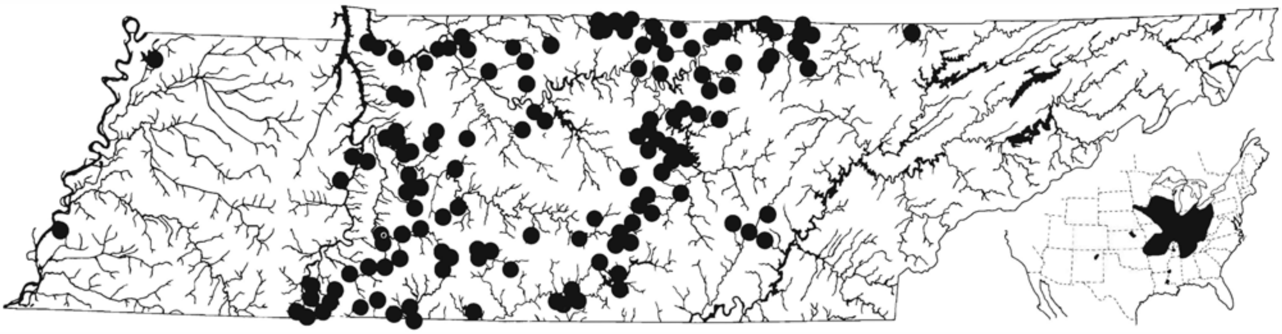
Plate 98b. *Phoxinus erythrogaster*, southern redbelly dace, breeding male, 60 mm SL, Caney Fork R. system, TN.

Plate 98c. *Phoxinus erythrogaster*, southern redbelly dace, breeding male (showing differences from above specimen in red and other coloration), 46 mm SL, Barren R. system, TN.

Biology: The southern redbelly dace inhabits small streams with clear, cool waters and some areas of gravel substrate. It occurs in pools up to about 1 m deep and generally remains near the bottom. Feeding behavior and diet are similar to that of *P. cumberlandensis*, with invertebrates perhaps more important on an annual basis. Phillips (1969a) suggested that diatoms might be digested by enzymes that penetrate the shells (frustrules) through openings rather than being broken by mechanical action. Spawning occurs from April to July in our area (Settles and Hoyt, 1976). Spawning habitat is either gravel riffles or over the nests of larger minnows such as stonerollers, river chubs, and common or striped shiners; *P. erythrogaster* occasionally hybridizes with species of *Luxilus* and *Notropis* (Greenfield et al., 1973; Robison and Miller, 1972) and *Semotilus atromaculatus*. Spawning behavior has been described by Smith (1908). The brilliantly colored males congregate over the spawning area with females staged in the run below. Occasionally a female darts up near the spawning area, where she is generally attended by two males, one on either side. The heavily tuberculate pectoral fins and caudal peduncle may aid in maintaining contact with the female, who is pressed to the substrate where eggs are extruded, fertilized, and fall into gravel interstices. Many additional males may join in the act, forming a writhing mass. Each act lasts only a few seconds. Very similar spawning behavior has been noted in the Eurasian *P. phoxinus* (Mottram, 1922; Frost, 1943) and in *P. cumberlandensis* (Starnes and Starnes, 1981) and *P. oreas* (Raney, 1947). Fecundity estimates averaged just over 300 ova per female in a study by Settles and Hoyt (1978), who counted only fully mature eggs at the time of dissection, but Phillips (1969b) counted up to 18,000 or more total oocytes per female, including primordial ones. It is likely that total eggs maturing during a spawning season number 1,000 or more as in *P. cumberlandensis*. Young are about 38 mm TL by fall of their first year, and average 51 mm and 64 mm TL after their first and second years of growth (Settles and Hoyt, 1976). Sexual maturity occurs at about 50 mm TL, with some age 1 and all age 2 and 3 fish mature (Becker, 1983). Maximum total length 90 mm (3.5 in).

Distribution and Status: Widespread in more upland portions of the Mississippi River basin and tributaries to Lake Michigan and Lake Erie. Isolated populations occur in west Tennessee, western Mississippi, east central Arkansas, northeastern Kansas, and northeastern New Mexico. In Tennessee most common on the Highland Rim, but also occurs on the Cumberland Plateau, in the Nashville Basin, and as relict populations in streams draining Chickasaw Bluff along the Mississippi River (Bear Creek, Tipton County) and near Reelfoot Lake. Similar populations inhabit isolated, cool, high-gradient, gravel bottom streams draining similar bluffs along the east side of the Mississippi River far to the south in Mississippi (Hemphill, 1957; Cashner et al., 1979). In the upper Cumberland drainage several *P. erythrogaster* populations have probably been extirpated by siltation from coal mining, with only two records from the Tennessee portion of that system. Populations in the Sequatchie system may be introduced from the adjacent Cumberland. However, a single population of distinctively pigmented *erythrogaster*-like dace, perhaps representing an area of contact with *tennesseensis*, is known to occur in the Rock-Sale creek system, tributary to the Tennessee River, on Waldens Ridge to the east of Sequatchie Valley.

Similar Sympatric Species: Occasionally occurs with *P. cumberlandensis* in the upper Cumberland drainage in Tennessee. See comments under that species regarding these two *Phoxinus* plus *Semotilus atromaculatus*



Range Map 97. *Phoxinus erythrogaster*, southern redbelly dace.

and *Rhinichthys atratulus*. Ranges of *P. erythrogaster* and *P. tennesseensis* overlap in the Tennessee drainage above Chattanooga. Young of these species are very similar, but the latter may be distinguished at small sizes by the incipient break in the lower lateral stripe above the pelvic fin. In the aforementioned Waldens Ridge population, this stripe is kinked slightly upward at this juncture, and is convergent with the upper stripe on the caudal peduncle, but shows no break.

Systematics: Differences in breeding colors among redbelly dace populations in Tennessee (e.g., Barren vs. Cumberland) and other regions, particularly with regard to the proximity of ventral red to the dark midlateral stripe, suggest that this taxon is polytypic.

Etymology: *erythro* = red, *gaster* = belly.

Phoxinus tennesseensis Starnes and Jenkins

Tennessee dace

Characters: Lateral line incomplete, scales in lateral series 67–95, usually 78 or more. Pectoral fin rays 15–17. Gill rakers 9–13, length of longest rakers about twice their basal width. Vertebrae 38–39. Peritoneum dark, gut long and looped. Dorsal coloration ranges from nearly plain olivaceous to profusely speckled with black. The lower lateral stripe (barely interrupted in juveniles), varies from slightly interrupted above the pelvic fin to completely decurved ventrally to near the anus. Nuptial males have red lower sides and bellies, and red occurs above and below the black stripe on the operculum, in the preorbital area, and at the base of the dorsal fin. Bright silver areas occur at the anterior base of the dorsal, pectoral, and pelvic fins and on the cheek and upper operculum. Pectoral, pelvic, and anal fins are yellow, and the breast and lower head are coal black.

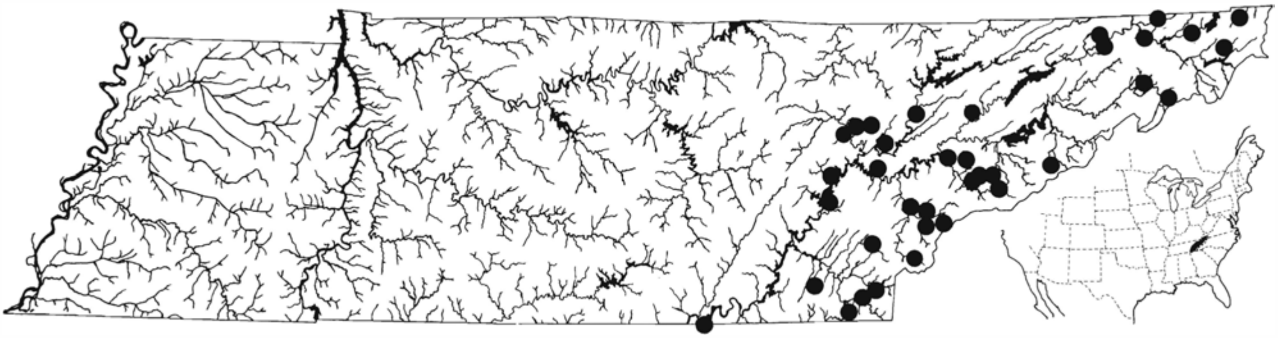
Plate 99a. *Phoxinus tennesseensis*, Tennessee dace, female, 54 mm SL, Holston R. system, TN.

Plate 99b. *Phoxinus tennesseensis*, Tennessee dace, breeding male, 56 mm SL, Clinch R. system, TN.

Patterns of tuberculation and seasonal trends in chromatic coloration are as described for *P. cumberlandensis*.

Biology: *Phoxinus tennesseensis* is restricted to very small low gradient woodland tributaries in the upper Tennessee River drainage, most of which do not exceed 2 m in width. This dace inhabits shallow pools in association with undercut banks and debris. Starnes and Jenkins (1988) indicated that spawning season, reproductive behavior, and diet are similar to that of other Tennessee *Phoxinus* species, with growth and age at sexual maturity essentially as described for *P. cumberlandensis*. Maximum total length 72 mm (2.8 in).

Distribution and Status: Occurs sporadically in small tributaries in the Ridge and Valley and margins of the Blue Ridge and Cumberland Plateau provinces of the



Range Map 98. *Phoxinus tennesseensis*, Tennessee dace.

upper Tennessee drainage from Virginia southwestward through the Emory and lower Clinch river systems and south to the Hiwassee River system. Probably extirpated from a former locality at Whiteside, just west of Chattanooga, and may be much less abundant than formerly with fewer than 40 extant populations known. Abundant in portions of the East Fork Poplar Creek system, Roane County (on the Department of Energy Reservation) (Ryon and Loar, 1988), which may offer a stronghold for the species. The Tennessee dace (as *Phoxinus oreas* subspecies) is listed as of Special Concern by the Tennessee Heritage Program and Deemed in Need of Management by the Tennessee Wildlife Resources Agency (Starnes and Etnier, 1980).

Similar Sympatric Species: Comments under *P. cumberlandensis* and *P. erythrogaster* concerning *Rhinichthys*, *Semotilus*, and overlapping ranges of *tennesseensis* and *erythrogaster* apply. *Phoxinus oreas* is a very similar species known to be introduced into the Tennessee drainage in Virginia (Starnes and Jenkins, 1988) and is possibly to be expected in Tennessee. It has the same ventrally deflected lateral stripe pattern as *tennesseensis* but is a more robust minnow with fewer scales in lateral series (usually less than 75), and a typically complete (vs. interrupted) infraorbital canal. In adults with fully developed dorsolateral pigmentation, *oreas* has black blotches larger than the pupil while those of *tennesseensis* are much smaller, usually appearing as tiny specks.

Systematics: Until recently considered a subspecies of *Phoxinus oreas*, and hypothesized to be closely related to that species plus *P. cumberlandensis* (Starnes and Jenkins, 1988). Gasowska (1979) erected a new genus, *Parchrosomus*, for *P. oreas* in which she presumably would have included this species. However, studies by W. C. Starnes and R. E. Jenkins reveal that minor osteological characters utilized to distinguish this genus also occur in some populations of other species.

Etymology: *tennesseensis* = of Tennessee, in reference to the Tennessee River drainage.

Genus *Pimephales* Rafinesque

Members of *Pimephales* constitute a distinctive genus of minnows whose shared characters include a naked breast, crowded predorsal scales, 7 anal fin rays, 8 pelvic fin rays, 14–17 pectoral fin rays, 4-4 pharyngeal teeth, an elongate digestive tract, a detached (nonfused) anterior dorsal fin ray rudiment; and, in breeding males, fleshy nape pads, extremely large snout tubercles, and thickened pectoral and dorsal fin membranes. Bright colors are absent, but males darken considerably during the breeding season. Spawning occurs on the undersurface of objects such as rocks, logs, boards, and lily pads. Males prepare the nest sites for spawning by excavating coarse materials with their mouth and snout and fanning away silt with swimming activities. The fleshy nape pad and fanning provided by the fins function in cleaning and aerating the eggs, which will not develop in the absence of a male unless a constant current of oxygenated water is provided to supplant his function (Markus, 1934; Westman, 1938). It seems likely that the swollen nape tissues are associated with preventing fungal growths on the eggs, but this interesting possibility has received little attention. The spawning territory is defended against conspecific males, and is occupied throughout the spring and summer breeding period. Eggs are deposited on the undersurface of the structure forming the nesting chamber, usually in a mono-layer. The eggs are not attached directly from the female's urogenital papilla, but by her tail in a poorly understood sequence of body and fin movements (Page and Ceas, 1989). Several females may contribute eggs to a single nest, with spawning typically occurring at night. The nest is guarded by the resident male until hatching occurs. All species reach sexual maturity by their second summer, and may live for a second or rarely a third spawning season. Males get considerably larger than females.

In addition to the three widespread species that occur in Tennessee, a fourth species, *P. tenellus* (Girard), occurs in the Ozark region. The phylogenetic relationships between *Pimephales* and other cyprinid genera have not been clarified. Hubbs and Black (1947) considered *Pimephales* to be derived from a *Notropis*-like ancestor. Cavender and Coburn (1985) preliminarily hypothesized relationships with *Opsopeodus* and the subgenus *Cyprinella* of *Notropis*; close affinity with *Opsopoeodus* is a good possibility based on their sharing a derived reproductive behavior (Johnston and Page, 1988). Mayden (1989) did not resolve its status in his analysis of cyprinid relationships. Mayden (1987) hypothesized that *P. notatus* and *P. promelas* were sister species, as were *P. vigilax* and *P. tenellus*.

Etymology: *Pime* = fat, *phales* = head.

KEY TO THE TENNESSEE SPECIES

1. Lateral line usually incomplete; predorsal scale rows 23 or more; gill rakers 14 or more . . . *P. promelas* p.250
   Lateral line complete; predorsal scale rows usually 22 or fewer; gill rakers 10 or fewer 2
2. Peritoneum black; intestine extremely long and with many loops; nuptial males with maxillary barbel and three rows of snout tubercles; mouth distinctly subterminal; preorbital dark blotch linear and extending well onto snout (Fig. 90a); gill rakers extend along most of lower limb of arch . . *P. notatus*
   Peritoneum silvery; intestine with single S-shaped loop; nuptial males lack barbel and have two rows of snout tubercles; mouth nearly terminal; preorbital dark blotch round and not extending anteriorly past lachrymal groove (Fig. 90b); gill rakers absent from lower half of lower limb . . . . . . *P. vigilax* p.252

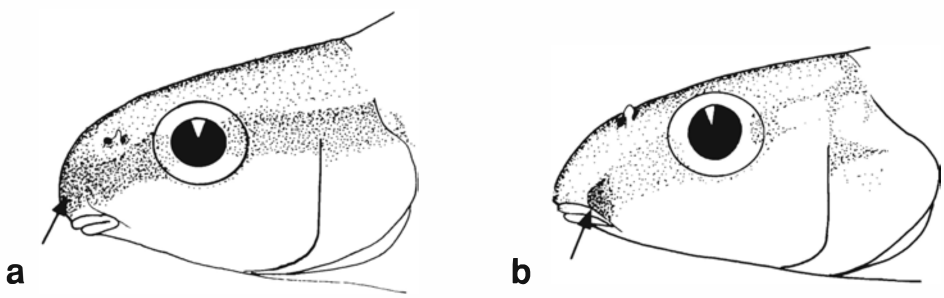


Figure 90. Snout pigmentation of *Pimephales*: a) *P. notatus*; b) *P. vigilax*.

Pimephales notatus (Rafinesque)

Bluntnose minnow

Characters: Lateral line complete with 39–44 scales in our area (up to 50 in northern portions of range), predorsal scale rows 18–22. Gill rakers 7–10, length of longest rakers 1–1.5 times their basal width. Vertebrae 37–38. Nuptial tubercles are extremely large on the snout and consist of three horizontal rows with 5–6 tubercles in the ventral row, 7–10 in the middle row, and 4 in the upper row. Additional small tubercles occur on dorsal surfaces of pectoral fin rays 2 or 3 through 6 or 7, and are uniserial, extending from the middle of the ray to the major branching and then continuing on the posterior branch. In life, they are silvery fishes with straw-colored tints on the fins. Dark scale edgings and a black midlateral stripe terminating in a caudal spot are apparent except in specimens from turbid waters, and a dark blotch is often present on the anterior middle of the dorsal fin. Nuptial males develop a conspicuous maxillary barbel that does not occur in other *Pimephales*, and the caudal fin, head, and back darken. Other characters in generic discussion and key.

Biology: The bluntnose minnow typically inhabits pools and gently flowing waters from small streams to large

Plate 100a. *Pimephales notatus*, bluntnose minnow, 58 mm SL, Hatchie R. system, TN.

Plate 100b. *Pimephales notatus*, bluntnose minnow, breeding male, 66 mm SL, Duck R. system, TN.

rivers, is occasionally taken in reservoirs, and is common in glacial lakes to the north. Food consists of algae, detritus, entomostraca, and immature insects, especially midge larvae and pupae (Keast and Webb, 1966; Kraatz, 1928; Moyle, 1973). General aspects of reproduction are included in the generic discussion. Females lay 200–500 eggs per season (Hubbs and Cooper, 1936). Females are mature at age 1, but males do not mature until age 2. Total length is 40–51 mm at age 1, and life span is 3–4 years (Becker, 1983). Maximum total length 110 mm (4.3 in).

Distribution and Status: Abundant in the Mississippi Basin and adjacent drainages of the Great Lakes and middle Atlantic regions. Avoids more sluggish Coastal Plain streams, but abundant in all physiographic regions of Tennessee except Blue Ridge. Absent from upper Mobile Basin, including Conasauga River.

Similar Sympatric Species: Although specimens from clear water are distinctly marked and easy to recognize, those from turbid waters can easily be confused with *P. vigilax*. The appearance of the preorbital dark blotch (see Key) is distinctly different in fresh specimens and provides an excellent field character. The more slender head and cylindrical body form of *P. notatus* are useful characters in addition to those included in the Key. In clear water, the combination of crowded predorsal scales, a distinct caudal spot, a cylindrical body, and melanophores edging scales and forming diamond-shaped patterns is not shared by other Tennessee minnows.

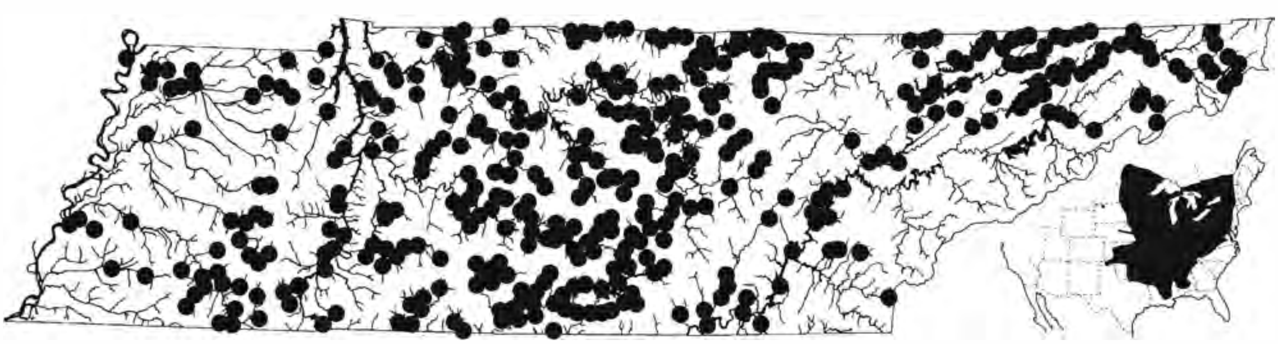
Etymology: *notatus* = distinctly marked or spotted.

Pimephales promelas Rafinesque

Fathead minnow

Characters: Lateral line incomplete with 40–54 (usually 40–46 in our area) scales in lateral series, lateral line varies from virtually absent to nearly complete. Predorsal scale rows 22–26. Gill rakers 15–18. Vertebrae 35–38. Color silvery gray with dark lateral stripe evident except in large specimens. Nuptial males, with their blackened heads and enlarged pale nape pads, are striking fish. Snout and pectoral fin tubercles are as described for *P. notatus*. In addition, fatheads have a row of 5–7 large tubercles on the lower jaw. Other characters in generic account and key.

Biology: The fathead minnow, or "tuffy" of local minnow dealers is probably the most valuable bait fish in North America. It is an abundant species in small lakes, ponds, bogs, and sluggish streams of the north central states and occurs sporadically in our area in similar habitats. Most of the fatheads sold locally for bait come from Wisconsin, Michigan, and Minnesota. Several au-



Range Map 99. *Pimephales notatus*, bluntnose minnow.

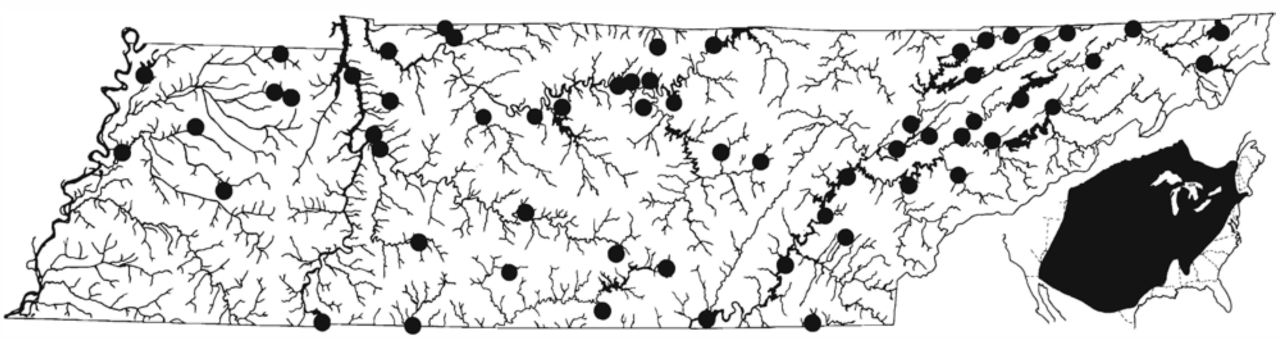
Plate 101a. *Pimephales promelas*, fathead minnow, 46 mm SL, Tennessee Aquarium, Chattanooga, TN.

Plate 101b. *Pimephales promelas*, fathead minnow, breeding male, 56 mm SL, Malone Hatchery, Lonoke, AR.

thors have studied food habits of the fathead and found the diet to consist of detritus and algae. Coyle (1930) reported several species of algae, which are apparently selected for by the morphology of the pharyngeal teeth, constituting the vast majority of the diet. Held and Peterka (1974) found North Dakota populations to feed primarily on small aquatic insects and zooplankton, with Cladocera the predominant food. General aspects of reproduction appear in the generic introduction. Female fatheads produce 4,000–5,000 eggs per year (Markus, 1934; Pflieger, 1975), and incubation time is about 5 days. Markus (1934) and Dobie et al. (1956) found that young hatched in late May in Iowa and Missouri had reached sexual maturity and reproduced by late July of the same year. Very few individuals live past their second summer. Techniques for propagation of these minnows as bait have been elaborated by Prather et al. (1953) and Flickinger (1971). Maximum total length (McCarraher and Thomas, 1968) 101 mm (4 in), but usually less than 80 mm.

Distribution and Status: Since many fatheads used for bait are eventually released at the end of a day's crappie fishing, it is rather difficult to define the species's original distribution in Tennessee, or anywhere else. That it was native to Tennessee is uncertain. The fathead is not a common fish in the state, but specimens have been taken in scattered areas in all drainages in Tennessee. Currently fatheads are to be expected in any state waters containing warmwater game fish, where releases from bait buckets may create temporary or persistent populations. The fact that substantial reproducing populations are not known from natural habitats in the state suggests the fathead may not be indigenous to the region. It is interesting to note that this species was not collected in the extensive TVA preimpoundment studies throughout the Tennessee River drainage during 1936–1942. The earliest record from Tennessee (Jordan and Brayton, 1878) was from the Cumberland drainage near Nashville. We do not know if these specimens are extant. No additional records were available from Tennessee prior to Evermann's (1918) compilation of the fishes of Tennessee and Kentucky, and an unpublished list of Tennessee River drainage fishes compiled by Carl Hubbs in 1939 did not contain this species. Vandermeer (1966) did not outline a precise range in his broad study of variation in this species, but patterns of variation revealed would suggest a native range from the glaciated region east of the Rockies to southern Quebec and southwestward through the Great Plains into Mexico but not including southeastern states.

Similar Sympatric Species: *Semotilus atromaculatus* juveniles are very similar, but have a much larger jaw, 11 or fewer gill rakers, a complete lateral line, and dorsal fin pigment is at the anterior base rather than as a median band through the fin. In preservative, blood



Range Map 100. *Pimephales promelas*, fathead minnow (range extends north and west off inset to Hudson Bay, Great Slave Lake, and western Alberta).

vessels between the muscle bands above the horizontal myoseptum are often conspicuous as oblique dark lines, a rather uncommon character in Tennessee cyprinids.

Systematics: Vandermeer (1966) studied range-wide variation and suggested that previously recognized subspecies were not valid.

Etymology: *pro* = forward, *melas* = black, referring to the black head of nuptial males.

Pimephales vigilax (Baird and Girard)

Bullhead minnow

Plate 102. *Pimephales vigilax*, bullhead minnow, 64 mm SL, Kentucky Res., TN.

Characters: Lateral line complete with 38–47 scales (usually 44 or fewer except in Gulf Coast drainages). Predorsal scale rows 18–22. Gill rakers 5–8 and absent from lower half of lower limb. Color silvery on sides grading to gray or straw-colored on back; dark basicaudal spot prominent. Snout tubercles in our subspecies occur in 2 rows, with 4 tubercles in the upper row and 5 in the lower. Pectoral fin tubercles are absent or very weakly developed in nuptial males we have examined; when present their pattern is as described for *P. notatus*. Other characters in generic account and key.

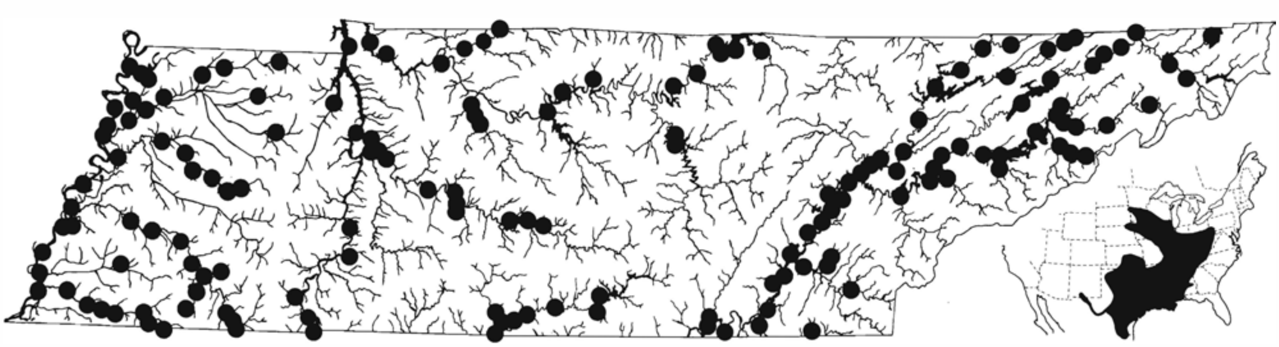
Biology: The bullhead minnow is an inhabitant of sluggish, medium to large rivers throughout the state and is also a common small forage species in many of our reservoirs. It typically occurs in weak to moderate currents over silty sand substrates. Food consists primarily of insect immatures, with detritus and seeds seasonally abundant in digestive tracts (Starrett, 1950). General reproductive habits are as described for the genus (Parker, 1964). In our area males reach peak tuberculation by about mid May, and highly tuberculate males are still found through July. Sexual maturity is reached at lengths of about 40 mm (Pflieger, 1975). Maximum total length 92 mm (3.6 in).

Distribution and Status: Widespread and abundant throughout the Mississippi River and Mobile basins west to the Rio Grande. Penetrating upland regions only in larger rivers.

Similar Sympatric Species: *Opsopoeodus emiliae* and *Macrhybopsis storeriana* are often taken with this species; they are somewhat similar, but both lack a caudal spot. Most like *Pimephales notatus* (see comments under that species). *Cyprinella venusta* is the only other minnow with a caudal spot that commonly occurs with *P. vigilax*. It differs in being slab-sided rather than cylindrical, and in lacking a dark spot on the anterior margin of the dorsal fin; lower predorsal scale counts also separate *C. venusta* (and other occasionally sympatric Mobile Basin *Cyprinella* and *Notropis* with caudal spots) from *P. vigilax*.

Systematics: The nominate subspecies, restricted to the upper Red River of Texas and Oklahoma, and from the San Jacinto and Brazos rivers, Texas, southwest to the Rio Grande, differs from our form, *P. v. perspicuus* (Girard), in having only a single row of snout tubercles (Hubbs and Black, 1947; Cross, 1953).

Etymology: *vigilax* = watchful.



Range Map 101. *Pimephales vigilax*, bullhead minnow.

Genus *Platygobio* Gill

The genus consists of the single species accounted below.

Platygobio gracilis (Richardson)

Flathead chub

Plate 103. *Platygobio gracilis*, flathead chub, preserved specimen, 223 mm SL, Missouri R. system, NE.

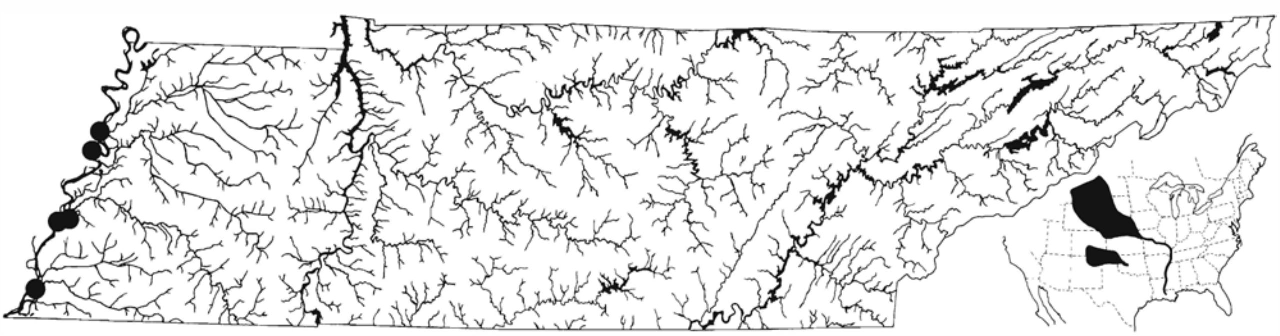
Characters: Lateral-line scales 44–56, predorsal scale rows 19–22. Anal fin rays 8 (7–9). Pectoral fin rays 15–19. Pelvic fin rays 8. Four to 6 short gill rakers. Pharyngeal teeth 2,4-4,2. Vertebrae 41–47. Breast fully scaled. Color silvery without distinctive markings. Lower lobe of caudal fin dark with white lower edge. Nuptial males have minute tubercles on the top of the head and back, on all fins except the caudal, and on the ventral scales of the caudal peduncle.

Biology: The flathead chub is a large midwestern cyprinid that occurs in Tennessee only in the main channel of the Mississippi River, where it is infrequently collected. In the western Plains region it penetrates into small headwater rivers where it is tolerant of exceedingly high turbidity and may be the dominant species present. Specimens we have collected in Tennessee were taken in swift current over gravel substrates, but it occurs over sand substrates elsewhere. Data presented in Olund and Cross (1961), McPhail and Lindsey (1970), and Scott and Crossman (1973) indicate it to feed on aquatic and terrestrial arthropods, breed throughout the summer, reach sexual maturity at standard length of 85 mm, and reach a maximum total length of 317 mm (12.5 in).

Distribution and Status: Widespread from Mackenzie River drainage of northwestern Canada, southwestern tributaries to Hudson Bay, throughout Missouri River drainage, and in Mississippi River main channel below the mouth of the Missouri. Also in upper Arkansas and Rio Grande rivers. In Tennessee known only from the Mississippi River. We have collected specimens 1 mile west of the end of Tenn. 59, Duvall Landing, Tipton County, a locality which also produced six species of darters and two species of madtoms. The area contained an extensive gravel shoal which has, unfortunately, been turned into a silt catchment area due to construction of long wing-dams both above and below the shoal. Although certainly uncommon in the Mississippi River, the difficulty of adequately collecting fishes in this river certainly contributes to its infrequent collection in the state.

Similar Sympatric Species: Most like *Macrhybopsis meeki* in fin and body shape, but differing in having the breast and belly entirely scaled, and in its slightly higher scale counts. Other barbeled minnows in the Mississippi River also have naked areas on the breast or belly (*M. aestivalis*, *M. gelida*), or lack its sickle-shaped, very falcate dorsal, anal, and pectoral fins (*M. storeriana*).

Systematics: In addition to the nominate subspecies, Olund and Cross (1961) recognized a southwestern sub-



Range Map 102. *Platygobio gracilis*, flathead chub (range extends northwest off inset into central Manitoba and Saskatchewan, much of Alberta, and north nearly to mouth of Mackenzie River).

species, *P. g. gulonellus* (Cope), which is smaller, heavier bodied, and has lower meristic counts. Tennessee is occupied by *P. g. gracilis*, which has 50–56 lateral-line scales (42–54 in *P. g. gulonellus*).

Etymology: *Platy* = flat, *gobio* = generic name for a somewhat similar Eurasian cyprinid called the gudgeon; *gracilis* = slender.

Genus *Rhinichthys* Agassiz

Members of *Rhinichthys* are the only Tennessee minnows with a nonprotractile premaxilla (frenum present, Fig. 65a). Other shared features include a barbel at the tip of the maxilla, 2,4-4,2 pharyngeal teeth, small scales, a scaled breast, gill membranes broadly connected to the isthmus, 7 anal fin rays, 8 pelvic fin rays, and a "salt and pepper" pattern of pigment on the sides. *Rhinichthys* populations vary greatly in habitat, coloration, and general appearance. Morphological and genetic variation is considerable (Merritt et al., 1978; Matthews et al., 1982), making systematic studies difficult. There are at least two or three eastern species in this genus. Besides *R. atratulus* and *R. cataractae*, an additional form, known as "*R. bowersi*" Goldsborough and Clark, questionably of hybrid origin (Stauffer et al., 1979; Cooper, 1980), occurs in the Monongahela system of Pennsylvania and West Virginia. Goodfellow et al. (1984) recently suggested that this form be accorded species status. At least three additional species occur in western North America. The genus is oddly absent from the Ozarks region. Woodward (1987) has studied intra- and intergeneric relationships and, along with Coburn and Cavender (1986), hypothesized close relationships with the western genera *Agosia* and *Tiaroga*.

Etymology: *Rhinos* = snout, *ichthys* = fish.

KEY TO THE TENNESSEE SPECIES

1. Eye diameter greater than distance from tip of snout to anterior tip of lower jaw . . . . *R. atratulus*
   Eye diameter less than or equal to distance from tip of snout to anterior tip of lower jaw . . . *R. cataractae* p.256

Rhinichthys atratulus (Hermann)

Blacknose dace

Plate 104a. *Rhinichthys atratulus*, blacknose dace, 38 mm SL, Little R., TN.

Plate 104b. *Rhinichthys atratulus*, blacknose dace, breeding male, 62 mm SL, upper Cumberland R. system, TN.

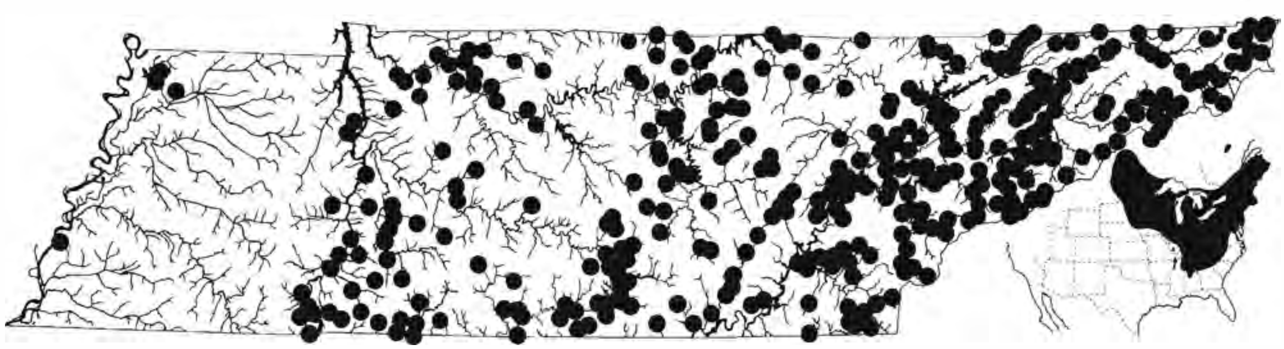
Characters: Lateral line complete with 52–62 scales in most Tennessee specimens (58–71 in specimens from upper Holston River system). Predorsal scale rows 35–43. Pectoral fin rays 13–16. Gill rakers 5–8. Vertebrae 37–40. Nuptial females have elongate urogenital tubes and anal fins. Color dark brown to gray on back grading to silvery on lower sides and belly, typically with scattered dark colored scales on sides. Males develop an orange- to rust-colored streak along the sides. Pectoral fin tubercles of males are unique among Tennessee cyprinids, consisting of elevated pads distal to the branching of the second through fifth rays. These smooth to rugose pads occur on the dorsal surface, are larger on the posterior branch of the ray, and probably represent fusion of the conical tubercles more typical of cyprinids. Large conical tubercles occur on other fins, where they are concentrated toward the leading edge of the fin. They generally have bases larger than the individual fin ray segments, often appear to emanate from the junction between adjacent fin ray segments, and are most prominent on the pelvic fins. Cephalic tubercles are crusty and concentrated on the upper half of the gill cover. A band of tubercles extends across the occiput and from above the orbits forward to the internasal area, leaving a large portion of the top of the skull free or virtually free of tubercles. Additional tubercles, 1 to several per scale, occur on edges of body scales, and cephalic tubercles may occur on the lower edge of the gill cover and lower edge of the lachrymal bone. Other characters in generic account.

Biology: The blacknose dace is a familiar minnow most commonly encountered in small creeks. It often occurs very near the headwaters, and is a common spring inhabitant. It feeds primarily on small aquatic invertebrates such as blackfly and midge larvae, amphipods, isopods, and oligochaetes (Bragg and Stasiak, 1978; Rollwagen and Stainken, 1980). Spawning, which occurs from early April through June in our area, has been described by several workers (Schwartz, 1958; Raney, 1940b; Phillips, 1967; Bartnik, 1970; Matthews et al., 1982). These accounts differ somewhat, and not necessarily along accepted subspecies lines. Spawning is a group effort, with nuptial males assembled over the gravel spawning area, usually in shallow water with at least some current. Males often are territorial, defending a small portion of the spawning area against conspecific males. Males court females in a manner similar to that described for *R. cataractae* except that circling and "dancing" behavior replace "trembling." Females wander into the spawning area to mate, push their snouts into the gravel, and eggs are deposited in or on the substrate. Spawning activities of the pair often result in localized gravel disturbance that creates depressions in the substrate. These have been referred to as nests by several observers, but it seems unlikely that actual nest-building behavior occurs. Though interfertile and often syntopic with *R. cataractae*, hybridization apparently rarely occurs because of differences in peak spawning time, spawning habitat (*cataractae* in faster water), and courtship behavior (Bartnik, 1970) (see further under *R. cataractae*). Each female produces about 750 eggs per year, and life span is about 3 or 4 years, with sexual maturity occurring after 1 or 2 years (Carlander, 1969; Scott and Crossman, 1973). Bragg and Stasiak (1978) found growth in a Nebraska population as follows: age 1, 22–44 mm SL, age 2, 40–72, age 3, 68–81, with females averaging larger, and both sexes maturing at 2 years. Our largest specimens, from the Cumberland River drainage, are 124 mm (4.9 in) TL.

Distribution and Status: Common in uplands of the Ohio, Cumberland, Tennessee, and upper Mississippi drainages. Also in upper Mobile Basin where it is rare. In Tennessee *R. atratulus* occurs in all upland physiographic provinces but is uncommon in the Nashville Basin and northern Highland Rim. Relict populations occur in isolated streams draining bluffs along the Mississippi River in west Tennessee. Its complete absence from the Ozark uplands west of the Mississippi is surprising.

Similar Sympatric Species: Juveniles may be confused with the often sympatric stoneroller or creek chub. The former has a black peritoneum that is visible through the body wall; the latter has a larger, more terminal mouth. Neither has a frenum. Large adults, especially from the Cumberland River drainage, might be confused with *R. cataractae*. In *R. cataractae*, pectoral fin tuberculation is much more normal, consisting of conical tubercles; paired fins are stiffer; and the anterior tip of the lower jaw is slightly posterior to the nostrils (under the nasal septum in *R. atratulus*). Lateral-line scale counts (52–62 for *atratulus* except in upper Holston system; 64–76 in *cataractae*) are useful in confirming identity of Cumberland River drainage specimens.

Systematics: The several nominal subspecies recognized by various workers have been summarized by Matthews et al. (1982). The nominate subspecies occurs from the eastern Great Lakes drainage east to northern and central Atlantic slope drainages. The southern Atlantic slope, Gulf slope, Tennessee, Cumberland, and



Range Map 103. *Rhinichthys atratulus*, blacknose dace.

southern Ohio river drainages are occupied by *R. a. obtusus* (Agassiz), and the subspecies to the north and west of these areas is *R. a. meleagris* (Agassiz). A fourth subspecies name, *R. a. simus* Garman, is sometimes applied to Gulf drainage populations but was regarded as synonymous with *obtusus* by Matthews et al. (1982). Taxonomy of this species continues to be poorly understood. The blacknose dace often occurs in headwater streams that are virtually isolated from other populations in the same river system by falls and large streams which are generally avoided. Long periods of such isolation of often small gene pools have apparently resulted in differences at the population level whose magnitude may swamp meaningful regional differences. Matthews et al. (1982) did find scale count characters that provided excellent separation between populations of *R. a. atratulus* and *R. a. obtusus* in the James River drainage of Virginia but were unable to find reliable characters to differentiate between *R. a. meleagris* and *R. a. obtusus*; they also noted considerable overlap in coloration of nuptial males of the subspecies. Our specimens from the upper and middle portion of the Cumberland River drainage are very large, have small eyes and extremely inferior mouths, and would "key to" *R. cataractae* in most available keys.

Etymology: *atratulus* may be derived from *atratus*, or "clothed in black".

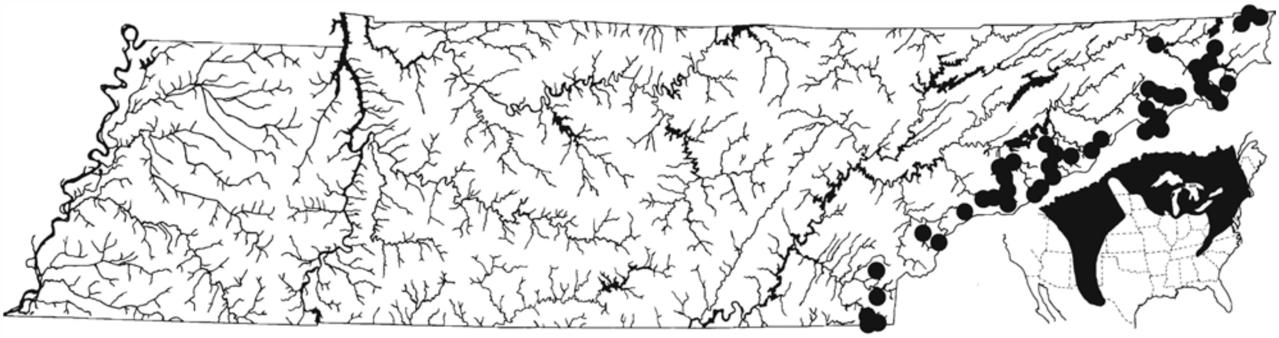
Rhinichythys cataractae (Valenciennes)

Longnose dace

Characters: Lateral line complete with 64–76 scales, predorsal scale rows 30–43. Pectoral fin rays 13–15. Gill rakers 8–10. Vertebrae 37–41. Color reddish brown to dark olivaceous on back and upper side, and with scattered dark colored scales on side. Nuptial males have red lips and red at bases of pectoral, pelvic, and anal fins. Large uniserial tubercles occur on dorsal surfaces of pectoral fin rays 2–5 or 6 and less conspicuous tubercles mostly concealed by tissue occur on the first ray. Anterior dorsal fin rays and upper and lower caudal fin rays have tubercles partially fused to form ridges. Body scales have a single (occasionally 2) tubercles except on belly and breast, and small tubercles are scattered over the entire head. Anal and pelvic fins lack tubercles in our specimens. Other characters in generic account.

Biology: The longnose dace differs markedly in appearance and habitat from its congener, the blacknose dace. It prefers swift riffle areas in cool to cold streams; adults are frequently taken in the swiftest waters collectable, and it often occurs in trout streams. In northern latitudes it also occurs in cold lakes. Longnose dace feed primarily on aquatic insect immatures with baetid mayfly, blackfly, and midge larvae being very important in the diet (Reed, 1959; Gerald, 1966). Spawning is in the spring (April to early June) in our area. Bartnik (1970) described spawning behavior in detail. Males defend stations over gravel in swift current, biting at and butting away intruders. They court females by following, nudging, nibbling, trembling, and quivering. Submitting females enter the station, push their snouts into the gravel, and spawning occurs. Female blacknose dace are also often courted but do not respond; conversely, blacknose males do not court longnose females, so hybrids probably seldom occur (see also comment under *R. atratulus*). Hybrids are known however with *Nocomis* and several other cyprinids (Schwartz, 1981). This is an additional species that often spawns in the clean gravel of nests of other cyprinids as noted by Cooper (1980), who detailed early development in this species. In Pennsylvania, Reed (1959) estimated growth as follows: most age 1 fish were 56–62 mm TL; age 2, 74–78; age 3, 80–82; age 4, 86–90; and age 5, 100–102. As in *R. atratulus*,

Plate 105. *Rhinichthys cataractae*, longnose dace, 67 mm SL, Little Tennessee R. system, NC.



Range Map 104. *Rhinichthys cataractae*, longnose dace (range extends off inset through much of Canada, including Mackenzie River drainage and Pacific slope).

females were larger than males by the second year and dominated older age classes with males disappearing completely from age class 5. Hill and Grossman (1987) found that longnose dace spend most of their lifetime in a very limited area with home ranges of perhaps only 10–15 m of stream. Maximum total length 178 mm (7 in), but usually 130 mm or less.

Distribution and Status: Wide ranging in mountainous regions of North America, including both the Rockies and northwest coastal ranges as well as eastern ranges. Also present in north central glaciated regions. In the southeast, virtually restricted to the Blue Ridge region. All Tennessee records are from the upper Tennessee drainage. Gilbert (1980) did include one Cumberland River drainage record on the map he prepared for the Atlas of North American Freshwater Fishes. Our earlier collection records contain two references to *R. cataractae* from the Cumberland drainage, but specimens are not extant in our collection. It seems possible that the long-snouted Cumberland River form of *R. atratulus* has been misidentified several times as *R. cataractae* and that these misidentifications (some perpetrated by us), rather than actual specimens, are responsible for Cumberland River drainage records of *R. cataractae*.

Similar Sympatric Species: See *R. atratulus*.

Systematics: Western populations have been recognized as subspecies, *R. c. dulcis* (Girard) (Bartnik, 1972). A range-wide study of this species is needed.

Etymology: *cataractae* = of the cataract, after the type locality, Niagara Falls.

Genus *Semotilus* Rafinesque

The Creek Chubs

In addition to the widespread creek chub, the genus currently contains *Semotilus corporalis* (Mitchill), the fallfish, in Atlantic Coastal drainages south through the James River; *S. margarita* (Cope) (often referred to the monotypic genus or subgenus *Margariscus* Cockerell), the pearl dace, from the eastern slope of the northern Rocky Mountains east across Canada and northern United States to the Atlantic Coast; and the recently described *S. lumbee* Snelson and Suttkus (1978), the sandhills chub, from the Cape Fear and Pee Dee drainages of the Carolinas. Additionally, *S. thoreauianus* Jordan of eastern Gulf Coast drainages has been resurrected from the synonymy of *S. atromaculatus* (Johnston and Ramsey, 1985, 1990). Shared generic characters include a pharyngeal tooth formula of 2,5-4,2, and the presence of a triangular, flaplike barbel in the groove between the maxilla and the snout (Fig. 64c). Pharyngeal tooth replacement in *Semotilus* has been detailed by Evans and Deubler (1955). All members of the genus construct gravel nests for spawning. Affinities of *Semotilus* are likely with *Couesius* (formerly *Hybopsis*) *plumbeus* according to Lachner and Jenkins (1971a). Cavender and Coburn (1987) treated *Margariscus* as a separate genus and sister group to *Phoxinus*, with *Semotilus* as the closest relative to those two genera.

Semotilus atromaculatus (Mitchill)

Creek chub

Characters: Lateral-line scales 42–70 (47–63 in Tennessee), predorsal scale rows 30–33. Anal fin rays 8 (7–9). Pectoral fin rays 13–18. Gill rakers 7–11. Breast

Plate 106a. *Semotilus atromaculatus*, creek chub, 65 mm SL, Obion R. system, TN.

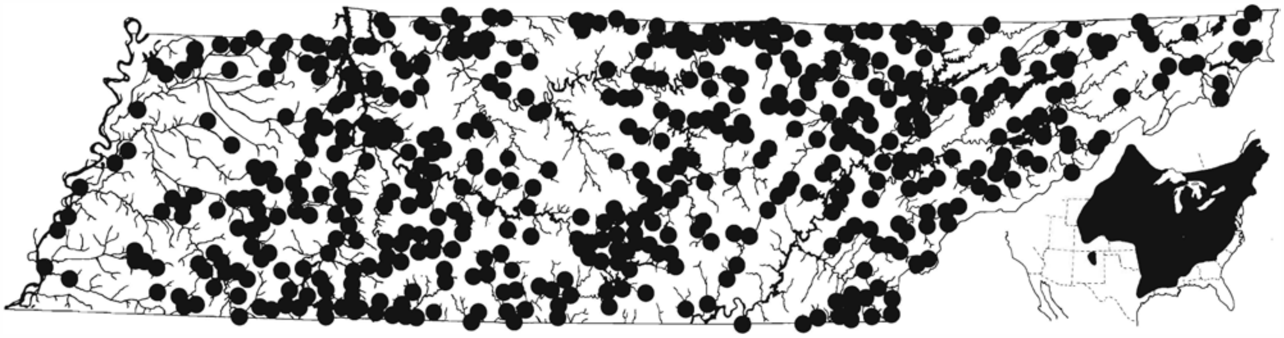
Plate 106b. *Semotilus atromaculatus*, creek chub, breeding male, 140 mm SL, upper Cumberland R. system, KY.

scaled. Vertebrae 42–43 (39–44). Peritoneum silvery. Color dark gray to brown on back, with cream-colored sides interrupted by conspicuous dark lateral stripe; a dark spot is present at the anterior base of the dorsal fin. Nuptial males develop a rosy band along the side and red around the dark dorsal fin spot. A row of 3 (3–9) large, hooked tubercles extends on each side of the head from just in front of the nostrils to just behind the upper portion of the eye. Pectoral fin rays 2–7 bear large uniserial tubercles on their dorsal surfaces, and tubercles may develop on the upper edge of the caudal fin base, dorsal fin rays, and posterior anal fin rays. Body scales posterior to the anal origin have a marginal row of 6–8 tubercles that are best developed on mid sides. Tiny tubercles also occur on cheeks and opercles.

Biology: Although occasional creek chubs are likely to occur in all aquatic habitats except the largest rivers, permanent swamps, and lakes, they are more typical of tiny, often intermittent streams where they occupy pool areas with available escape cover. Except in lowland streams, frequent associates are *Campostoma*, *Phoxinus*, and *Rhinichthys atratulus*. Biological information concerning this species is extensive. The account here is summarized from Reighard (1910), Dinsmore (1962), Moshenko and Gee (1973), Shemske (1974), and Copes (1978). Spawning activity begins in spring when water temperatures reach about 13 C. Males construct nests by carrying pebbles with their mouths and pushing them with their snouts. Pebbles are moved upstream throughout the spawning season, and the end result is a ridge of gravel aligned with the current flow, with the most recently excavated depression at the downstream end of the ridge. Such nests may be 2 m long. Although a single male typically aggressively defends each nest, this resident male may temporarily move into a downstream pool area, leaving the nest to be occupied by a smaller male. However, these lesser males are usually soon chased away by the resident male and return to a position of "nest-watching," waiting for an opportunity to reenter the nest (Ross, 1977). Spawning occurs throughout nest construction with females that enter the nest while the male's attention is directed elsewhere; females sighted before entering the nest often are repelled along with other males (Ross, 1976). In spawning, the male places his expanded pectoral fin under the belly of the female and encircles her anal region with his caudal peduncle. Spawning may occur with the female pressed against the side or bottom of the depression, or the female may be thrust upward by the male into a vertical position. About 50 eggs are laid per spawning act, which are subsequently covered with gravel by additional nest construction activities. Females produce about 1,100 to 7,500 eggs per year. Growth is rapid with young reaching lengths of 50–90 mm during their first year and averaging 120 mm at age 2 and 150 mm at age 3. Sexual maturity occurs during the third or fourth year, and life span is about 6 years. Young feed on small aquatic invertebrates. Adults are voracious predators, consuming small fish, crayfish, and other large invertebrates. Creek chubs also feed considerably on terrestrial insects floating on the water surface, where their large mouth allows them to engulf even the largest insects. Their proficiency at exploiting this resource allows them to survive in many east Tennessee streams where benthic invertebrates and other fishes have been eliminated by pollution from coal mines. Creek chubs are often caught by anglers, and although rarely eaten in this area, are said to be satisfactory food fishes. They are popular as bait minnows wherever they occur. Maximum total length (Trautman, 1957) 303 mm (11.9 in).

Distribution and Status: Abundant throughout much of eastern North America, the creek chub avoids only the lowest Coastal Plain areas. It is common in all physiographic regions of Tennessee.

Similar Sympatric Species: Juveniles might be confused with stonerollers or blacknose dace, but both of these species have mouths that are much smaller and more ventral. In preservative, the black peritoneum of young stonerollers is apparent without dissection. Blacknose dace have a conspicuous frenum. Chubs of the genus *Nocomis* are similar in appearance, but have red or orange caudal fins, much coarser scales, non-



Range Map 105. *Semotilus atromaculatus*, creek chub.

crowded predorsal scales, and the barbel is at the tip of the maxilla. Also, see *Pimephales promelas* and *Phoxinus* accounts.

Etymology: *Semotilus* = spotted banner, referring to the dorsal fin; *ater* = black, *maculatus* = spotted.

FAMILY CATOSTOMIDAE

The Suckers

The suckers constitute a large family of northern-hemisphere fishes that are restricted to fresh water. They are ostariophysan (see Cyprinidae) fishes closely related to cyprinids, Old World loaches (Cobitidae), and three other Asian families with which they are included in the order Cypriniformes (Fink and Fink, 1981); their closest relatives may be the loaches (Siebert, 1987). All but two of the approximately seventy species of catostomids are confined to North America. One of the two, *Catostomus catostomus* (Forster), the longnose sucker, has apparently recently invaded eastern Siberia from Alaska. The other Eurasian species, *Myxocyprinus asiaticus* (Bleeker), is confined to China. Because *Myxocyprinus* has many characteristics considered to be primitive or ancestral within the catostomids, and since it is isolated from all other catostomids, it has been assumed that this family was formerly more abundant in Eurasia, and probably originated there (Darlington, 1957). However, the relationship of *Myxocyprinus* to North American sucker groups is unclear (Patterson, 1981), and it is equally possible that the primitive ancestors of it and other suckers inhabited North America as well. Eurasian suckers may have been replaced by cyprinid fishes occupying niches essentially the same as that of many North American suckers, or the cyprinids may have predated them, curtailing their radiation in Eurasia. *Myxocyprinus*-like fossils are known from Eocene deposits from central Asia, and the fossil genus *Amyzon* (at least four species), with *Ictiobus* or possibly *Myxocyprinus* affinities, occurs in middle Eocene and Oligocene deposits in western North America (Miller, 1959; Wilson, 1977; Bruner, 1991).

Suckers are similar in appearance to the minnows (Cyprinidae). They typically have cycloid scales, 18 principal caudal fin rays (19 in minnows), 10 or more dorsal fin rays (native minnows have nine or fewer), and a single row of pharyngeal teeth that are numerous and gradually decrease in size to the point that they are difficult to count (Fig. 20b). In Tennessee minnows there are five or fewer teeth in the greater row of the pharyngeal arch (see detailed morphology in Eastman, 1977), and a second row of teeth is often present. Suckers also differ from native minnows in the more posterior placement of the anal fin, which is placed much nearer the caudal fin base relative to that of minnows. They further differ from most cyprinids (except carp and a few other large Asian species) in having twice as many chromosomes, about 100 versus 48–50 (Uyeno and Smith, 1972). Two Eurasian cyprinid species introduced to North American waters, the carp and goldfish, are similar in general appearance to some sucker species but differ from suckers in having a serrated spine anteriorly in the anal and dorsal fins. Further morphological information on suckers is given in Nelson (1961) and Eastman (1980).

Most Tennessee sucker species are inhabitants of medium to large rivers as adults, where they have considerable value as commercial food fishes. Although they have numerous intermuscular bones (epineurals), the flesh is firm and usually of excellent flavor. Suckers feed primarily on larval aquatic insects, although vegetable matter and detritus are often present in the gut, and several species feed primarily on mollusks as adults. Spawning is "random," with eggs being scattered about the habitat, except in *Moxostoma carinatum*, the river redhorse, where males construct a nest-like depression in gravel substrates (Jenkins, 1970) and in *Erimyzon* spp, the chubsuckers, in which males defend territories (Page and Johnston, 1990). Reproductive behavior and its systematic implications in suckers were reviewed by Page and Johnston (1990), with territorial tendencies being considered evolutionarily derived. Spawning is from early spring to early summer, with the larger species frequently migrating up smaller streams; occasional homing to spawning habitats has been noted (Olson and Scidmore, 1963; Curry and Spacie, 1984). Suckers may be quite vulnerable to capture by various methods—including spearing, snagging, and trapping—during their spawning runs, and bones of many species are typically common in Indian middens. V-shaped piles of rocks were placed in streams to funnel and concentrate migrating suckers for easy harvest.

Catostomid systematics has been characterized by considerable confusion during the past 100 years or so. Among the major studies are Jordan (1878), Hubbs (1930), Miller (1959), Jenkins (1970), Eastman (1977), Bussjaeger and Briggs (1978), Ferris and Whitt (1978), and Buth (1978, 1979b). In all of the polytypic genera there is much similarity between species and considerable variability within species. In many cases juveniles are extremely difficult to identify. The family is currently (Nelson, 1984) divided into three subfamilies: Cycleptinae, including *Cycleptus* and *Myxocyprinus*; Ictiobinae, including *Ictiobus* and *Carpiodes*; and Catostominae, including *Catostomus* and the related western genera *Chasmistes* and *Xyrauchen*, plus *Erimyzon*, *Hypentelium*, *Minytrema*, *Moxostoma*, and *Lagochila*.

KEY TO THE TENNESSEE GENERA

1. Dorsal fin rays 23 or more 2
   Dorsal fin rays 16 or fewer 4
2. Body slender, depth 25% or less of standard length; lateral-line scales 50 or more . . . *Cycleptus elongatus* p.268
   Body deep and compressed, depth more than 25% of standard length; lateral-line scales 43 or fewer 3
3. Silvery fishes with few or no melanophores on pelvic fins; suboperculum asymmetrical, with its greatest depth anterior to middle (Fig. 91a); anal fin rays 7, rarely 8; also, see comments under *Carpiodes carpio* . . . . *Carpiodes* p.261
   Dusky gray fishes with pelvic fins densely pigmented with melanophores; suboperculum symmetrical, with its greatest depth at middle (Fig. 91b); anal fin rays 8–11 (rarely 7 in our area); also, see comments under *Carpiodes carpio* . . . . *Ictiobus* p.276

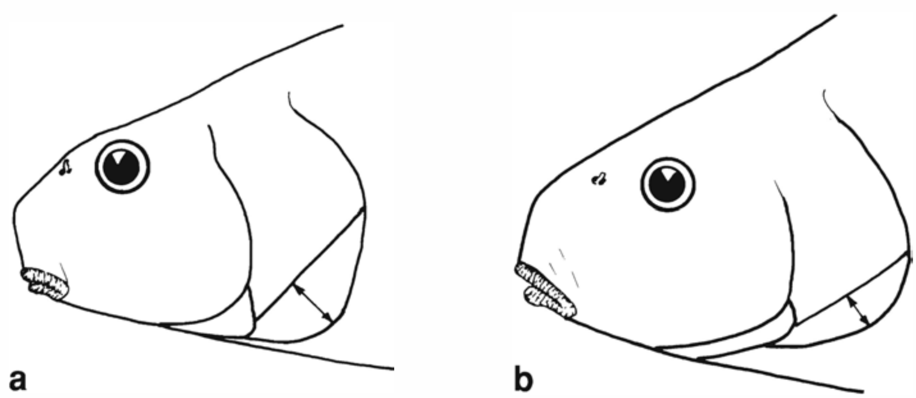


Figure 91. Shape of suboperculum in ictiobine suckers: a) *Carpiodes*; b) *Ictiobus*.

4. Scales near head much smaller than those on posterior part of body; scales in lateral series 60 or more . . . . *Catostomus commersonnii* p.266
   Scales of uniform size; scales in lateral series fewer than 50 5

5. Lateral line absent or virtually so (occasionally well developed in large adult *Minytrema*, which has sides marked with parallel dark lines) 6
Lateral line complete and well developed 7
6. Scales in lateral series 41 or fewer; sides with a single lateral stripe, blotched, or uniformly colored; dorsal fin with convex margin and never with black blotch . . . . *Erimyzon* p.270
Scales in lateral series 42 or more; each lateral scale with a dark spot in center, these spots forming about ten horizontal lines; dorsal fin with straight or concave margin and with distal black blotch in young . . . . *Minytrema melanops* p.282
7. Head flat or concave between eyes; eyes posteriorly positioned behind midpoint of head length; 4–6 conspicuous dorsal saddles; dorsal fin rays 11 or fewer . . . . *Hypentelium* p.273
Head rounded between eyes (convex); eyes positioned near midpoint of head length; dorsal saddles absent in adults; dorsal fin rays 12 or more except in *Moxostoma atripinne*, which has a black blotch on the dorsal fin 8
8. Upper lip protractile (separated from snout by groove); lower lip not divided into separate lobes; widespread in occurrence . . . . *Moxostoma* p.283
Upper lip non-protractile; lower lip completely divided into two lobes; probably extinct . . . . *Lagochila lacera* p.280

Genus *Carpiodes* Rafinesque
The Carpsuckers

As currently conceived, this genus consists of only three species, all of which occur in Tennessee. Carpsuckers are insectivorous or ooze-feeding fishes of large rivers, and two species apparently have considerable tolerance for reservoirs. These two larger species, *C. cyprinus* and *C. carpio*, have some importance as commercial fish and are often referred to as "silver carp" or "chalkeye." Carpsuckers are very similar in appearance to the buffalo fishes (*Ictiobus*) and with them comprise the subfamily *Ictiobinae*. Separation of these two genera may be aided by utilizing characters mentioned under *Carpiodes carpio*, in addition to those in the generic key.

Etymology: *Carpiodes* = carp-like.

KEY TO THE SPECIES

1. Lateral-line scales 36 or fewer (33–37); nipple-like projection (Fig. 92) present on tip of lower lip; dorsal fin rays usually 27 or fewer 2

Figure 92. Nipple-like projection on lower lip of *Carpiodes*.

Lateral-line scales 37 or more (36–40); nipple-like projection absent from tip of lower lip; dorsal fin rays usually 28 or more . . . . *C. cyprinus* p.264
2. Depressed anterior rays of dorsal fin reach to or nearly to end of dorsal fin base in adults . . . *C. velifer* p.265
Depressed anterior rays of dorsal fin only about 2/3 the length of dorsal fin base . . . . *C. carpio*

Carpiodes carpio (Rafinesque)

River carpsucker

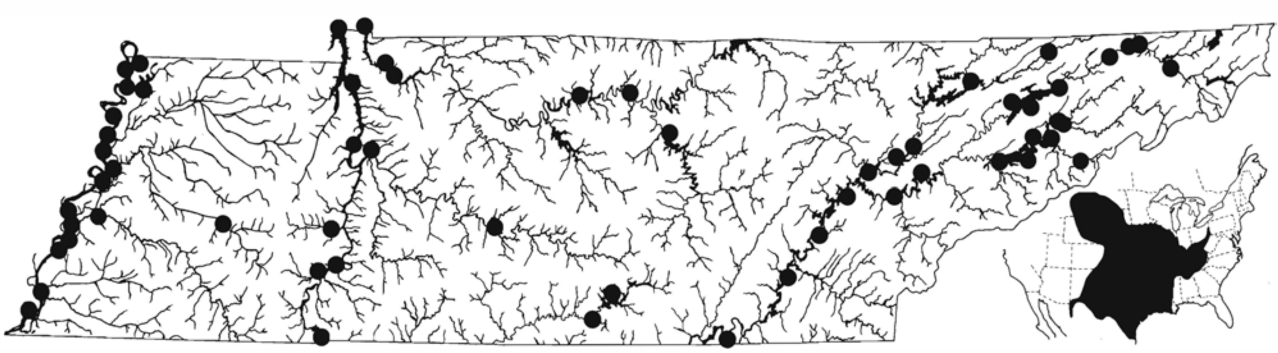
Plate 107. *Carpiodes carpio*, river carpsucker, juvenile, 132 mm SL, Mississippi R., TN.

Characters: Lateral-line scales 34–35 (33–37). Dorsal fin rays 23–30. Anal fin rays 7 (7–8). Pectoral fin rays 14–17. Pelvic fin rays 9 (8–9). Gill rakers 50–70 in four specimens 100 mm (4 in) to 600 mm (24 in), 40–55 gill rakers in six smaller specimens (counts do not include fused ventral vestiges). Breeding males develop tiny nuptial tubercles on the entire head and nuchal ridge except for the snout tip and much of the opercles, and on the leading ray of the pelvic, pectoral, and anal fins (Huntsman, 1967). Color dull gray or brown dorsally, silvery on sides with yellowish or golden tinge. Dorsal and caudal fins with sparse dusky pigment darker at extreme margins; other fins plain.

Biology: The river carpsucker is a dominant species in Tennessee's largest rivers and low-elevation reservoirs. It is gradually replaced by the quillback at higher elevations and in smaller rivers. The following account of its life history is summarized from Jester (1972) and other papers cited therein. Food of adults consists of organic detritus indiscriminately sucked from the substrate. Summerfelt et al. (1972) found significant quantities of aquatic microinvertebrates (primarily entomostraca) and small numbers of insect larvae among stomach contents. Spawning occurs from late spring through early summer at a temperature of 19–24 C (66–75 F) in shallow water, with eggs being broadcast over silty sand substrates. Females produce 100,000–300,000 eggs per year. Life span is about 10 years, and mean total lengths at the end of the first, second, third, and fourth growing seasons are, respectively, about 120, 250, 325, and 370 mm. Sexual maturity occurs after the third, occasionally after the second, year of life. Maximum total length 636 mm (25 in) and maximum weight 4.65 kg (10.25 lb).

Distribution and Status: Wide ranging throughout the Mississippi Basin and westward across the Great Plains to Mexico. In Tennessee the river carpsucker is abundant in the Mississippi and lower Tennessee and Cumberland Rivers, but less common in more upland areas to the east.

Similar Sympatric Species: Very similar, especially when young, to *Carpiodes cyprinus*, *C. velifer*, *Ictiobus bubalus*, and *I. niger*. Hubbs and Lagler (1958) indi-



Range Map 106. *Carpiodes carpio*, river carpsucker .

cated the following differences between the genera *Carpiodes* and *Ictiobus* in addition to those in the generic key: In *Carpiodes* there are two fontanelles (openings) on the dorsal midline of the skull (Fig. 93a) (only one in *Ictiobus*, Fig. 93b); the pharyngeal arch is paper thin and almost linear in cross-section (more robust and with the edge opposite the teeth reinforced by a thickening of the bone in *Ictiobus*); and the whorls of the intestine (Fig. 94a) form a helical pattern in ventral view (longitudinal and parallel to sides of body in *Ictiobus*, Fig.

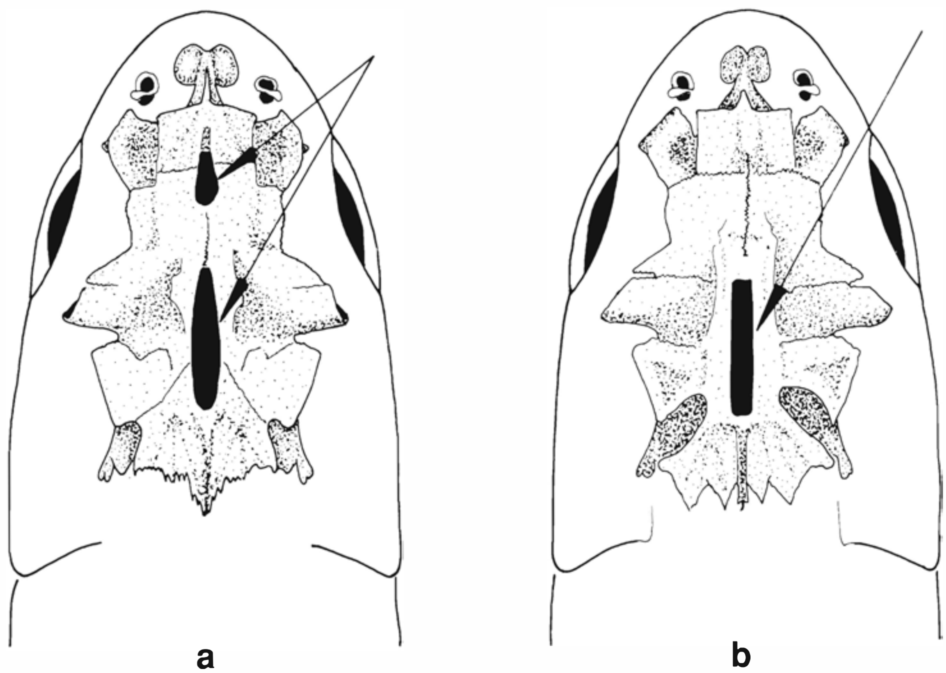


Figure 93. Configuration of fontanelles in roof of skull of ictiobine suckers: a) *Carpiodes*; b) *Ictiobus*.

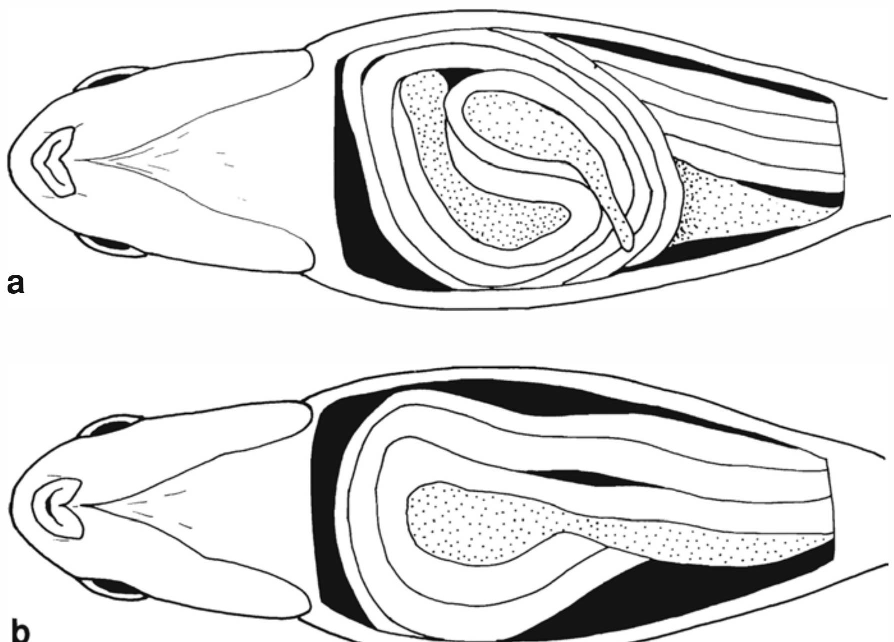


Figure 94. Intestinal coiling patterns of ictiobine suckers: a) *Carpiodes*; b) *Ictiobus*.

94b). In the other two *Carpiodes* species the depressed anterior rays of the dorsal fin typically reach to or past the posterior base of the fin, but in *C. carpio* the tip of the longest ray rarely reaches past the middle of the fin base. *Carpiodes carpio* further differs from *C. velifer*, an uncommon species in Tennessee, in reaching much larger size, and in being less deep-bodied (body depth 2.6 or more times in standard length in *carpio*, 2.6 or fewer in *velifer*).

Systematics: Hubbs (1930) and Hubbs and Black (1940a) treated systematics of the species and regarded the more slender form from southwestern portions of the range as the subspecies, *C. c. elongatus* Meek.

Etymology: *carpio* = carp, in reference to its similarity to that fish.

Carpiodes cyprinus (Lesueur)

Quillback

Characters: Lateral-line scales 36–38 (35–41). Dorsal fin rays 25–33. Anal fin rays 7 (7–8). Pectoral fin rays 15–17 (14–19). Pelvic fin rays 8–10. Gill rakers 27–44 in 13 specimens 43–90 mm SL and 51 in one adult 240 mm SL (counts omit fused ventral vestiges). The low gill raker counts listed by Scott and Crossman (1973) are suspect, especially since they indicate gill raker length to be only 2 mm. The longest gill rakers in a 240 mm SL specimen in our collection are 10 mm long. Vertebrae 38–40. Nuptial tubercles of males (Huntsman, 1967) are larger than on the river carpsucker, cover the head except its dorsal portion, and occur on pectoral fin rays 1–8 or 9 and the first 2 pelvic fin rays. Color as in *Carpiodes carpio*.

Biology: The quillback is the dominant carpsucker in east Tennessee, where it is fairly abundant in many of the reservoirs and larger rivers. Its distribution suggests that it is less tolerant of silt and turbidity than is the river carpsucker. Its biology has received little attention. Spawning occurs from late April through May and is somewhat earlier than for other carpsuckers. Life span is about 10 years (Vanicek, 1961). Food consists of bottom ooze and probably more benthic invertebrates than in the river carpsucker. Maximum total length and weight (Trautman, 1957) reported to be 610 mm (24 in) and 5.45 kg (12 lb), but specimens larger than 6 lbs are not common.

Distribution and Status: Widespread in Mississippi Basin, Great Lakes (except Lake Superior), eastern Gulf Coastal drainages (uncommon), and some middle Atlantic drainages. In Tennessee the quillback is much more common in upland areas than on the Coastal Plain.

Similar Sympatric Species: This is the only carpsucker that lacks the tiny, nipple-like projection (Fig. 92) on

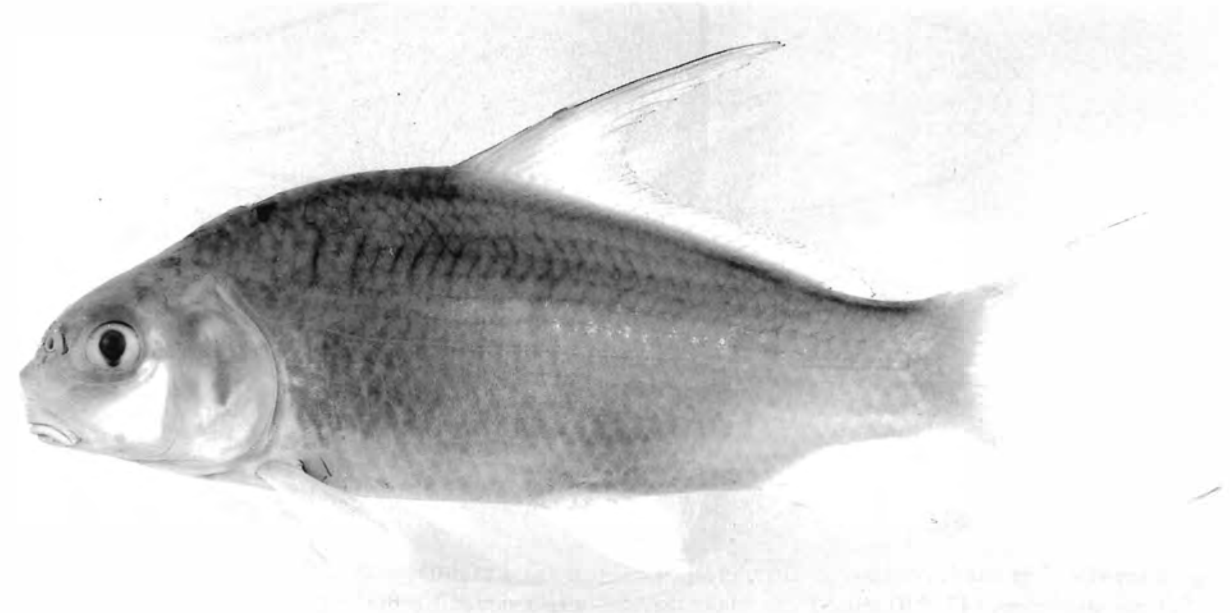
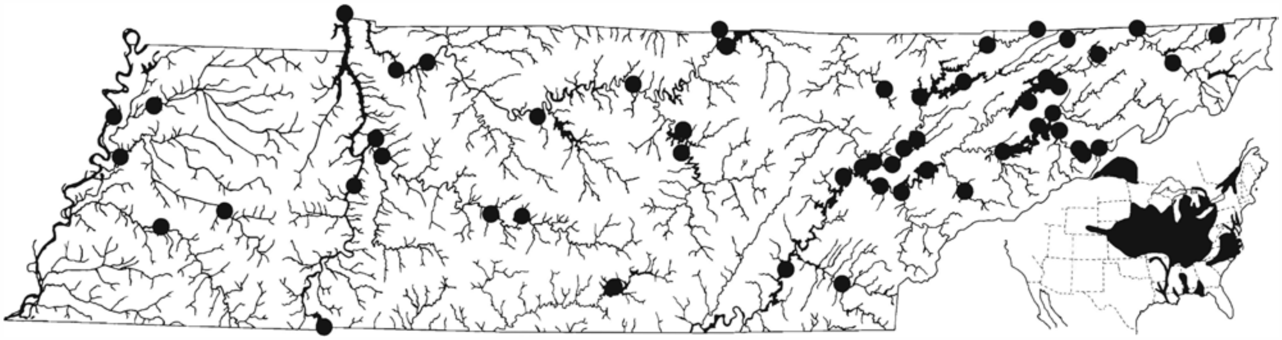


Plate 108. *Carpiodes cyprinus*, quillback, preserved juvenile specimen, 126 mm SL, Ohio R., KY



Range Map 107. *Carpiodes cyprinus*, quillback (range extends off inset northwest across southern and central Manitoba, Saskatchewan, and Alberta).

the lower jaw, but young carpsuckers of other species may have this process absent or weakly developed, and are very difficult to identify. Gill raker counts (see Characters) may offer reasonable separation of this species and *C. carpio*. Also similar to *Ictiobus bubalus*—see comments under *Carpiodes carpio*.

Systematics: Several names formerly applied to this species are still occasionally used, such as the more elongate *C. forbesi* Hubbs (Midwest, Southwest) and *C. cyprinus hinei* Trautman. Most current workers concur with Bailey and Alum (1962) that a single taxon is involved.

Etymology: *cyprinus* is the generic name of the carp, and alludes to its similarity to that fish.

Carpiodes velifer (Rafinesque)

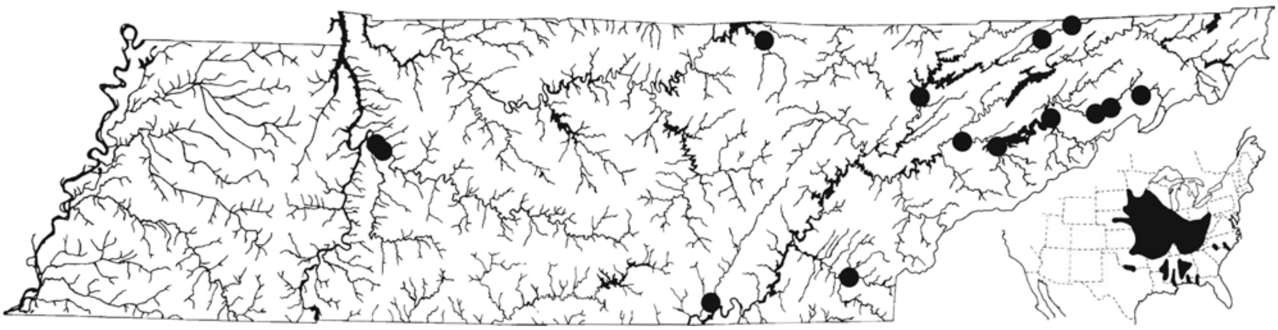
Highfin carpsucker

Plate 109. *Carpiodes velifer*, highfin carpsucker, juvenile, 95 mm SL, Little Pigeon R., TN.

Characters: Lateral-line scales 33–35 (33–37). Dorsal fin rays 22–24 (21–27). Anal fin rays 7 (7–8). Pectoral fin rays 15–17 (14–17). Pelvic fin rays 9–10 (8–10). Gill rakers 40–57 in five specimens 40–70 mm SL, 62–70 in three specimens 147–210 mm SL. In adults the elongate anterior rays of the dorsal fin, when depressed, may reach to the caudal fin base. In juveniles 30–50 mm SL these rays already extend well past the middle of the dorsal fin base. Nuptial tubercles are larger than those of *C. carpio* and cover the head except for the cheeks and opercles, and occur on most body scales and on all fins (Huntsman, 1967). Color as in *C. carpio* except that edges of lateral body scales are often more distinctly outlined with dark pigment.

Biology: The highfin is the smallest of the carpsuckers, and apparently the species that has been most adversely affected by environmental changes. Both Trautman (1957) and Smith (1979) indicated that *C. velifer* was formerly common in Ohio and Illinois, respectively, but it is currently much less abundant than its congeners. This is likely the case in Tennessee, but there are so few early records that it may have never been abundant in our state. Its habitat, consisting of areas of gravel substrate in relatively clear medium to large rivers, differs considerably from that of the other carpsuckers (Pflieger, 1975; Smith, 1979) and is more susceptible to change by siltation and impoundment. Sexual maturity occurs at lengths of 230 mm (9 in) or less (Trautman, 1957), and spawning occurs in late July in Missouri over deep gravel riffles (Pflieger, 1975). Life span is about 8 years (Vanicek, 1961). Trautman (1957) noted that the highfin is much more likely than other carpsuckers to swim at the surface with the dorsal fin and part of the back exposed, especially during calm evenings. Maximum total length and weight (Trautman, 1957) reported to be 382 mm (15 in) and .91 kg (2 lb).

Distribution and Status: Mississippi River basin and eastward in Gulf drainages to Choctawhatchee River of Florida and Alabama; Lee and Platania (1980) mapped single occurrences from the Santee and Cape Fear drainages of North Carolina. Recent records suggest that this species is increasing in the Tennessee River



Range Map 108. *Carpiodes velifer*, highfin carpsucker.

drainage. Our experience indicates that *C. velifer* is much more abundant in the free-flowing rivers of the Gulf Coastal Plain to the south. Tennessee populations apparently persist in the Nolichucky, French Broad, Clinch, Hiwassee, Sequatchie, and Duck river systems, but questionable records from the Holston River (Pfitzer, 1954, not plotted on map) and the 1930 record (University of Michigan collection) from the Obey River (now Dale Hollow Reservoir) may represent populations that have been extirpated. Although its rarity in collections from Tennessee may be partially due to the difficulty of collecting its preferred habitat, our ignorance concerning its status in our state certainly justifies its Deemed in Need of Management (TWRA) and Special Concern (Tenn. Heritage Program) status (Starnes and Etnier, 1980). Recent works on midwestern fishes (Smith, 1979; Becker, 1983) noted a sharp population decline in that region where *C. velifer* was formerly abundant.

Similar Sympatric Species: This is the deepest bodied of the carpsuckers, and the anterior rays of the dorsal fin are even more produced than in *C. cyprinus*. The combination of the elongate anterior dorsal fin rays that reach to or past the posterior base of the fin and a nipple-like structure (Fig. 92) on the tip of the lower lip is diagnostic for adults. Additional characters that may be useful in identifying subadults and juveniles are: body width two or more times in body depth (less than two in *C. carpio*), and body depth 2.9 (young) to 2.4 (adults) times in standard length (3.3 and 2.7 for young and adults, respectively, of *C. carpio*). Differs from *C. cyprinus* in scale and dorsal fin ray counts as indicated in key. See also comments under *C. carpio*.

Etymology: *velifer* = sail bearer.

Genus *Catostomus* Lesueur

The genus *Catostomus* contains about 20 species, most of which are confined to western North America. Although similar in appearance to the redhorses (*Moxostoma*) and spotted sucker (*Minytrema*), species of *Catostomus* have, among other differences, much smaller scales, especially anteriorly. Sizes of *Catostomus* range from a maximum of about 152 (6 in) in some populations of the smaller western mountain suckers (subgenus *Pantosteus*) to about 762 mm (30 in) in the nearly circumboreal *Catostomus catostomus*. Systematics of the genus has been treated by Smith and Koehn (1971). The systematic relationships of *Catostomus* relative to the nominal western genera or subgenera *Chasmistes*, *Deltistes*, *Pantosteus*, and *Xyrauchen* are problematical and still in a state of flux (e.g., G. R. Smith, in press). Larger species of *Catostomus* are often taken for food in large numbers during spring spawning runs and were probably very important in the diets of early Native Americans. A single species occurs in Tennessee.

Catostomus commersonii (Lacepede)

White sucker

Characters: Lateral-line scales 60–70 in Tennessee specimens (53–85 elsewhere). Dorsal fin rays 10–13. Anal fin rays 7 (6–8). Pectoral fin rays 16–19. Pelvic fin rays 9–11. Gill rakers 22–24 in ten Tennessee specimens, with the lower 6 or 7 vestigial. Vertebrae 45–48. Males develop large breeding tubercles on rays of the anal and lower lobe of the caudal fin that are widely scattered in a single row per fin ray. Large single tubercles also occur on the edges of the lower caudal peduncle scales. Tiny tubercles occur on both surfaces of the

Plate 110a. *Catostomus commersonnii,* white sucker, 139 mm SL, Holston R. system, TN.

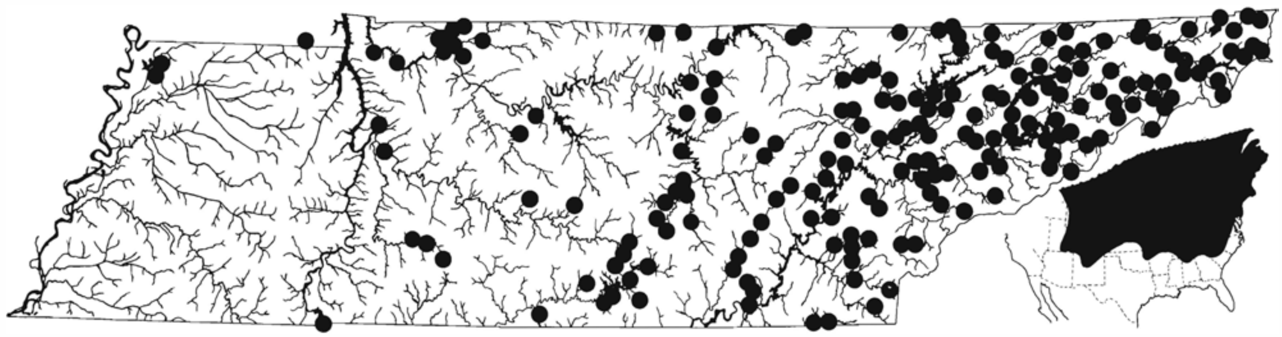
Plate 110b. *Catostomus commersonnii,* white sucker, breeding male 128 mm SL, upper Cumberland R. system, TN.

pelvic and pectoral fin rays, between the pectoral fin bases, and on the suboperculum and branchiostegal rays. Color mottled olive or gray dorsally with scale rows faintly marked by horizontal streaks; lower sides and belly white. Males often develop a copper to red midlateral streak during spawning activity. Juveniles have four diffuse dark blotches (parr marks) along the sides.

Biology: Habitat of the white sucker is variable, with southeastern populations usually occurring in pool areas of tiny to moderate-sized streams that are often intermittent. It is often associated with spring habitats in the Tennessee River drainage. Growth rates and age at sexual maturity are quite variable (Beamish, 1973). Specimens from streams in our area become sexually mature at about 150 mm or less, and specimens over 250 mm TL are uncommon; individuals in our few reservoir populations may attain greater size. The following information is summarized from Olson and Scidmore (1963), Carlander (1969), Schneberger (1972), Scott and Crossman (1973), and Krieger (1980). Sexual maturity occurs during the third or fourth year in northern waters (seventh in Colorado), where life span is up to 17 years. Southern populations are probably shorter lived. In the Midwest the white sucker is a common inhabitant of cool lakes, and in these populations sexual maturity occurs at about 300 mm and adults are commonly 450 mm. Krieger (1980) reported total lengths of about 75 mm at age 1, 150 mm (age 3), 225 (5), 300 (7) and 400 mm at age 11–12 in a Colorado reservoir. Spawning occurs in early spring over gravel areas in lakes or streams at water temperatures of about 10 C (50 F). At least some individuals return to the same streams year after year. Males congregate over the spawning area, and several of them press against the sides of receptive females when they enter the area. Spawning is most active during dusk and dawn. Eggs number about 30,000 per female and are randomly scattered over the substrate. Schwartz (1981) reported several hybrid combinations involving *commersonnii* and western *Catostomus* species, but no intergeneric crosses with eastern suckers are reported. Larvae were described by Fish (1932), and early development was detailed by Long and Ballard (1976). Food of young is primarily zooplankton, while adults feed on benthic invertebrates, especially midge larvae, amphipods, and snails. Seasonal stomach analyses of stream specimens from our area revealed an average composition of 50% benthic invertebrates with the remainder comprised of unidentified organic and inorganic matter probably incidentally ingested (Starnes and Starnes, 1981). White suckers are not an important sport species in our area but in the North are often taken by angling and spearing during spawning runs. The flesh is tasty but bony. The white sucker is a very popular bait fish in the Midwest, where 150–250 mm specimens are used as bait for northern pike, muskellunge, and large walleye. These game fish, when reared in hatcheries, are often fed sucker fry, which are cultured in the same hatchery for that purpose. Maximum weight reported is the current world angling record of 3.3 kg (7.25 lb) from Wisconsin; maximum total length probably approaches 64–65 cm (25+ in) in northern lake populations (McPhail and Lindsey, 1970).

Distribution and Status: Widespread throughout the uplands of eastern North America, throughout the Plains region, and into northern Canada. In Tennessee the white sucker occurs throughout upland areas and is locally common in relatively undisturbed areas of the Cumberland Plateau. It apparently has established populations in some of the cooler reservoirs of eastern Tennessee (e.g., Calderwood and possibly others). In the Coastal Plain it is known from streams draining bluffs along the Mississippi River near Reelfoot Lake.

Similar Sympatric Species: General appearance is similar to that of the redhorses (*Moxostoma*), which have fewer than 50 lateral-line scales and usually have



Range Map 109. *Catostomus commersonnii,* white sucker (range extends off inset throughout much of Canada, including the Mackenzie River drainage and several Pacific slope drainages of British Columbia).

some orange or red pigment in the fins. In the white sucker there are over 55 lateral-line scales, and the fins lack bright colors.

Systematics: The widespread white sucker's extreme variability in meristic characters, appearance, and size, has lead to description of a number of forms now believed to belong to a single, plastic species. However, no recent rangewide systematic treatment exists.

Etymology: *Cato* = inferior, *stomus* = mouth, referring to the ventral position of the mouth; *commersonnii* is a patronym for the early French naturalist, P. Commerson.

Genus *Cycleptus* Rafinesque

Cycleptus elongatus, the blue sucker, is the only species in the genus (but see Distribution below). Nelson (1948) suggested a close relationship to the Asian *Myxocyprinus*, which is currently included with *Cycleptus* in the subfamily Cycleptinae.

Cycleptus elongatus (Lesueur)

Blue sucker

Characters: Lateral line complete with 53–60 scales. Dorsal fin rays 28–37. Additional counts for ten UT specimens are: anal fin rays 7 (8) or 8 (2), pectoral fin rays 16–17, pelvic fin rays 9–11, gill rakers 12–24. Body color dark blue-gray in life, lower lobe of caudal fin dark, especially in juveniles; males becoming more intensely blue during late-spring spawning season (Rupprecht and Jahn, 1980). Branson (1961) described tubercles from a single adult, presumably a male, as covering the entire head except for an area on the anterior snout, with tubercles more abundant on top of head and larger on sides of head. Small tubercles occur on the snout tip just above the upper lip. Body scales each with up to 25 tubercles that are most abundant above the lateral line on the posterior portion of the body, and on the ventral portion of the caudal peduncle. Pectoral and pelvic fin rays have one to three rows of tubercles on both ventral and dorsal surfaces. Dorsal, anal, and caudal fins also have tubercles that tend to form multiple rows near leading or outer edges, and single rows elsewhere. Moss et al. (1983) found small nuptial tubercles to be present on both sexes from April through June, with tubercles of males becoming enlarged on the snout and side of the head during peak spawning.

Biology: The blue sucker, also known as Missouri sucker or blackhorse, is an inhabitant of swift waters over firm substrates in big rivers. Although once fairly common throughout its range, it has declined drastically, probably in response to impoundment and possibly siltation in many of our big rivers. It seems unlikely that its plight will improve. The swift, deep waters the blue sucker normally occupies suggest it to be virtually invulnerable to normal collecting or commercial fishing techniques during most of the year, and our concept of abundance may be an underestimate. Electrofishing gear was used successfully to obtain specimens for life history studies in Illinois (Rupprecht and Jahn, 1980) and Kansas (Moss et al., 1983). Commercial fishermen report spawning runs in the Hatchie River in west Tennessee during February (Starnes, 1973), and Pflieger (1975) noted tubercle development during that month. Although the pre-spawning movements of blue suckers may make them vulnerable to capture in late winter, both studies cited above indicated that spawning did not occur until late April or May, at water temperatures of

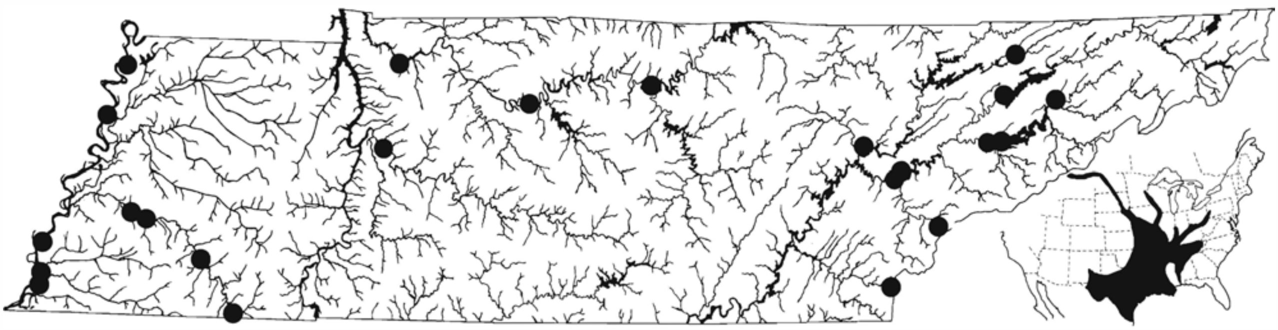
Plate 111a. *Cycleptus elongatus*, blue sucker, tuberculate male, about 58 cm SL, Tallapoosa R., AL (photo J.S. Ramsey).

Plate 111b. *Cycleptus elongatus*, blue sucker, small juvenile, 32 mm SL, Mississippi R., TN.

20–23 C (68–73 F). Our captures of young that could hardly have been more than a few weeks old (15–34 mm SL) from localities in Louisiana, Mississippi, and Tennessee on 17–20 May and from the Missouri River in Nebraska on 13 June (11–17 mm SL) are in agreement with the later spawning time. Spawning site for the Kansas population was a narrow portion of the Neosho River with limestone bedrock and cobble substrate, 1–1.7 m depths, and flows of about 1.8 m/sec. Nonspawning adults occurred in similar but somewhat deeper habitats with flow of up to 2.6 m/sec. Age and growth studies cited in Carlander (1969) and from Moss et al. (1983) indicate the following lengths (mm) after the first through seventh years of life: 1 (109–252), 2 (196–412), 3 (282–511), 4 (338–580), 5 (424–614), 6 (511–644), 7 (523–649). Rupprecht and Jahn (1980) gave mean lengths near the tops of these ranges for comparable age groups, gave a maximum lifespan of 10–13 years, and total lengths up to 817 mm at that age. Moss et al. (1983) indicated that females were larger than males at all ages, males reached sexual maturity as early as age 3, and life span was at least 9 years. Food of the Kansas population consisted of benthic invertebrates dominated by hellgramites (*Corydalus cornutus*), hydropsychid caddisflies, and fingernail clams (*Sphaerium*) in adults, with juveniles feeding primarily on midge and caddis larvae. Adults in the Mississippi River study in Illinois had fed primarily on caddis larvae. Adults often had filamentous algae and detritus in their digestive tracts. Trautman (1957) reported the blue sucker to be the finest food fish in the family, and mentioned a specimen of 1.03 m (40 in) total length weighing 6.8 kg (15 lb). Pflieger (1975) reported unverified early records of specimens up to 9.1 kg taken by commercial fishermen.

Distribution and Status: Widespread throughout larger rivers of the Mississippi Basin and Gulf Coastal drainages from the Mobile Basin to the Rio Grande. Seemingly common now only in the Missouri, Neosho, and middle Rio Grande rivers. B. M. Burr and R. L. Mayden (pers. comm.) are of the opinion that Rio Grande and Mobile Basin forms represent distinct taxa. Recent Tennessee records are scarce. Postlarvae, juveniles, and two adults have been collected from the Mississippi River, a juvenile from the Nolichucky River, and one adult each from Ft. Loudoun Reservoir and lower Cumberland River. Treated as Threatened or Endangered throughout much of its range, and in Tennessee treated by the Wildlife Resources Agency as Threatened and by the Heritage Program as Endangered (Starnes and Etnier, 1980).

Similar Sympatric Species: This striking fish bears little resemblance to any other North American species. Some redhorses (*Moxostoma*) and chubs (*Macrhybopsis*) have similar body shapes and caudal fin pigmentation, but these all have short-based dorsal fins with 14 or fewer rays.



Range Map 110. *Cycleptus elongatus*, blue sucker.

Etymology: *Cycleptus* = round and slender, an apt name. The author of the name, Rafinesque, meant it to mean "small round mouth"; *elongatus* = elongate.

Genus *Erimyzon* Jordan
The Chubsuckers

This genus contains three species, all of which are confined to eastern North America. Two species occur in Tennessee. The third species, *E. tenuis* (Agassiz), is confined to Gulf Coast drainages and lower Mississippi River tributaries from Louisiana to western Florida. Together with *Minytrema* they comprise the tribe Erimyzontini within the subfamily Catostominae (Jenkins, 1970). Chubsuckers are small species that lack lateral lines and have 8–12 dorsal fin rays and 7 anal fin rays; nuptial tubercles on the heads of breeding males are large and typically number 3 or 4 on each side of the head between the eye and upper lip. Only one ovary is present. Breast scales are large and slightly embedded. All are species of clear, often vegetated, low-gradient streams, lakes, and oxbows. Unlike most other sucker genera in which females attain larger size, there is no sexual dimorphism in this trait in *Erimyzon* which is perhaps a function of territoriality in males of this genus (Page and Johnston, 1990a). Chubsuckers, with their terminal mouths, small size, and short dorsal fins, are quite similar to some of the more robust cyprinids, but they differ in lacking a lateral line and in having a more posterior anal fin placement, sucker-like mouths, only 18 principal caudal fin rays, and usually 9 or more dorsal fin rays.

Etymology: *Eri* = an intensifying prefix; *myzon* = to suck.

KEY TO THE TENNESSEE SPECIES

1. Dorsal fin rays 9 or 10 (8–11) in Tennessee, 12 (11–13) in many Atlantic slope populations; scales in lateral series 39–41 (37–43); adults with body depth contained more than 3.3 times in standard length; juveniles with amber anal fin and with lateral stripe broken into a series of confluent blotches . . . . *E. oblongus*

   Dorsal fin rays 11 or 12 (10–13); scales in lateral series 35–38 (33–40); adults with body depth less than 3.3 times in standard length; young with red anal fin and a continuous black lateral stripe . . . . *E. sucetta* p.272

Erimyzon oblongus (Mitchill)

Creek chubsucker

Plate 112a. *Erimyzon oblongus*, creek chubsucker, 70 mm SL, Hatchie R. system, TN.

Plate 112b. *Erimyzon oblongus*, creek chubsucker, breeding male, 120 mm SL, Obion R. system, TN.

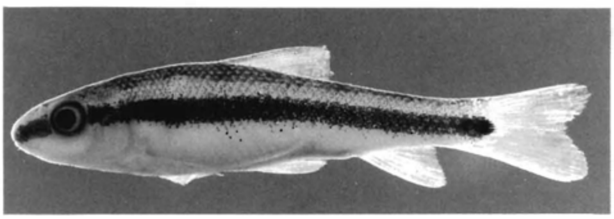
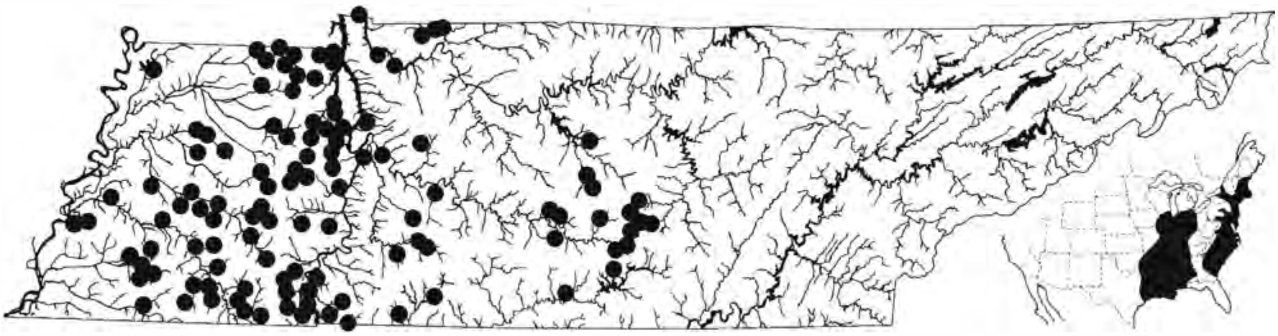


Plate 112c. *Erimyzon oblongus*, creek chubsucker, small preserved juvenile specimen in black stripe phase, 28 mm SL, lower Tennessee R. system, TN.

Characters: Pectoral fin rays 14–17. Pelvic fin rays consistently 9 in Tennessee specimens. Gill rakers (exclusive of rudimentary ventral pads) 22–30. Also see generic account and key. Life colors brownish to olivaceus above, paler below. A diffuse lateral stripe of nearly confluent blotches is often present; young less than 30 mm TL have a uniform black stripe. Nuptial males have 3 large, slightly hooked tubercles and usually 1 or 2 smaller tubercles on each side of the head between the eye and upper lip. Anal fin tubercles occur as a single row per ray branch, typically with 1 tubercle per fin ray segment. Tubercles on the lower half of the caudal fin are smaller than those on the anal fin, but have a similar pattern. Scales on the lower half of the caudal peduncle have 1 to 4 large tubercles near the scale edge. Small tubercles may occur on the pelvic and dorsal fins (Carnes, 1958; Branson, 1961; Wagner and Cooper, 1963).

Biology: The creek chubsucker is abundant in some Tennessee stream habitats. It occurs commonly in pools in sluggish streams, spring pools, and backwater areas in west and middle Tennessee. Spawning occurs from March through May, with peak spawning in North Carolina in April at water temperatures of about 17–18 C (60 F) (Carnes, 1958). Pflieger (1975) indicated that males congregate in small groups over gravel substrates in areas of little current and that several males court and mate with individual females as they enter the spawning area. Page and Johnston (1990a) observed males defending territories over gravel beds or near gravel nests constructed by large minnows (*Campostoma*, *Semotilus*). Females drifted downstream into these territories, buried their snouts in gravel, and spawned individually with males. Females in a Pennsylvania population in which individuals grew rapidly produced 7,500 to 29,000 eggs at lengths of 200 to 375 mm (Wagner and Cooper, 1963). North Carolina specimens (Carnes, 1958) produced up to 80,000 eggs in females slightly over 1 kg. Creek chubsuckers are known to hybridize with lake chubsuckers where stream channelization has altered habitat integrity (Hanley, 1977). Biological data summarized by Carlander (1969) and Carnes (1958) indicate first year's growth of 50–165 mm, a life span of 5–6 years, and a diet of microcrustacea, aquatic insects, and some algae. Maximum total length is typically less that 250 mm (10 in), but Wagner and Cooper (1963) reported specimens up to 376 mm (14.8 in) and 750 gm (1.65 lb) in Pennsylvania. Many populations have sexually mature individuals at small sizes of 150 mm TL or less. Males and females attain similar size (Page and Johnston, 1990a). Carnes (1958) examined a 398 mm (15.5 in) female that weighed 1.17 kg (2.6 lb).

Distribution and Status: A species with disjunct eastern and western populations occurring primarily on the Coastal Plain (also Piedmont in the east) and midwestern streams east of the Plains. In Tennessee, *E. oblongus* penetrates the Highland Rim area as well, but is less common there than on the Coastal Plain. Jordan (1877a) listed fishes from "a visit to Powell's River and other tributaries of Clinch River, near Cumberland Gap, Tenn., and to the French Broad and Big Pigeon Rivers, near Newport, Tennessee. . . ." *Erimyzon oblongus* occurred in Jordan's listing, but there was no indication as to which of the localities produced which species. Ever-



Range Map 111. *Erimyzon oblongus*, creek chubsucker.

mann (1918), in his compilation of fish species known from Kentucky and Tennessee, attributed the vague record of Jordan to the French Broad River system, but did not give any explanation for this choice of locality. Evermann (1918) listed another record of *Erimyzon* from the Clinch River in Virginia that was reported by Jordan (1878). Jenkins (1967) did not indicate the presence of *Erimyzon* west of the Appalachian divide in Virginia, but two records appear in Wall and Gilbert (1980) that presumably represent the upper French Broad and the Cumberland Gap areas. We prefer to regard these records as questionable at present, since there are no recent records of this predominantly lowland genus from the upper Tennessee River drainage.

Similar Sympatric Species: Very similar to the lake chubsucker, differing primarily as noted in the Key. Specimens we have examined from the Atlantic Coastal drainages tend to have higher dorsal fin counts (up to 13), but this source of confusion has not been encountered in Tennessee specimens.

Systematics: Hubbs (1930) recognized three subspecies, with western portion of range, including Tennessee, occupied by *E. o. claviformis* (Girard).

Etymology: *oblongus* = oblong.

Erimyzon sucetta (Lacepede)

Lake chubsucker

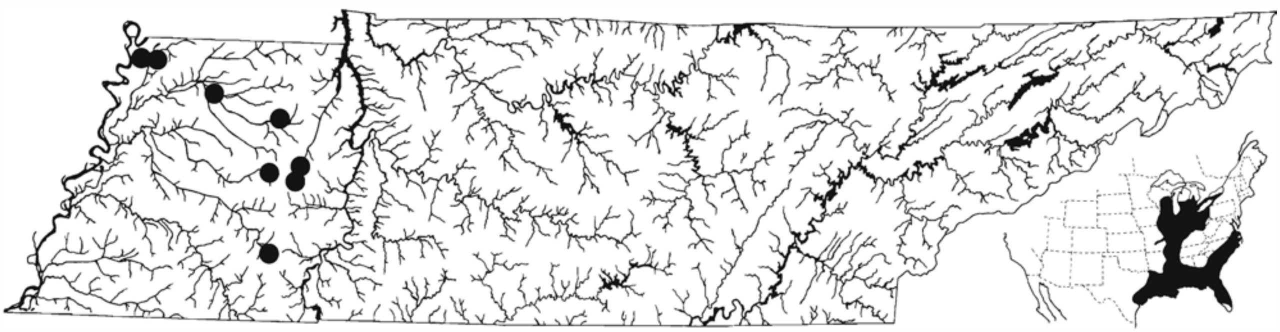
Characters: Pectoral fin rays 14–16. Pelvic fin rays 8–10. Gill rakers 20–31 (exclusive of vestigial ventral pads). Scott and Crossman (1973) report 31–35 gill rakers (their counts presumably include ventral vestigial rakers) and 31–32 vertebrae. Also see generic account and Key. Adults olive green to gray dorsally with a series of midlateral blotches. Juveniles with their bright red fins and jet black lateral stripe are very distinctive. Nuptial tubercles (Scott and Crossman, 1973) similar to those of *E. oblongus*. A single available nuptial male specimen, from the Forked Deer system, lacks tubercles on lower caudal peduncle scales and on lower caudal fin rays.

Biology: The lake chubsucker avoids all but the lowest-gradient streams and is typically found in vegetated backwaters, oxbows, and in Reelfoot Lake in Tennessee. Data summarized in Carlander (1969) and Scott and Crossman (1973) indicate a March through July spawning period, depending on latitude. Spawning usually occurs over gravel areas in streams but may occur in still water over vegetation. The male is reported to clean a gravel area for a nest. Fecundity ranges from 3,000 to 20,000 eggs per female. See comment under *E. oblongus* regarding hybridization. Food consists of microcrustacea and midge larvae. Life span is 5 or 6 years. Maximum size to 394 mm (15.5 in) total length and nearly 1 kg (2.2 lb) (Carlander, 1969).

Distribution and Status: The lake chubsucker shares a range very similar to that of the creek chubsucker but does not occur in northern Atlantic Coastal states and occurs only below the Fall Line except in the Midwest. In Tennessee, it is restricted to the Coastal Plain where its abundance is hard to assess because of difficulty of sampling its habitat. Based on reasonably thorough surveys of that area (Medford and Simco, 1971; Dickinson, 1973; Starnes, 1973; Clark, 1974; Boronow, 1975), it would appear to be very uncommon and perhaps extirpated from many habitats altered by agricultural practices.

Similar Sympatric Species: See *E. oblongus*.

Plate 113. *Erimyzon sucetta*, lake chubsucker, juvenile (preserved several days before photo), 105 mm SL, Lumber R. system, NC.



Range Map 112. *Erimyzon sucetta*, lake chubsucker.

Systematics: Hubbs (1930) recognized subspecies whose validity has since been in question.

Etymology: *sucet* = sucker (Fr.).

Genus *Hypentelium* Rafinesque
The Hogsuckers

The genus *Hypentelium* consists of three closely related species, two of which occur in Tennessee. The third species, *H. roanokense* Raney and Lachner, occurs with *H. nigricans* in the Roanoke River drainage of North Carolina and Virginia. Hogsuckers are members of the tribe Moxostomatini along with the redhorses (*Moxostoma*) and jumprocks (*Thoburnia*). Jenkins (1970) considered the hogsuckers to be most closely related to the subgenus *Thoburnia* of *Moxostoma*, and this view was supported in electrophoretic studies by Buth (1979b). Buth (1980) hypothesized relationships among *Hypentelium* species with *nigricans* and *etowanum* most closely related. All hogsucker species have massive heads and slender, tapering, cylindrical bodies with four dark saddles across the back. The eyes are placed far back on the head, and lips are fleshy and papillose. Anal fin rays are consistently 7, and there are 9 pelvic fin rays.

Etymology: of Greek origin, *Hy* = below, *pent* = five, *lium* = lip or labium, or, lower lip five-lobed.

KEY TO THE TENNESSEE SPECIES

1. Dorsal fin rays 11 (rarely 10); scales above lateral line (counted in scale row in front of dorsal fin obliquely back to the lateral line on each side, but not including the lateral-line scale row) usually 15 (rarely 13 or 14); widespread . . . . *H. nigricans* p.275
   Dorsal fin rays 10 (rarely 11); scales above lateral line 14 or fewer; restricted to the Conasauga River system and portions of the Ocoee River system in Polk and Bradley counties . . . . *H. etowanum*

Hypentelium etowanum (Jordan)

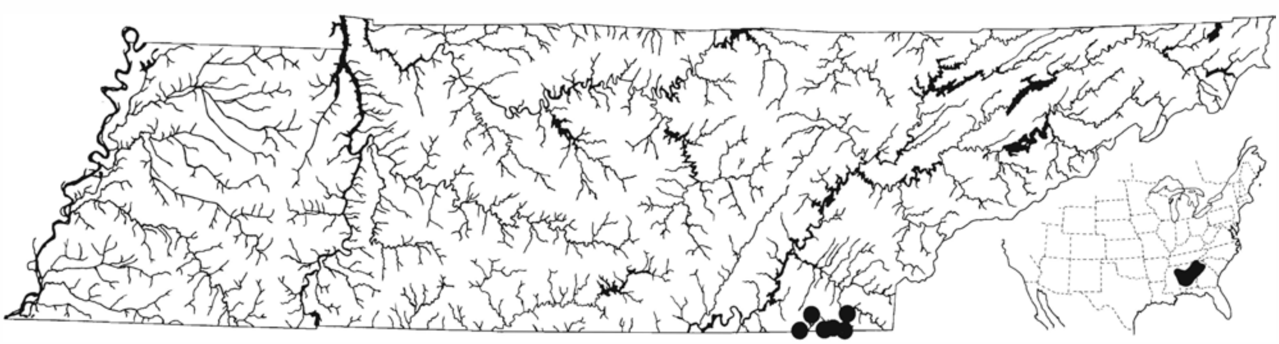
Alabama hogsucker

Characters: Lateral-line scales 43–49. Dorsal fin rays 10 (9–11). Pectoral fin rays 15–17. Gill rakers 20–24. Vertebrae 41–45. Upper sides dark with pale horizontal lines through scale centers. Sides with blotches corresponding somewhat to dorsal saddles. Tip of dorsal fin dark; all fins except anal mottled with dark pigment. Males develop large scattered nuptial tubercles on rays of the anal and lower caudal fin, and smaller, uniserial tubercles on the dorsal, pectoral, and pelvic fin rays. These are best developed on dorsal surfaces of the pectoral and pelvic fins. Tiny, granular tubercles occur on body scales, mostly on margins, and on dorsal and lateral surfaces of the head except for the anterior part of the snout.

Biology: Like its congeners, *H. etowanum* is a species that occurs in gravel riffle areas of tiny creeks to moderately large rivers. Tubercle development in our specimens suggests a March–April spawning period. Sexual maturity occurs at about 110 mm, and length-frequency distributions suggest a life span of at least 5 years. Other aspects of its biology are unstudied, but presumably similar to that of *H. nigricans*. Maximum total length about 230 mm (9 in).

Distribution and Status: The Alabama hogsucker is by far the more abundant *Hypentelium* species in the entire Mobile Basin, including the Conasauga River and its tributaries in Bradley and Polk counties, Tennessee, where it is common. An additional population, possibly the result of an inadvertent introduction, occurs in Baker Creek, tributary to Parksville Reservoir, Ocoee River system, Polk County (Hitch and Etnier, 1974).

Plate 114. *Hypentelium etowanum*, Alabama hogsucker, 66 mm SL, Tallapoosa R. system, GA.



Range Map 113. *Hypentelium etowanum*, Alabama hogsucker.

Similar Sympatric Species: See comments under *H. nigricans*.

Etymology: *etowanum* refers to the type locality, the Etowah River.

Hypentelium nigricans (Lesueur)

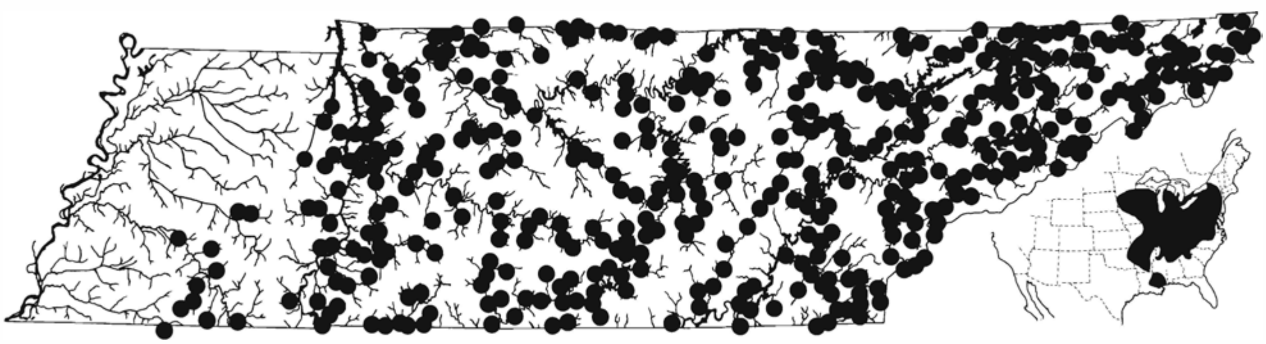
Northern hogsucker

Plate 115. *Hypentelium nigricans*, northern hogsucker, 103 mm SL, Sulphur Fork R., TN.

Characters: Lateral-line scales 42–55 (42–48 in Tennessee). Dorsal fin rays 11 (10–12). Pectoral fin rays 15–18. Gill rakers 21–26. Vertebrae 42–46. Color similar to *H. etowanum* except pale horizontal streaks on dorsum tend to be absent. Nuptial tubercles are as described for *H. etowanum*, with the following possible differences noted in Tennessee specimens. In *H. nigricans* pelvic fin tubercles are considerably larger than those on the pectoral fins, and head tubercles extend over the entire snout and onto the branchiostegal area.

Biology: The northern hogsucker is a very common species that reaches maximum abundance in or adjacent to riffle areas in warmwater, moderate sized creeks and small rivers. It is also tolerant of coldwater streams, occurs in tiny creeks and large rivers, and extremely large specimens are occasionally taken in reservoirs. Biological information has been summarized from Raney and Lachner (1946) and Scott and Crossman (1973). Spawning occurs over shallow gravel areas in early spring when water temperatures reach 15 C (59 F). Males congregate over these areas, and receptive females are typically courted by several males. Although an actual nest is not constructed, the violent spawning activity clears sediment from the area and may result in the formation of shallow depressions in the gravel. Eggs are non-adhesive and settle on the substrate. Early development was described in detail for specimens up to about 30 mm TL by Buynak and Mohr (1978a). Hogsuckers reach total lengths of about 90, 165, 245, 300, and 330 mm by the ends of their first through fifth growing seasons, respectively. Males reach sexual maturity during their second season, and females during their third. Extremely large specimens are typically females, and life span is about 11 years. In small streams growth is slower and sexual maturity may occur at lengths of 100 mm. Food consists primarily of immature stages of benthic insects and snails. Feeding is accomplished by turning over small stones with the protrusible mouth and ingesting exposed and dislodged organisms. Other stream fishes often follow feeding hogsuckers, opportunistically utilizing this food source. Maximum size (Trautman, 1981) 570 mm (22.5 in) total length and 1.93 kg (4.25 lb).

Distribution and Status: A wide-ranging upland species of the Mississippi, eastern Great Lakes, and middle Atlantic drainages. Disjunct southern populations occur on the Coastal Plain in the relatively higher gradient streams of southern Mississippi and eastern Louisiana. *Hypentelium nigricans* is the only hogsucker in most of Tennessee, and it occurs statewide except for the Obion River system of northwest Tennessee; it is rare in other Coastal Plain systems. It occurs rarely with the Alabama hogsucker in the Conasauga River (Stiles and Etnier, 1971), and the two species may co-occur in portions of the Ocoee River system.



Range Map 114. *Hypentelium nigricans*, northern hogsucker.

Similar Sympatric Species: Very similar to *H. etowanum* (see key), but specimens of both species agree with fin ray and scale counts used in the key with about 90% conformity. We have counted many specimens from areas where only one of the two species occurs, and have not encountered individuals that have counts of both dorsal fin rays and scales above lateral line of the "wrong" species. In areas of sympatry, specimens not identifiable as either species based on counts will be very difficult to separate. Various authors have suggested that the interorbital area is more concave and the lateral striping is less pronounced in *H. nigricans*. These characters are useful, but certainly not diagnostic. The northern hogsucker attains much greater size, and hogsucker specimens exceeding 250 mm total length would probably be this species.

Etymology: *nigricans* = blackish.

Genus *Ictiobus* Rafinesque
The Buffalofishes

The genus *Ictiobus*, the buffalofishes, consists of three species, all of which occur in Tennessee. They constitute, with the carpsuckers, the catostomid subfamily Ictiobinae. These are the largest and commercially most valuable of the suckers. The flesh is extremely firm and of good flavor. They are quite successful in reservoirs, medium to large rivers, and some natural lakes. Hybrid combinations of *Ictiobus* species have been evaluated for fish-farming (Jhingran and Gopalakrishnan, 1974). All are grayish, deep-bodied fishes with 32–41 lateral-line scales, 23–32 dorsal fin rays, 7–11 anal fin rays (rarely 7 except in *I. cyprinellus*), 15–19 pectoral fin rays, and 9–11 pelvic fin rays. These counts are of little use in differentiating between the three species. Gill raker counts are extremely helpful in separating *I. cyprinellus* from the other two species, even though the counts increase gradually with size in all three species. The entire arch must be removed to allow accurate counts. All dorsal rudiments are included in counts used in the Key, but completely or partially fused pad-like ventral elements were not counted. Buffalofish are occasionally confused with carp, from which they differ in lacking barbels and serrated anterior spines in dorsal and anal fins. The two buffalofish with subterminal mouths (*I. bubalus* and *I. niger*) are very similar to the river carpsucker (*Carpiodes carpio*) in appearance and dorsal fin shape. In addition to differences in shape of the suboperculum (Fig. 91) and anal fin ray counts (8 or more in these two *Ictiobus*, usually 7 in *Carpiodes carpio*), gill raker counts can be used to separate these two taxa, with the two *Ictiobus* having 30 or fewer in juveniles and 40 or fewer in large adults (*C. carpio* has 40–55 gill rakers in specimens 100 mm SL or less, and 60 or more in adults). Colorful common names employed in the commercial fishing industry include gourdhead for the bigmouth, razorback for the smallmouth, and rooter, blue rooter, or mongrel buffalo for the black buffalo.

Etymology: *Ictiobus* = bull fish.

KEY TO THE SPECIES

1. Mouth terminal and oblique (except in specimens less than 100 mm SL), with tip of upper lip above lower orbital rim; gill rakers 40 or more (juveniles) to about 60 (adults) .... *I. cyprinellus* p.278
   Mouth inferior and horizontal, with tip of upper lip below lower orbital rim; gill rakers 35 or fewer 2
2. Eye diameter greater than distance from fleshy posterior tip of maxilla to fleshy anterior tip of lower jaw (may not be true in extremely large fish); body deep and compressed, body depth, even in juveniles, usually less than 2.7 times in standard length; back sharply ridged anterior to dorsal fin .... *Ictiobus bubalus*
   Eye diameter equal to or less than distance from fleshy posterior tip of maxilla to fleshy anterior tip of lower jaw in adults; body depth usually more than 2.9 times in standard length; back rounded anterior to dorsal fin .... *Ictiobus niger* p.279

Ictiobus bubalus (Rafinesque)

Smallmouth buffalo

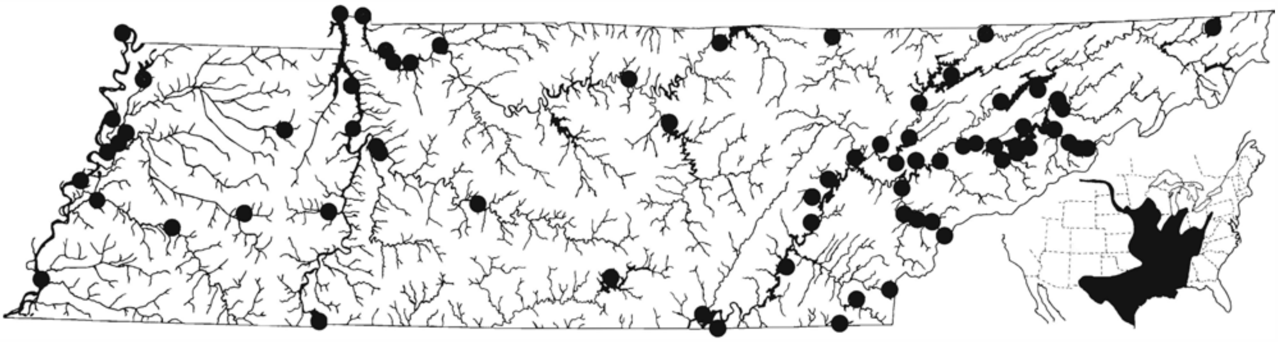
Plate 116. *Ictiobus bubalus*, smallmouth buffalo, 190 mm SL, Running Reelfoot Bayou, TN.

Characters: See generic account and Key for general characters. Branson (1961) noted the presence of many small nuptial tubercles on top of the head from just behind the eyes anteriad. Color dusky dorsally, light gray on sides. Fins dusky.

Biology: The smallmouth buffalo, also called "razorback" because of its elevated, compressed dorsum, is reported to be less tolerant of turbidity than the bigmouth, and more inclined to occupy swift waters than either of its congeners. Jester (1973) indicated that, where the three species co-occur, the smallmouth and black buffalo prefer deeper water than the bigmouth buffalo, and that the smallmouth is more apt to occur over fine substrates. Food consists mostly of benthic invertebrates, entomostraca, and some vegetation. Wrenn (1969) found the introduced Asiatic clam (*Corbicula manilensis*) to be the dominant food in Wheeler Reservoir, Alabama, as did Minckley et al. (1970) in an introduced Arizona population. In other populations studied, zooplankton (copepods and cladocerans) were most important in both juvenile and adult diets (McComish, 1967). Spawning season in the Tennessee area (Wrenn, 1969) is in early to mid spring at water temperatures of 15–16 C (59–62 F). Jester (1973) reported ripe males during all months in New Mexico, with spawning from May through September, peaking during July at water temperatures of 22–26 C (72–79 F). Upstream migration of presumably spawning specimens were often noted, prior to impoundment of Tellico Reservoir, in the clear waters of the lower Little Tennessee River during late April and early May, and probably represented migrants from Watts Bar Reservoir. Spawning may occur in water depths from 1 to 6 m over virtually any substrate, but a possible preference for submerged vegetation has been noted. Spawning is random, eggs are adhesive, and from 18,000–500,000 eggs are laid per female per year. Larval development was described in detail by Wrenn and Grinstead (1971). Sexual maturity occurs at lengths of about 25–35 cm, with males maturing at slightly smaller sizes than females. Depending upon habitat and growing conditions, adulthood is reached from the second through the sixth year of life. Life span is about 15–20 years. Schoffman (1944) reported average growth as follows in a Reelfoot Lake population: age 1 (12 cm SL), 2 (27), 3 (33), 8 (50), 10 (65), and 13 (70); the largest specimen was 75 cm SL (29.5 in) and weighed 13 kg (28.5 lbs). Maximum size variously reported to be 14–18 kg (30–40 lbs). Record sizes for the smallmouth and black buffaloes are difficult to interpret because of identification problems between the two species and even possible confusion with the largemouth buffalo. Pflieger (1975) considered the black buffalo to be the larger of the two species. Specimens appearing to be 25–30 lbs are not uncommon in the Mississippi River, but verified lengths and weights of these large specimens are not available.

Distribution and Status: Widespread in larger rivers of the Mississippi Basin and Gulf Coastal drainages from the Mobile to the Rio Grande. Common in Tennessee in the Mississippi River and throughout the larger rivers of the Tennessee and Cumberland drainages, and the dominant buffalo in the Tennessee drainage above the Chattanooga area. It is also present in the Conasauga River.

Similar Sympatric Species: Very difficult to separate from the black buffalo, especially at lengths less than 300 mm. The following ratios of measurements used by



Range Map 115. *Ictiobus bubalus*, smallmouth buffalo.

various authors may be useful (*bubalus* listed first): eye diameter in head length 4.4–5.9 vs. 5.1–7.4; eye diameter in snout length 1.5–2 vs. 2–2.5; maximum head width in standard length 5.2–6.1 vs. 4.7–5.5; maximum body depth in standard length 2.4–2.8 vs. 2.9–3.4.

Etymology: *bubalus* = buffalo.

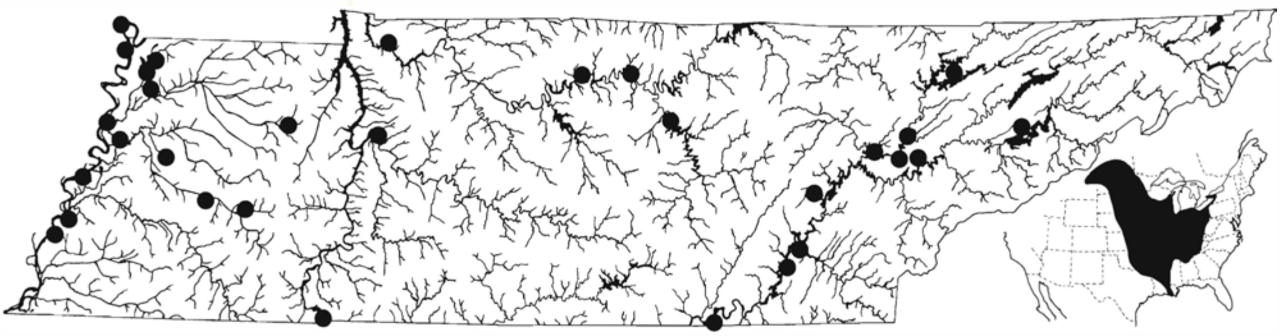
Ictiobus cyprinellus (Valenciennes)

Bigmouth buffalo

Characters: See generic account and Key. Mouth terminal and oblique, not adapted for bottom sucking as in other *Ictiobus*. Vertebrae 36–37. Nuptial tubercles (Morris and Burr, 1982) from Illinois males collected on 1 May were most prominent on caudal peduncle scales, where they formed a marginal row of 6–12 per scale with occasional slightly larger tubercles near the base of the scales. The head and nape were covered with tiny tubercles, and all fins had 1 to 4 rows of tubercles per fin ray, with pectoral and pelvic fin tubercles mostly confined to the upper surfaces, and dorsal fin tubercles restricted to the anterior rays. Color as in *I. bubalus*. Ventral fins may be nearly black.

Biology: The bigmouth buffalo, sometimes called "gourdhead," is more commonly encountered in quiet, shallow waters than its congeners, and is occasionally seen basking just under the surface in calm, sunny weather. It also appears to be more tolerant of turbidity than the other buffaloes. The following information is summarized from papers by Schoffman (1943), Johnson (1963), McComish (1967), Minckley et al. (1970), Starostka and Applegate (1970), and Burr and Heidinger (1983). Bigmouth buffalo apparently feed just above the bottom. Food is primarily cladocera and cyclopoid copepods supplemented with midge larvae; considerable amounts of algae and diatoms are also ingested. The extremely slender and numerous gill rakers are well adapted to this type of feeding. Spawning movements are often in response to spring floodwaters and occur at water temperatures of 15.5–18 C (60–65 F), usually in

Plate 117. *Ictiobus cyprinellus*, largemouth buffalo, juvenile, 203 mm SL, Running Reelfoot Bayou, TN.



Range Map 116. *Ictiobus cyprinellus*, bigmouth buffalo.

April and May. Adults often enter flooded fields where they become vulnerable to spearing. Spawning "rushes" are made in shallow water just under the surface with backs exposed, often by one female with a male on each side. The spawners then sink to the bottom, often in a head-down attitude with tails exposed, thrashing side to side. Eggs are scattered on underwater debris and vegetation. Fecundity of 6.5 kg specimens is about 750,000 eggs per female. Young reach lengths of 50–140 mm during their first summer. Average total lengths in excess of 300 mm are reached at age 3, 370 mm at age 5, and 550 mm or more at age 8. Sexual maturity occurs at lengths of 330–380 mm, with males maturing at somewhat smaller sizes than females. Life span is presumably similar to that of the smallmouth buffalo. This is the largest of the buffaloes. The recognized world angling record of 70 lbs 5 oz was taken in Louisiana. Harlan and Speaker (1969) reported specimens up to 36 kg (80 lbs).

Distribution and Status: Restricted to the Mississippi Basin, southern Great Lakes, and the Hudson Bay drainage. In Tennessee, *I. cyprinellus* is abundant in the Mississippi River but less common in the Tennessee and Cumberland rivers, perhaps due to loss of reproductive habitat resulting from flood control.

Similar Sympatric Species: Although adult bigmouths are readily separated from other buffaloes on the basis of their terminal and oblique mouths, small specimens may be difficult to identify. Counts of gill rakers on the first arch (see key) should offer positive identification of juveniles.

Etymology: *cyprinellus* is a diminutive of *cyprinus*, or carp.

Ictiobus niger (Rafinesque)

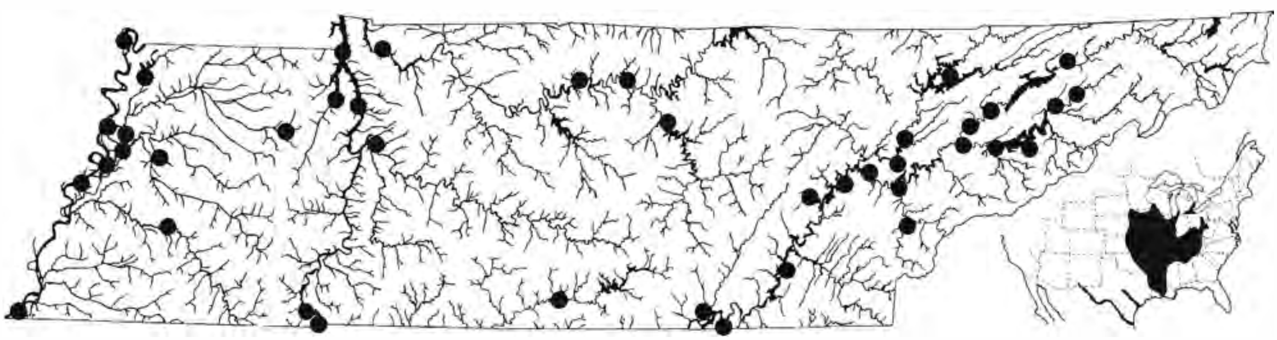
Black buffalo

Characters: See generic account and Key. Shape and mouth position rather intermediate between *bubalus* and *cyprinellus*. Because of this, commercial fishermen considered it to be a hybrid between these two species, and often referred to it as mongrel buffalo. Color as in *I. bubalus*.

Biology: Although a reasonably common species throughout most of its range, the black buffalo has received little biological study. Its biology is likely quite similar to that of the smallmouth buffalo. Minckley et al. (1970) reported a much more benthic-oriented diet for this species than for the bigmouth buffalo as might be postulated from its more ventrally positioned mouth. They reported the introduced Asiatic clam (*Corbicula*) as the principal food item with small amounts of algae, diatoms, and crustaceans also consumed. Presumably, native mollusk species are also utilized. Maximum size uncertain due to identification difficulties, but probably 20–30 lb or larger. The Tennessee Wildlife Resources Agency accepts as valid an 80-lb specimen from Robco Lake, Shelby County, 1 April 1980, taken by Hiluard J. DeLoach. The photograph of this fish published in the Memphis Press-Scimitar, 2 April 1980, is certainly more suggestive of a black buffalo than of either of the other two species.

Distribution and Status: Mississippi Basin and southern Great Lakes, and very rarely in coastal drainages west to Rio Grande (possible introductions or misidentifications). Throughout its range it appears to be less common than the other *Ictiobus* species.

Plate 118. *Ictiobus niger*, black buffalo; 250 mm SL, Running Reelfoot Bayou, TN.



Range Map 117. *Ictiobus niger*, black buffalo.

Similar Sympatric Species: See smallmouth buffalo account.

Etymology: *niger* = black.

Genus *Lagochila* Jordan and Brayton

The single species, the harelip sucker, has not been collected since 1893 and is presumed extinct. Very similar to the redhorses (*Moxostoma*) and included in the tribe *Moxostomatini* (Jenkins, 1970).

Lagochila lacera Jordan and Brayton

Harelip sucker

Characters: Lateral line complete with 42–46 scales, predorsal scale rows 15–18, caudal peduncle scale rows 12. Dorsal fin rays 12 (11–12). Anal fin rays 7. Pectoral fin rays 15–17. Pelvic fin rays 9. Breast scaled. Vertebrae 41–45. (Data from Jenkins, 1970.) Upper lip nonprotractile; lower lip cleft back to dentary on midline, leaving a separate lobe on each side of cleft (Fig. 95). Life colors (Jordan and Brayton, 1877) olivaceus to dark bluish brown above, paler on sides and belly, and with lower fins faintly orange.

Biology: Jenkins (1970) presented a summary of available information concerning this fascinating species. All collections of harelip suckers were made in rivers 10–30 m wide, typically in still water or gently flowing

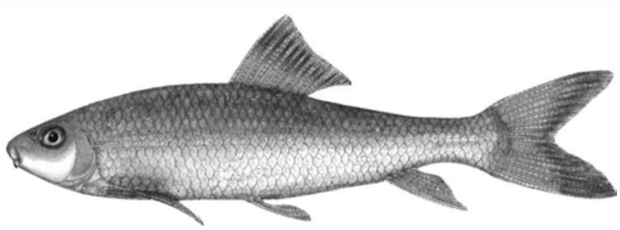


Plate 119. *Lagochila lacera*, harelip sucker, illustration based on small adults, U.S. National Museum nos. 36331 (131 mm SL) and 68853 (135 mm SL) (by W. Starnes); see also Fig. 95.

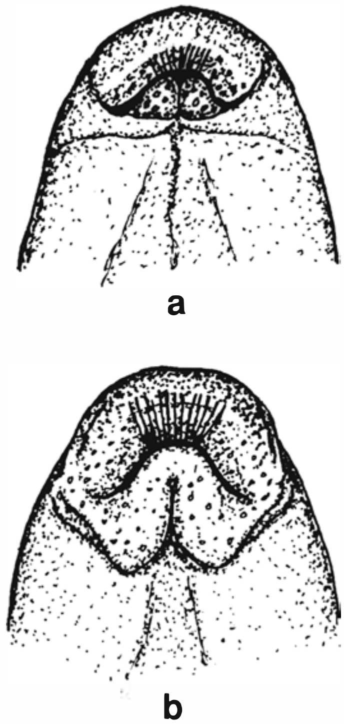
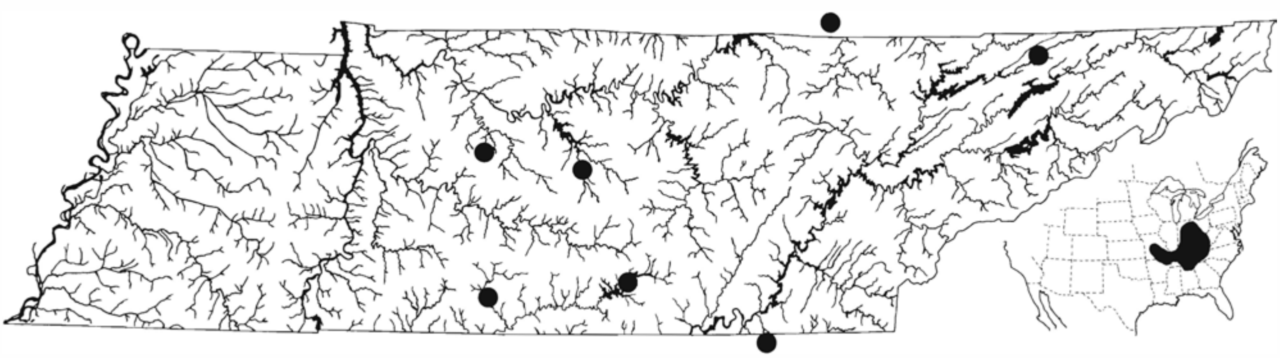


Figure 95. Lips of *Lagochila*: a) from a small adult (123 mm SL, U.S. National Museum 70609); b) from a juvenile (65 mm SL, USNM 31129, the holotype).

pools. Since most specimens are juveniles, and the only available adults were taken from the larger rivers represented, it seems likely that adults normally occurred in waters larger than those usually collected by early ichthyologists. May spawning migrations were well known to local fishermen, who often referred to *Lagochila* as the May sucker. It was a valued food fish in the 1870s (Jordan and Brayton, 1877). The diet was primarily snails, which passed through the alimentary tract uncrushed. The pharyngeal arches are much too delicate to function in crushing snails. Its apparent extinction remains a mystery. Dr. Jenkins cited anatomical evidence suggesting it to be a sight feeder and surmised that increasing turbidity inhibited their ability to find snails. Although many clear streams of the dimensions inhabited by *Lagochila* remain within its former range, adults may have been dependent on larger rivers where the effects of turbidity would have been most severe. Although reported to reach sizes of up to 460 mm (18 in) total length, the largest extant specimen is 313 mm SL, or about 390 mm TL (Jenkins, 1970).

Distribution and Status: *Lagochila* was collected at about 20 localities between 1859 and 1893, and occurred widely in the Ohio River basin (including the Tennessee and Cumberland river drainages), in the White River drainage of Arkansas and Missouri, and in the Maumee River system (Lake Erie drainage) of Ohio. Jordan and Brayton (1877) stated that fishermen in the southern bend of the Tennessee River region indicated that it was the most common of suckers in area streams. Bones of this sucker are common in Indian middens or caves near the Duck (Dickinson, 1986), Little Tennessee (Bogan and Bogan, 1985), and South Fork Holston rivers (Manzano, 1986). There is no indication that anyone was aware of the disappearance of *Lagochila*. There was little ichthyological activity in central North America between about 1896 (the end of the Jordan era) and 1931 when Carl Hubbs and his students reawakened interest in North American freshwater fishes. Collette (1967) referred to this era as the "doldrums." *Lagochila* went into the doldrums as a widespread, fairly well-known, and not uncommon species. Jenkins pointed out that it was not collected as frequently as the small-stream redhorses *Moxostoma erythrurum* and *M. duquesnii,* but it was taken slightly more often than the big-river species *M. carinatum* and *M. macrolepidotum*. *Lagochila* had disappeared by the end of the doldrums, and how long it persisted into the twentieth century is conjectural. The dam-building era did not begin in earnest until about 1935, and although



Range Map 118. *Lagochila lacera*, harelip sucker.

impoundments of most of our big rivers may have dealt the final blow, *Lagochila* may have already disappeared or virtually disappeared by this time.

Similar Sympatric Species: Similar to redhorses in body form, and probably colored much like the black and golden redhorses, but the structure of the lower jaw is unlike that of any central North American fish.

Systematics: Jenkins (1970) hypothesized closest relatives of *Lagochila* to be members of the subgenus *Moxostoma* of *Moxostoma*. If this is the case, then continued recognition of *Lagochila* at the generic level creates a paraphyletic (and thus unnatural) grouping for the genus *Moxostoma*.

Etymology: *Lago* = hare, *chila* = lip, *lacera* = form.

Genus *Minytrema* Jordan

A single species in the genus. Although similar in appearance to redhorses (*Moxostoma*), closest relatives of *Minytrema* are considered to be the chubsuckers, genus *Erimyzon* (Nelson, 1948; Miller, 1959), with which it constitutes the tribe Erimyzontini of subfamily Catostominae (Jenkins, 1970).

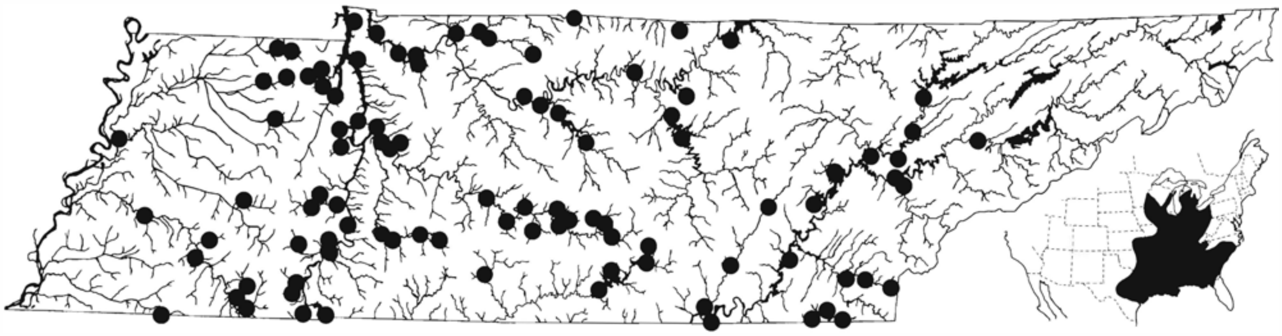
Minytrema melanops (Rafinesque)

Spotted sucker

Characters: Scales in lateral series 42–47; lateral line absent in juveniles and increasing in degree of completion with size, often complete or nearly so in large adults. Dorsal fin rays 11–13 (10–13). Anal fin rays 7. Pectoral fin rays 16–18. Pelvic fin rays 9–10. Gill rakers 20–26 plus 5–6 ventral rudiments. Vertebrae 43–44. Life coloration olivaceus above, paler below, and sides marked with a series of dark horizontal lines formed by dark spots at scale bases. Juveniles with dark posterior margin on dorsal fin. Nuptial males with dark midlateral stripe, above which is a grayish pink streak, and above that another dark area with lavender highlights. Males have large nuptial tubercles on anterior portion of snout and between eyes and mouth, smaller tubercles above and behind eye, on lateral areas of gular region, and on cheeks. Anal fin and both lobes of caudal fin with tubercles, and small tubercles occasionally on other fins and on dorsolateral scales.

Biology: The spotted sucker is a species of low-gradient streams, rivers, and backwater areas. It is typically found in pool areas, but is more associated with at least moderate current than are the chubsuckers. Spawning behavior in Georgia has been reported by McSwain and Gennings (1972). Both sexes began spawning movements by late January, with gravid females appearing from 11 March through 4 May at water temperatures from 12.2 to 19.4 C (54–67 F). Loose territories were maintained over a shallow gravel shoal area with currents of .24 m/sec by three to seven adult males. Males chased conspecific males that came too near. When a female entered the spawning area, it was immediately courted by the nearest males, who prodded her with their snouts and repeatedly swam back and forth over her. Spawning occurred with a female flanked by a male on each side, the trio oriented upstream. The males began a 2–6 sec. vibration of their caudal peduncles, and the thrust pushed the spawners off the substrate with their tails angled down. Eggs were released

Plate 120. *Minytrema melanops*, spotted sucker, 210 mm SL, lower Tennessee R. system, TN.



Range Map 119. *Minytrema melanops*, spotted sucker.

near the end of this upward movement, and the spawners often broke the water surface after disengaging. Spawning did not appear to be successful when a single male or more than two males courted a female. Females presumably spawn repeatedly. Various aspects of early development were described in detail by Hogue and Buchanan (1977) and White (1977). In Oklahoma, spotted suckers reached total lengths of 155, 287, 338, 410, and 440 mm by the ends of their first through fifth growing seasons, and were sexually mature at 3 years (Pflieger, 1975). White and Haag (1977) examined the feeding habits of Kentucky populations. Young smaller than 50 mm were midwater planktivores. At larger sizes they fed on the bottom, with smaller specimens feeding during midday, and adults feeding mostly at dawn and dusk. Stomachs contained large amounts of particulate organic detritus, copepods, cladocerans, midge larvae, and diatoms, in addition to large amounts of sand. Maximum size (Trautman, 1957) 450 mm (18 in) total length and about 3 lbs.

Distribution and Status: Widespread in the Mississippi Basin and coastal drainages from North Carolina to Texas, and in some Great Lakes tributaries. In southern states the spotted sucker is much more common on the Coastal Plain. In Tennessee it also occurs uncommonly in the Highland Rim and Ridge and Valley portions of the Tennessee River drainage upstream to the Knoxville area, in the Barren and Conasauga river systems, and in the Cumberland River drainage. It appears to be decreasing in abundance in parts of its range, perhaps due to increased turbidity (Smith, 1979).

Similar Sympatric Species: Very similar to redhorses in shape. The only Tennessee redhorse with a pattern of many dark horizontal lines is *Moxostoma atripinne*, which has a distinct black blotch at the anterior edge of the dorsal fin. Juvenile spotted suckers have a dark posterior border on the dorsal fin that is lacking or very vague in other redhorses and have the horizontal lines on the body indistinct.

Etymology: *Minytrema* = reduced aperture, referring to the reduced lateral line; *melanops* = black appearance.

Genus *Moxostoma* Rafinesque
The Redhorses

The redhorses of the genus *Moxostoma* constitute the most speciose genus of suckers in eastern and central North America. Nineteen of the 20 recognized species occur in that area, while an additional species (*M. austrinum*) occurs in Pacific slope streams of northern Mexico. Together with the hogsuckers (*Hypentelium*) and harelip sucker (*Lagochila*), they comprise the tribe Moxostomatini of the subfamily Catostominae (Jenkins, 1970). Data presented in this introduction and the species accounts are taken from Jenkins's work unless otherwise indicated. Earlier work on the systematics of *Moxostoma* was conducted by Robins and Raney (1956). Four subgenera are recognized, with six of seven Tennessee species members of the subgenus *Moxostoma*. The two additional members of this subgenus are *M. papillosum* of Atlantic Coast drainages, and an undescribed relative of *M. poecilurum* from the Apalachicola drainage. The subgenus *Megapharynx* Legendre includes two species, *M. hubbsi* of the St. Lawrence drainage and the more widely distributed northern species, *M. valenciennesi*. The seventh Tennessee species, *M. atripinne*, is tentatively a member of the subgenus *Thoburnia* Jordan and Snyder, which includes two other species of small streams in the James and Roanoke drainages, *M. hamiltoni* and *M. rhoth-*

oecum. The fourth subgenus, *Scartomyzon* Fowler, includes the remaining species, all of which are small and typically occur in small to medium streams of the Atlantic and Gulf coastal drainages into Mexico. Buth (1978) studied biochemical systematics of *Moxostoma*, with results, for the most part, concordant with those of Jenkins's (1970) morphological studies.

Redhorses have complete lateral lines with 38–48 scales in Tennessee species, 7 anal fin rays, 11–17 dorsal fin rays, and 15–19 pectoral fin rays. There is a considerable range of morphology in pharyngeal arches (see Eastman, 1977). Redhorses derive their name from the orange or red colors on the fins of most species. Habitats range from sluggish areas of big rivers to swift-water areas of small creeks. They are most typical of clear, small to medium rivers, many of which contain all five of our widespread species. Redhorses are spring spawners, and most migrate upstream into shallow gravel shoals during the spawning season. During these runs they become vulnerable to trapping and spearing. All the larger species are excellent food fishes, and their firm, white, delicately flavored flesh certainly compares favorably with the best of our game and pan fishes. The presence of numerous intermuscular bones in the back muscles has discouraged their popularity as food fishes. These small bones can be avoided by pressure cooking, breaking up the softened bones and flesh with a meat grinder, and making fish patties. They are less of a problem in large fish. Redhorses were heavily used by Indians, and their bones are commonly present in archaeological excavations. Adult redhorses are not easy to capture with a seine, and most species do not readily take a baited hook, though anglers occasionally take at least river and silver redhorses from shoal areas on hooks baited with worms or the soft parts of freshwater mussels. Because of their active habits, they are easily captured in gill, trammel, and hoop nets. Most redhorses feed on aquatic insect larvae. All Tennessee species except *M. atripinne* have some tolerance for reservoirs, but successful reproduction is dependent on gravel shoal areas in tributaries.

Minytrema melanops and *Catostomus commersonnii* are similar to redhorses in general appearance. The former typically has an incomplete lateral line, but its pattern of dark horizontal lines could cause confusion with *M. atripinne* and *M. poecilurum* (refer to species accounts for differences between these three species). *Catostomus* differs in having tiny, crowded predorsal scales and in having completely papillose lips (plicate or plicate-papillose in *Moxostoma*, see Figs. 96a–c). Redhorses can be very difficult to identify, and immature specimens are a challenge for even the most competent ichthyologist. Field notes concerning the color of the caudal and dorsal fins in freshly caught specimens are extremely useful in differentiating between the five species commonly encountered in Tennessee waters.

Etymology: *Moxo* = to suck, *stoma* = mouth.

KEY TO THE TENNESSEE SPECIES

1. Sides marked with about 7 horizontal black lines; distal 1/3 of anterior half of dorsal fin black (Pl. 122); confined to the Barren River system of Clay, Macon, and Sumner counties ..... *M. atripinne* p.287
   Sides and dorsal fin lacking these markings 2
2. Caudal fin with lower lobe distinctly bicolored (Pl. 127), with a white lower margin above which the rays and membranes are black; Conasauga River and Mississippi River tributaries in west Tennessee ..... *M. poecilurum* p.294
   Caudal fin with lower lobe not bicolored, widespread 3
3. Halves of lower lip meet at an acute angle, lower lips with plicae broken into papillae (Fig. 96a); dorsal fin rays usually 14 or more ..... *M. anisurum* p.285
   Halves of lower lip meet at an obtuse angle, lips plicate (Fig. 96b,c); dorsal fin rays usually 13 or fewer ... 4
4. Margin of dorsal fin very concave (Pl. 126); head length less than 22% of standard length; total pelvic fin rays 19–20; halves of lower lip meet to form a relatively straight line (Fig. 96b) ..... *M. macrolepidotum breviceps* p.292
   Margin of dorsal fin straight or slightly concave; head length more than 24% of standard length in specimens over 150 mm; caudal fin yellow to dirty orange in life except in *M. carinatum*; total pelvic fin rays usually 18; halves of lower lip meet to form a shallow V (Fig. 96c) 5

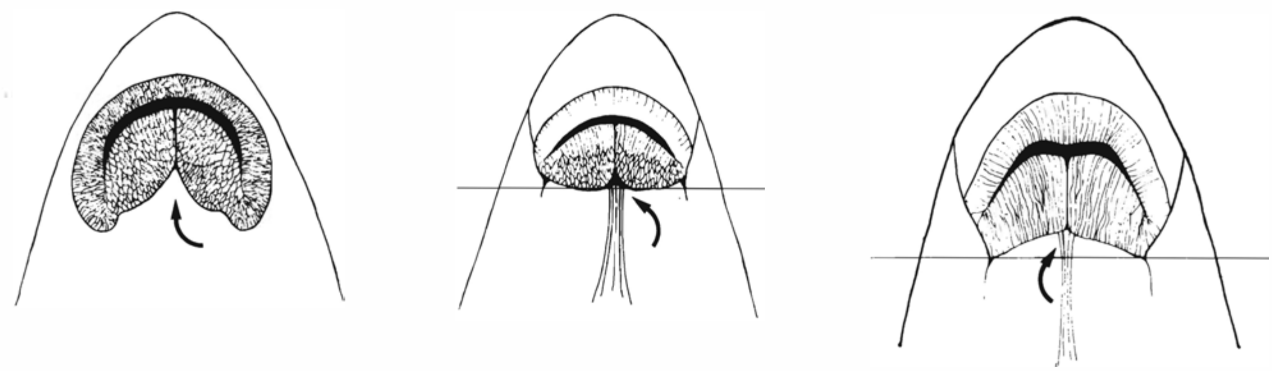


Figure 96. Lips of redhorse suckers: a) *Moxostoma anisurum*; b) *M. macrolepidotum*; c) *M. erythrurum*.

5. Pharyngeal teeth molariform (Fig. 97); caudal and dorsal fins bright red in life .... *M. carinatum* p.288

Figure 97. Molariform pharyngeal teeth of *Moxostoma carinatum*.

Pharyngeal teeth comb-like and compressed (Fig. 20b); caudal and dorsal fins not bright red in life except in occasional young 6

6. Lateral-line scales 38–84 (37–44); breast scales of adults well exposed and not abruptly smaller than adjacent belly scales .... *M. erythrurum* p.291

Lateral-line scales 44–47 (43–49); breast scales of adults partially embedded and abruptly smaller than adjacent belly scales .... *M. duquesnii* p.290

Moxostoma anisurum (Rafinesque)

Silver redhorse

Characters: Lateral-line scales 39–43 (38–48), caudal peduncle scale rows 12 (12–14), predorsal scale rows 12–17 (12–18). Dorsal fin rays 14–15 (13–17). Pectoral fin rays 16–19. Total pelvic fin rays 18 (16–20). Gill rakers 19–32 (24–32 in adults). Vertebrae 40–43. Life colors silvery, with lower fins often orange; a brassy sheen may develop on sides of nuptial specimens. Nuptial tubercles of males are largest on the anal fin and lower lobe of the caudal fin. Smaller tubercles occur on upper lobe of caudal fin and on anterior rays (occasionally all rays) of other fins. Nape scales covered with tiny tubercles, other body scales with marginal row of tiny tubercles that are best developed on lower half of caudal peduncle.

Biology: The silver redhorse is more characteristic of still waters and pool areas with soft substrates than other redhorses, and it typically inhabits only large rivers except during the spawning season. Hackney et al. (1971) studied the biology of the silver redhorse in Flint River, a tributary to Wheeler Reservoir, Tennessee River, Alabama. Only sexually mature individuals were taken in the river (age 5 and older), with younger age classes oc-

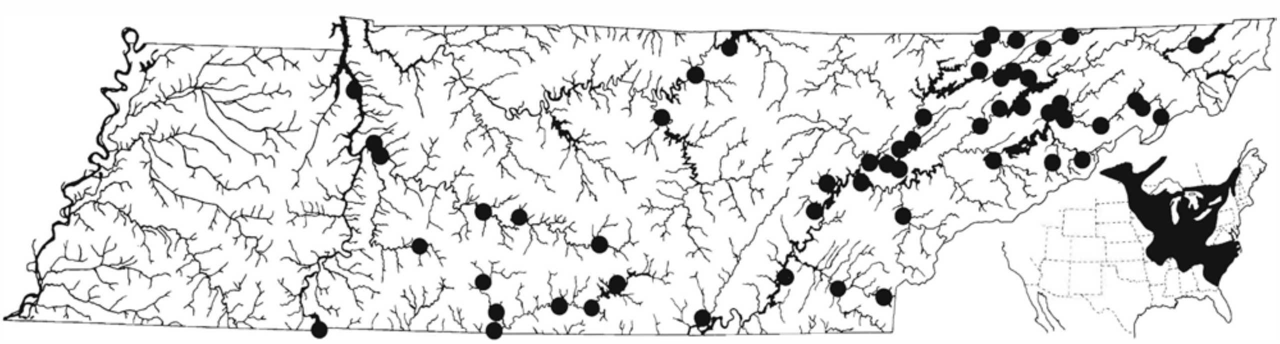
Plate 121. *Moxostoma anisurum*, silver redhorse, 495 mm SL, Nolichucky R., TN.

curring in Wheeler Reservoir. Spawning in Flint River occurred in late March and early April at water temperatures of 14–15 C (56–58 F). Spawning was random over gravel shoal areas, where males outnumbered females about four to one. Fecundity of females in an Iowa population was about 15,000–36,000 eggs for females 338–490 mm TL (Meyer, 1962). Larvae were described by Fish (1932). Average growth reported in the Iowa and Alabama studies for the first 8 years of life was (Iowa specimens listed first): 108 and 171 mm TL, 168 and 296, 302 and 381, 349 and 451, 391 and 511, 452 and 546, 496 and 575, and 514 and 626. Sexual maturity was not reached until the fifth or sixth year at total lengths of 507 mm (males) and 548 mm (females) in the Flint River study. Food (Meyer, 1962) consisted of immature midges, mayflies, and caddisflies. Hackney et al. (in litt.) reported a significant fishery for silver redhorse in Flint River. Just prior to spawning, adults were taken by angling, using worms as bait. When the fish moved onto the spawning shoals, they were taken by snagging with one or more treble hooks jerked through the water. This sucker is an excellent food fish. Maximum size (Trautman, 1957) 635 mm (25 in) TL and 3.75 kg (8.25 lb), but reported up to 4.5 kg by commercial fishermen.

Distribution and Status: Upland portions of Mississippi Basin, tributaries to the Great Lakes and Hudson Bay, and southeastern Atlantic Coastal drainages. In Tennessee, the silver redhorse probably occurs in all regions except the Coastal Plain. We collect it less frequently than the other four Tennessee and Cumberland drainage redhorses, but its apparent scarcity is probably due, at least in part, to its preference for waters too deep to collect effectively with seines.

Similar Sympatric Species: Because of its large head, mouth shape, deep body, and long dorsal fin, this is one of our most distinctive redhorses. Even juveniles have the halves of the lower lip meeting to form an acute angle.

Systematics: Jenkins (1970) reduced to only racial status Atlantic Coastal populations of *M. anisurum* which had formerly been recognized as a distinct species, *M. collapsum* (Cope).



Range Map 120. *Moxostoma anisurum*, silver redhorse (range extends off inset northwest to central Manitoba and Saskatchewan and southeastern Alberta).

Etymology: *aniso* = unequal, *urum* = tail, referring to the asymmetry of the caudal fin lobes of this and most other species of the genus.

Moxostoma atripinne Bailey

Blackfin sucker

Characters: Lateral-line scales 46–50, caudal peduncle scale rows 16, predorsal scale rows 16–20. Dorsal fin rays 10. Pectoral fin rays 15 (14–16). Pelvic fin rays 9 (8–9). Gill rakers 16–20 (including ventral rudiments) in specimens over 80 mm SL. Breast scales deeply embedded. Vertebrae 43–45. Body with two dark horizontal lines below lateral line and six or seven additional dark lines in dorsolateral area. Dorsal fin with black blotch on distal half of anterior 5 or 6 rays. Nuptial tubercles (Bailey, 1959a) of males are largest on rays of the anal fin and lower lobe of the caudal fin, small to tiny on upper caudal fin lobe, dorsal surfaces of paired fins, ventral surface of pectoral fins, entire head, and body scales (best developed on lower caudal peduncle where they form a marginal row on each scale).

Biology: Within its very restricted range the blackfin sucker typically occurs in quiet or gently flowing pools with scattered slabrocks and undercut banks in larger creeks; juveniles are occasionally encountered in smaller tributaries. Concentrations of adults have been noted under large slab-rocks, especially during colder months, by both R. W. Bouchard and B. H. Bauer (pers. comm.). Bailey (1959a) found gravid specimens from 6 to 10 April at water temperatures of 54–65 F (12–18 C), and collected a probable spawning aggregation of seven nuptial adults in a riffle area about 8 cm deep. Timmons et al. (1983) found nuptial males aggregated over riffles on 19–20 March at water temperature 12 C, but females did not have free flowing eggs at that time; females produce from 1,000 to nearly 2,000 eggs per year. Juveniles reach about 55–70 mm SL at the end of their first year, 80–102 mm SL at age 2, about 120 mm SL at age 3, and nearly 140 mm SL at age 4 (Bailey, 1959a; Timmons et al., 1983), with females sexually mature at age 3, and males sexually mature at age 2 or occasionally at the end of their first year. Timmons et al. found the diet to consist primarily of midge larvae for all age groups, supplemented with microcrustacea and occasional larger insect larvae. Maximum total length 155 mm (6.1 in).

Distribution and Status: Endemic to headwaters of Barren River system, Kentucky and Tennessee, in Highland Rim province. The blackfin sucker and other endemic fishes of the upper Barren River system do not appear to be under immediate threat, but their restricted geographical range has prompted concern for their future. *Moxostoma atripinne* is included in Tennessee's list of rare wildlife as a Species of Special Concern (Starnes and Etnier, 1980).

Similar Sympatric Species: *Minytrema melanops* is a somewhat similar species that occurs sympatrically but has an incomplete lateral line with only 42–47 scales in lateral series and 11–12 dorsal fin rays; black pigment, if present on the dorsal fin, occurs marginally rather than as a blotch on the anterior rays.

Systematics: Buth (1979b) has suggested that the subgenus *Thoburnia* should be accorded generic rank based on a hypothesized closer relationship of these fishes to the genus *Hypentelium* than to *Moxostoma* based on limited genetic evidence. If such a relationship is cor-

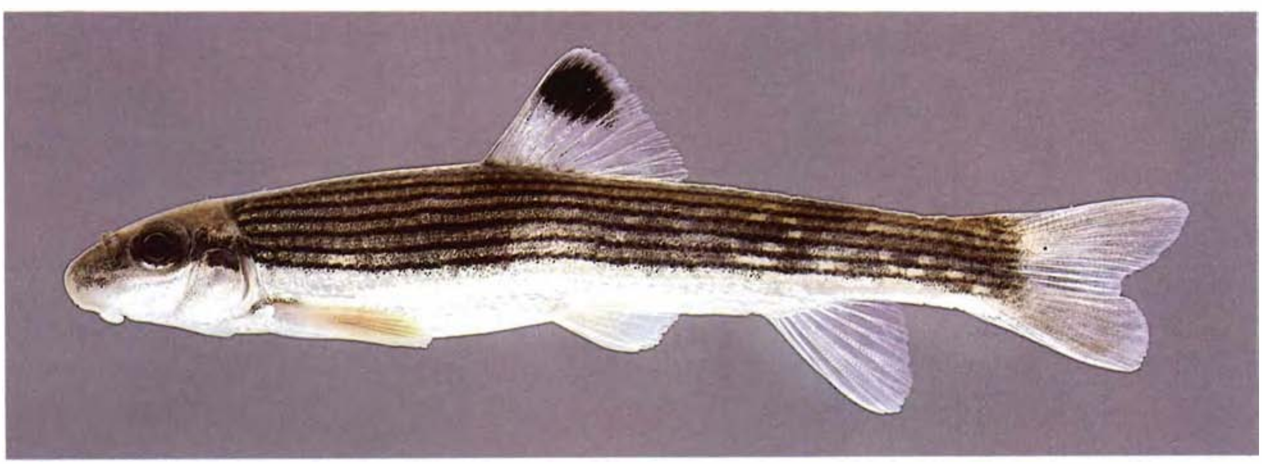
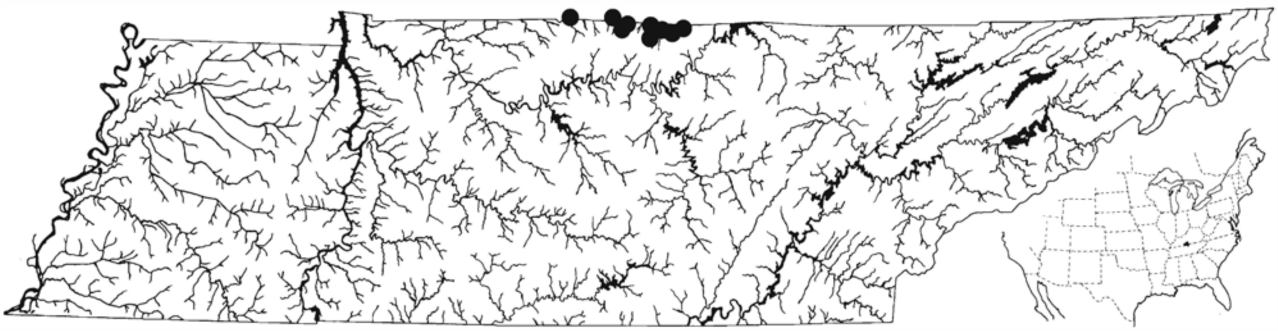


Plate 122. *Moxostoma atripinne*, blackfin sucker, 70 mm SL, Barren R. system, TN.



Range Map 121. *Moxostoma atripinne*, blackfin sucker.

roborated by further studies, we certainly would concur in this arrangement (to avoid recognition of a paraphyletic *Moxostoma*), but because of some latitude in interpretation of Buth's results and uncertainty in the minds of other students of catostomid systematics (pers. comm. R. E. Jenkins), particularly with regard to the phylogenetic position of *atripinne*, we treat it in *Moxostoma* for the present. Buth (1979c) studied biochemical systematics of *Thoburnia* and found the Atlantic slope species *hamiltoni* and *rhothoeca* much closer related to one another than to *atripinne*.

Etymology: *atri* = black, *pinne* = fin.

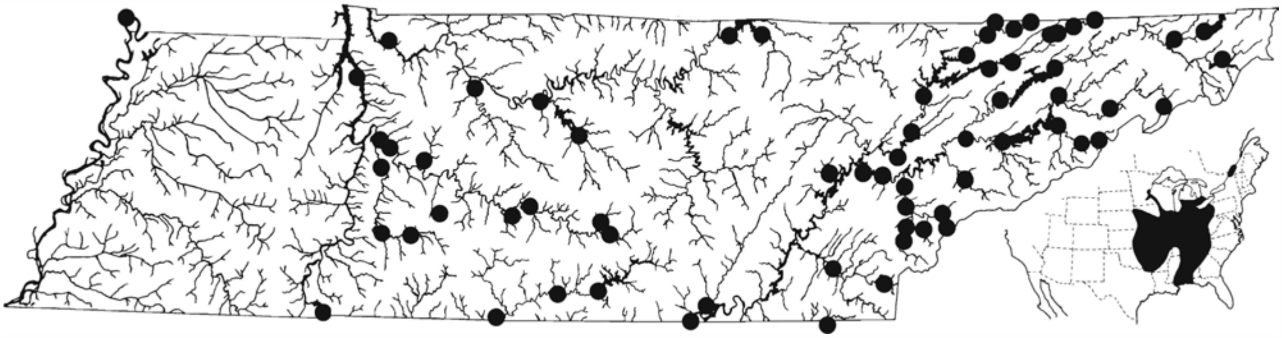
Moxostoma carinatum (Cope)

River redhorse

Characters: Lateral-line scales 42–44 (41–47), caudal peduncle scale rows 12, predorsal scale rows 14–17. Dorsal fin rays 13 (12–15). Pectoral fin rays 16–17 (15–18). Total pelvic fin rays 18 (16–20). Gill rakers 19–31 (26–31 in specimens larger than 150 mm SL). Vertebrae 41–44. Pharyngeal arch heavy with teeth enlarged and molariform (Fig. 97). Fresh specimens with bright red caudal and dorsal fins and orange to red lower fins. Nuptial males with large tubercles on anterior and lateral areas of snout and cheek, and occasionally on opercles. Smaller tubercles occasionally present on gular area and top of head. Anal and caudal fin rays with moderate sized tubercles on all rays. Other fins and dorsal body scales may develop small tubercles in the "highest" males.

Biology: The river redhorse occurs in swift waters of medium to large rivers, and rarely enters smaller streams except during the breeding season. The destruction of a large number of our big rivers by impoundment has resulted in a considerable decrease in the abundance of this spectacular fish in recent years. Spawning is later than in other Tennessee species. Hackney et al. (1968) reported spawning during mid April at temperatures of 71–76 F (22–24 C) in the Cahaba River, Alabama. They also observed spawning behavior. Males constructed nests or redds in gravel shoal areas with water depths of .15–1.07 m. The redds

Plate 123. *Moxostoma carinatum*, river redhorse, 396 mm SL, Nolichucky R., TN.



Range Map 122. *Moxostoma carinatum*, river redhorse.

were constructed by sweeping with the caudal fin, pushing gravel with the head, and using the mouth, presumably to remove pebbles. Redds were tended by individual males, numbered eight or more per spawning shoal, were 1.22–2.44 m wide and 22–30 cm deep, and neighboring redds often overlapped. After a female entered the redd, the resident male began darting back and forth and was soon joined by a second male in this "nuptial dance," which lasted for several seconds. The female then took a position on the bottom of the redd between the two males, and the trio engaged in coordinated vibrations that resulted in eggs being released, fertilized, and buried in the gravel. Two males and a female were necessary for successful spawning. Fecundity of females from 455–562 mm ranged from 6,078 to 23,085 eggs. Growth from several studies (Carlander, 1969) was 43–137 mm TL, 122–254 mm, 193–376 mm, 264–335 mm, 297–424 mm, and 386–493 mm at the ends of the first through sixth growing seasons, respectively. Sexual maturity occurred at age 3 at about 415 mm TL in a more rapidly growing Cahaba River population that averaged 488 mm during July of the fourth year of life (Tatum and Hackney, 1970). The above two sources indicate a life span of 8–12 years. Adults feed largely on small bivalve mollusks which they crush with their heavy pharyngeal teeth. Hackney et al. (1968) found the Cahaba River population to feed largely on the introduced Asiatic clam, *Corbicula*, in addition to occasional benthic insect larvae. Although usually taken for food by using spears, nets, and snares, or by jerking a treble hook through the water, the river redhorse can be taken by angling, with the meat of mussels commonly used for bait. It is reported to be an excellent sport fish, and its large size makes it the most popular food fish of the redhorses. Maximum size (Trautman, 1957) 736 mm (29 in) TL and 4.8 kg (10.5 lb). Unconfirmed reports of larger fish (Tatum and Hackney, 1970) are 6.8 and 7.3 kg from the Duck and Harpeth rivers, Tennessee, and a 7.3 kg specimen from the Flint River, Alabama.

Distribution and Status: Mississippi Basin above the Fall Line, some Great Lakes tributaries, and eastern Gulf Coast drainages east to the Escambia River. Apparently disappearing from many Plains systems. In Tennessee, the river redhorse occurs in all regions above the Coastal Plain, but its range has probably been fragmented by impoundments.

Similar Sympatric Species: The river redhorse differs from all other Tennessee redhorses in having molariform rather than comb-like pharyngeal teeth (Fig. 97). These are diagnostic for the species even at small sizes. The only other redhorse with bright red dorsal and caudal fins is the shorthead, which has a tiny mouth with the posterior border of the lower lip straight (Fig. 96b) (slightly angled in the river redhorse), an extremely falcate dorsal fin (Pl. 126), and a very slab-sided rather than cylindrical body cross-section. In preservative, most like the golden redhorse. Although Jenkins (1970) suggested differences between these two species in the pigmentation of the scale bases, we still resort to examination of the pharyngeal teeth for positive identification. In adults of the river redhorse, the dorsal lobe of the caudal fin is triangular and sharply pointed in contrast to the more rounded lower caudal lobe. In the golden redhorse there is less asymmetry between the lobes of the caudal fin.

Systematics: Some authorities (e.g., Jordan, 1878; Hubbs, 1930) recognized the monotypic genus or subgenus *Placopharynx* Cope for *M. carinatum* because of its enlarged pharyngeal apparatus, a view not supported by Robins and Raney (1956), Jenkins (1970), or Buth (1978).

Etymology: *carinatum* = keeled.

Moxostoma duquesnii (Lesueur)

Black redhorse

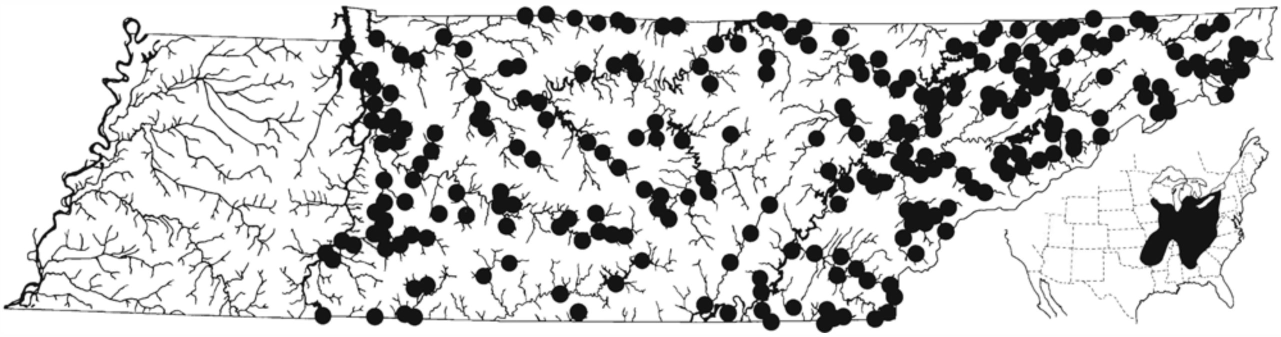
Plate 124. *Moxostoma duquesnii,* black redhorse, 221 mm SL. Nolichucky R., TN.

Characters: Lateral-line scales 44–48 (43–51), caudal peduncle scale rows 12 (12–15), predorsal scale rows 14–20. Dorsal fin rays (11–15), modally 13 in Mississippi Basin but modally 12 in Conasauga River. Pectoral fin rays 15–19. Total pelvic fin rays 18 in Conasauga River but often 19 or 20 elsewhere. Gill rakers 23–36 (27–36 in specimens larger than 150 mm SL). Vertebrae 43–47. Lower fins orangish, dorsal and caudal fins typically pale gray, but in the clear waters of trout streams these fins may be nearly as red as in the river and shorthead redhorses. Nuptial males in Missouri developed a light pink midlateral stripe above and below which was a streak of metallic greenish black. Nuptial tubercles small, best developed on lower caudal peduncle, anal fin rays, and rays of lower lobe of caudal fin. Tiny tubercles also occur on rays of other fins, on most body scales, and on the entire head where they are concentrated on the dorsal surface.

Biology: The black redhorse is a common inhabitant of clear, cool, larger creeks and small rivers. It is uncommon in big rivers and rarely occurs in reservoirs. Bowman (1970) studied its biology in two Missouri streams. Adults congregated in pools above spawning shoals just prior to spawning, and were often seen jumping clear from the water in these pools. Several hours later males began to drift tail-first onto the spawning shoals where they established territories about .2 to .5 m in diameter. Of many apparently suitable spawning shoals available in these streams, black redhorses were very precise in choosing those with substrates of 70% fine rubble, 10% coarse rubble, and 20% sand and gravel with .1 to .6 m depths. When females drifted into the spawning shoals they were attended by the two closest territorial males. The two males took a position on each side of the female and began vibrating their caudal peduncles. The thrust of these vibrations caused the trio to assume a tail-down position, with their heads often breaking the water suface at about the time of actual spawning. Kwak and Skelly (1988) reported the black redhorse to spawn in late April and early May in Illinois at water temperatures of 15–18 C; spawning habitat was in slightly deeper and swifter water and on coarser gravel then that of the syntopic golden redhorse. Growth during the first 5 years in populations studied by Bowman (1970) was, age 1, 66--83 mm SL; age 2, 95–149 mm; age 3, 118–195 mm; age 4, 156–227 mm; and age 5, 173–238 mm. Sexual maturity was reached at age 3 or 4, and life span was 9 or 10 years. Food of adults consists of a variety of small benthic invertebrates, especially microcrustacea and midge larvae. Maximum size (Pflieger, 1975) 658 mm (25.9 in) TL and 3.17 kg (7 lb), but specimens over 430 mm and about 0.9 kg are rare.

Distribution and Status: Mississippi Basin uplands, southern Great Lakes tributaries, and Mobile Basin above Fall Line. Common in all upland provinces in Tennessee.

Similar Sympatric Species: So similar in appearance to the golden redhorse that even the most experienced students of the group are forced to count lateral-line scales before making positive identification. Adults from Tennessee populations differ from golden redhorses in having breast scales that are slightly embedded and abruptly much smaller than adjacent belly scales (breast scales exposed and gradually smaller than belly scales in golden redhorse). In smaller specimens with borderline lateral-line scale counts (43–44), the shape of the caudal peduncle provides a useful diagnostic character. In the black redhorse, minimum peduncle depth is less than two-thirds of peduncle length, while in the golden redhorse minimum peduncle depth is more than two-thirds of its length. If breeding males are available, nuptial tubercle pattern differences offer easy



Range Map 123. *Moxostoma duquesnii,* black redhorse.

separation. The black redhorse lacks large, conspicuous head tubercles, while those of the golden redhorse are large and prominent on the anterior portion of the head.

Systematics: Mobile Basin population regarded as racially distinct by Jenkins (1970).

Etymology: Named after the type locality, Fort Duquesne, upper Ohio River drainage, Pittsburgh, Pennsylvania.

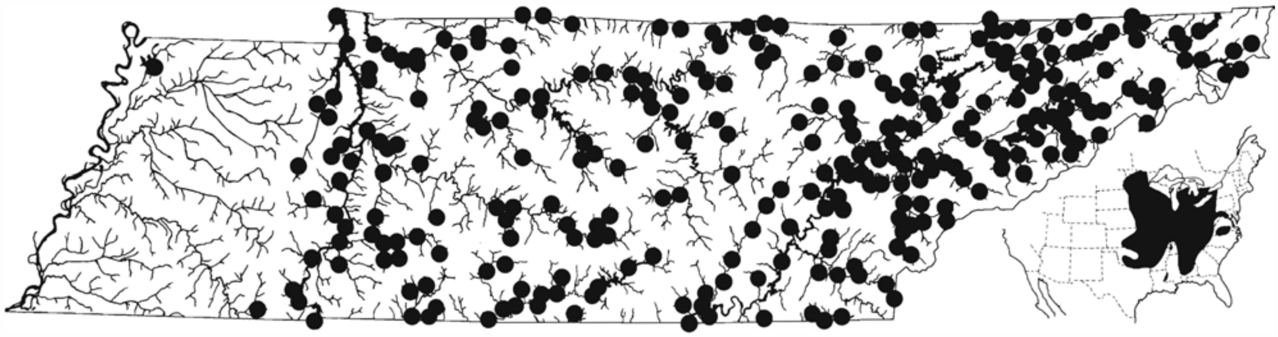
Moxostoma erythrurum (Rafinesque)

Golden redhorse

Characters: Lateral-line scales 39–43 (37–45), caudal peduncle scale rows 12 (12–15), predorsal scale rows 13–17. Dorsal fin rays 12–14. Pectoral fin rays 16–19. Total pelvic fin rays usually 18. Gill rakers 21–32 (25–32 in specimens larger than 150 mm SL). Vertebrae 39–43. Caudal and dorsal fins gray in adults but often tinted with red in young. Lower fins yellow to orange. Nuptial males have a dark horizontal midlateral stripe (copper-colored in specimens we saw from Conasauga River), above which is a golden area and then another dark stripe. Males have large nuptial tubercles on middle anal fin rays and rays of lower lobe of caudal fin, and on snout and suborbital areas of head. Body scale tubercles best developed on nape and lower caudal peduncle and covering the exposed field in these areas, mostly marginal elsewhere. Small tubercles may occur elsewhere on head, on other caudal and anal fin rays, and on anterior rays of dorsal, pectoral, and pelvic fins.

Biology: The golden redhorse is a common species of larger creeks and small rivers, where it often occurs with the black redhorse. It is more tolerant of larger rivers than the black redhorse, often occurring with the river, silver, and shorthead redhorses in these habitats. Reproductive behavior has not been thoroughly reported, but is presumably similar to that of other non-nest-building redhorses. Spawning season is generally later than in the black redhorse, and may occur from April through early June, depending on latitude, at water temperatures of about 16–21 C (60–70 F). Kwak and Skelly (1988) reported spawning in Illinois during

Plate 125. *Moxostoma erythrurum*, golden redhorse, 253 mm SL, Nolichucky R., TN.



Range Map 124. *Moxostoma erythrurum*, golden redhorse.

May at temperatures in this range. Males aggressively defended territories in shallow (to .25 m deep) shoal areas and were joined by females from adjacent pool areas; spawning occurred in groups of three to five. Males were more territorial and spawning occurred in shallower, slower water than for the syntopic black redhorse. Eddy and Underhill (1974) reported spawning in water so shallow that the backs of the fish were exposed. Sexual maturity is reached during the third or fourth year, and for males at total lengths as small as 230 mm. Data summarized by Carlander (1969) indicates fecundity of 6,100 to 23,350 eggs per female in fish 292–399 mm, and total lengths of 51–160 mm, 104–302 mm, 165–391 mm, 208–455 mm, and 239–551 mm respectively at the ends of the first five growing seasons. Food consists mostly of immature mayflies, caddisflies, and midges. Fingernail clams are eaten when available. Maximum size (Trautman, 1957) 660 mm (26 in) TL and 2.04 kg (4.5 lb).

Distribution and Status: Mississippi Basin, mostly above Fall Line, and Mobile Basin, Great Lakes tributaries, and some middle Atlantic Coastal drainages. In Tennessee the golden redhorse is common in all upland provinces, but absent from most of the Coastal Plain.

Similar Sympatric Species: See comments under *Moxostoma duquesnii.*

Etymology: *erythro* = red, *urum* = tail.

Moxostoma macrolepidotum (Lesueur)

Shorthead redhorse

Characters: Lateral-line scales 41–45 (40–46), caudal peduncle scale rows 12 (12–15), predorsal scale rows 15–17 (14–18). Dorsal fin rays (11–14), modally 12 in our subspecies. Pectoral fin rays 16–18. Total pelvic fin rays 18–20 (usually 20 in our subspecies). Gill rakers 22–30. Vertebrae 41–44. Lower lips meet to form a straight line (Fig. 96b, V-shaped lower lip junction in other redhorses). Dorsal fin with very concave margin and bright red distally. Caudal fin bright red, with upper and lower lobes very asymmetrical, upper lobe more sharply pointed and longer than lower lobe. Ventral fins yellowish to orange red. Males with nuptial tubercles best developed on rays of anal fin and lower lobe of caudal fin, and on scales of lower caudal peduncle. Smaller tubercles occur on rays of dorsal lobe of caudal fin, rays of other fins, most other body scales, and all over the head.

Biology: The southeastern subspecies of the shorthead redhorse typically occurs in large rivers over gravel to boulder substrates with swift water. It avoids small streams inhabited by the black and golden redhorses, and occurs occasionally in most of our reservoirs, especially if the reservoirs' headwater rivers are large enough to provide suitable habitat. The northern subspecies commonly occurs in glacial lakes. Spawning behavior of the northern subspecies was reported by Burr and Morris (1977) from Illinois streams. Spawning occurred over gravel shoals 15–21 cm deep during daylight hours in mid May at water temperature of 16 C (61 F). Other authors have reported spawning at 11 C (Iowa) and 14 C (Alabama). About 100 individuals were present on the spawning shoal studied in Illinois, and an equal number were nearby in quieter water. The spawning shoal contained about 30 "nests" in the form of circular depressions 40–45 cm in diameter and troughs 90 cm long by 50 cm wide. It is likely that these depressions were formed accidentally by spawning activities, since the authors did not observe nest construction, nor did they note any territorial or aggressive behavior between males. The spawning act was similar to that described for the black redhorse, but on occasions more than two males appeared to be spawn-

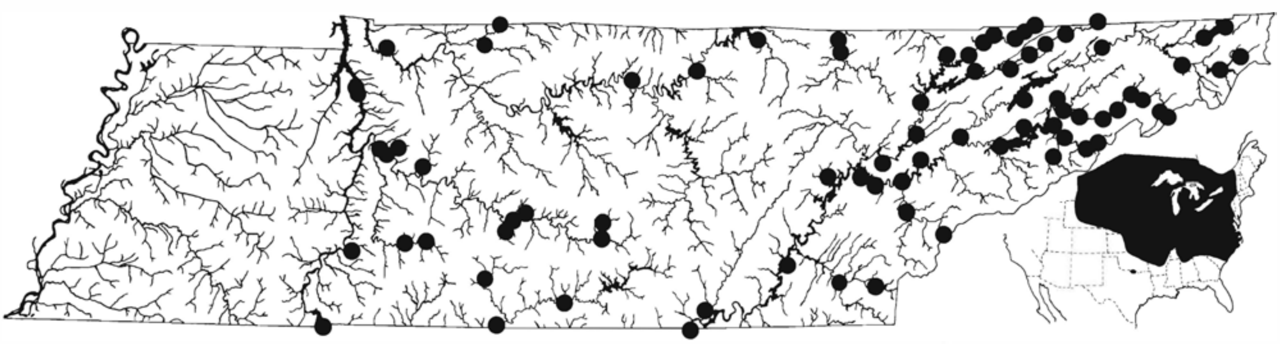
Plate 126. *Moxostoma macrolepidotum*, shorthead redhorse, 220 mm SL, Clinch R., TN.

ing with a single female. On these occasions there were typically two additional males stationed directly above the normal trio of a female flanked by two males. Sexual maturity probably occurs during the fourth year of life, and life span is about 8 years (here) to 12 years (Canada). In Iowa the northern subspecies averaged 117 mm total length at age 1, 224 mm at age 2, 292 mm at age 3, 343 mm at age 4, and 417 mm at age 5 (Carlander, 1969). Adult shorthead redhorse feed on benthic insect larvae; juveniles feed primarily on microcrustacea and midge larvae. Feeding is accomplished by considerable dislodging of the substrate with the head, mouth, and pectoral fins, especially in the Ozarkian subspecies where the upper lip has a thickened, callus pad. Maximum size (Trautman, 1957) 483 mm (19 in) TL and about 1.36 kg (3 lb) for our subspecies; the northern subspecies reaches 620 mm and 1.87 kg.

Distribution and Status: Widely distributed through the entire Mississippi Basin mostly above the Fall Line, and in Great Lakes, Hudson Bay, and middle Atlantic Coastal drainages. The shorthead is typically less common than black and golden redhorses, but probably more common than records indicate because of the difficulty of collecting its swift-water, big-river habitats.

Similar Sympatric Species: The river redhorse is our only other redhorse with bright red dorsal and caudal fins. The shorthead redhorse has a much more concave dorsal fin margin and a smaller head (18–21% of standard length) than the river redhorse and other sympatric redhorses (head length more than 21% of standard length). In preservative, it is best identified by the shape of the dorsal fin (Pl. 126) and mouth (Fig. 96b), in addition to head length. It is more laterally compressed than other redhorse species.

Systematics: Three subspecies were recognized by Jenkins (1970). *Moxostoma m. macrolepidotum*, the northern shorthead redhorse, occurs from Atlantic Coastal drainages and northern east and central North America; *M. m. pisolabrum* Trautman and Martin, the pealip shorthead redhorse, from the Ozark region and occasionally the lower Mississippi River; and *M. m.*



Range Map 125. *Moxostoma macrolepidotum*, shorthead redhorse (range extends off inset north to southern Hudson Bay and west to Alberta).

breviceps (Cope), the Ohio shorthead redhorse, from the Ohio, Cumberland, and Tennessee river drainages.

Etymology: *macrolepidotum* = large scaled; *breviceps* = shorthead.

Moxostoma poecilurum (Jordan)

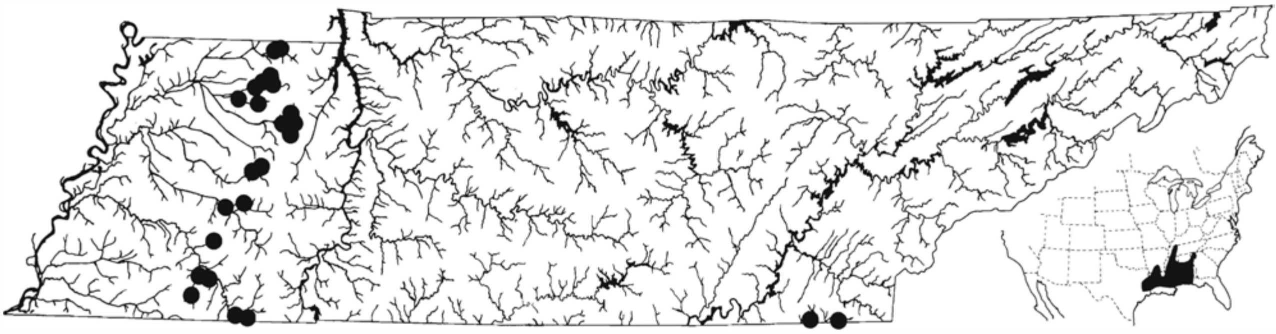
Blacktail redhorse

Characters: Lateral-line scales 41–44 (40–45), caudal peduncle scale rows 12 (12–14), predorsal scale rows 14–17. Dorsal fin rays 11–13. Pectoral fin rays 15–18. Total pelvic fin rays usually 18. Gill rakers 21–29 in adults. Vertebrae 41–43. All fins reddish in life, this color probably more intense in nuptial specimens and approaching the crimson color of the river and shorthead redhorses. Lower lobe of caudal fin black with white lower border. Sides marked with faint dusky horizontal stripes. Males with largest nuptial tubercles on rays of lower lobe of caudal fin and middle rays of anal fin. Other fin tubercles tiny, but occurring on all surfaces of all fins. Tiny tubercles also occur on all body scales (largest on lower caudal peduncle) and over the entire head (more concentrated on dorsal surface).

Biology: The blacktail is a small redhorse that is tolerant of both small creeks and large rivers, and it occurs in many southern reservoirs. Habitats range from sluggish coastal plain streams with soft sand and silt substrates to more typically upland streams and rivers with high gradients and firm, coarse substrates. Its biology has received little attention. Spawning occurs in April and May at water temperatures near 20 C (68 F) in shoal areas of small streams 1–10 m wide; two or three males may spawn with a female (Kilken, 1974). Kilken (1972) studied first year's growth and feeding habits in pond culture experiments in Alabama. Diets of these fish were supplemented with pelleted food. Natural foods consumed included detritus, diatoms, and a wide variety of small invertebrates such as microcrustacea, rotifers, caddisfly larvae, and phantom midge (*Chaoborus*) larvae. When stocked at 500 fish per acre and fed supplemental food, a total length of 143 mm was reached in 184 days. Growth was considerably poorer at higher stocking rates and without feeding. Maximum size (Carlander, 1969) 508 mm (20 in) TL.

Distribution and Status: Restricted to the Gulf Coastal Plain from eastern Texas to the Choctawhatchee system, Alabama and Florida, except in the Mobile Basin where

Plate 127. *Moxostoma poecilurum*, blacktail redhorse, 115 mm SL, Hatchie R. system, TN.



Range Map 126. *Moxostoma poecilurum*, blacktail redhorse.

it occurs above the Fall Line to the headwaters. In west Tennessee the blacktail redhorse occurs above the Alluvial Plain where stream gradients are slightly increased, whereas in the Conasauga River we have found it mostly in rocky pools. Uncommon in Tennessee.

Similar Sympatric Species: Occurs with the spotted sucker and black, golden, and river redhorses. The lower lobe of the caudal fin is not bicolored in any of these species.

Systematics: A closely related undescribed species occurs in the Apalachicola drainage to the east of the range of *poecilurum* (Jenkins, 1970).

Etymology: *poecil* = variegated, *urum* = tail.

ORDER SILURIFORMES

FAMILY ICTALURIDAE

The North American Freshwater Catfishes

The ictalurids, which are native to North America, are easily recognized as the only Tennessee fishes with conspicuous barbels around the mouth (four on upper jaw, four on chin) and scaleless bodies. Of the 38 species known from the United States, 22 occur in Tennessee. Two additional species, the white catfish and flat bullhead, have become established in Tennessee River tributaries in North Carolina (Harned, 1979; E. F. Menhinick, in litt.) and are almost certain future additions to the Tennessee fauna. Six Tennessee species are the familiar bullheads and catfishes (genera *Ameiurus*, *Ictalurus*, and *Pylodictis*) so important to commercial and sport fishermen. The 16 remaining Tennessee species, the madtoms (genus *Noturus*), are small, secretive inhabitants of creeks and rivers. In addition to these genera, the family contains three monotypic genera adapted for subterranean living, *Satan* Hubbs and Bailey and *Trogloglanis* Eigenmann of Texas and *Prietella* Carranza of Mexico (Hubbs and Bailey, 1947; Suttkus, 1961; Lundberg, 1982). The family dates to the Paleocene in the fossil record (Cavender, 1986), and representatives of some present-day genera are known from the Oligocene (Lundberg, 1975b). LeGrande (1981) provided information on chromosome evolution in the family. Ictalurids and other catfishes (Siluriformes) are classified among ostariophysan fishes (including also minnows and suckers plus several other groups of primarily freshwater fishes from many parts of the world) by virtue of the presence of a Weberian apparatus (see Cyprinidae introduction). Five anterior vertebrae are involved in this modification rather than the presumed 4 in Cyprinidae. Many other families of siluriform fishes are similar in general appearance to the ictalurids. Among these are the sea catfishes (family Ariidae), including two species that are commonly caught by saltwater anglers in the Atlantic Ocean and Gulf of Mexico; the much-publicized walking catfish (family Clariidae), which has been inadvertently introduced into Florida waters from Asia; and several families of South American and Old World freshwater catfishes popular with aquarium fanciers.

The ictalurids have apparently evolved considerably as social animals. All species for which breeding behavior is known build nests and provide parental protection for the eggs and young (Taylor, 1969b; Wallace, 1967; Clemens and Snead, 1957; and many others). Nesting sites for the catfishes and bullheads are frequently holes under overhanging banks in rivers and reservoirs, but bullheads often nest in open areas. Madtoms frequently spawn in beer cans and similar containers (Taylor, 1969b). Spawning occurs from spring to early summer in the various species. While both parents may contribute to nest site selection and construction plus guarding of eggs and young, parental care is often a strictly male function (Blumer, 1985). Nuptial males develop swollen lips and dorsal head musculature, and typically do not feed during nesting. The very interesting work by Atema et al. (1969) and Todd (1971) indicated that the yellow bullhead is a very social fish and can recognize other individuals and even the social status of other individuals by their smell. The olfactory apparatus (nose) is responsible for this ability, while the barbels and other dermal taste buds are used for locating food.

Ictalurids are equipped with spines (actually groups of fused rays, see Anatomy and Function) at the origins of the dorsal and pectoral fins. These spines or stings are capable of inflicting wounds that cause various degrees of discomfort, ranging from a short period of numbness and moderate swelling to extreme swelling that may last for several days. The degree of discomfort is dependent upon the species (Birkhead, 1972) and probably susceptibility of individuals. It had been generally assumed that the sting of the madtoms was more virulent than that of the larger catfishes, and that the glands at the bases of the spines produced the poison involved. Birkhead (1972) concluded that the two most virulent stings of the species he studied were those of the black bullhead and the slender madtom, that some of the madtoms had stings that were virtually nontoxic, and that the membrane surrounding the spine rather than the basal gland was responsible for the toxin. The function of the glands at the base of the spine remains unknown.

Albinism seems to be a relatively common phenomenon among ictalurids. There are several reports in the literature (e.g., Menzel, 1944; Holder and Ramsey, 1972; Stasiak and Evans, 1978, and others) involving a variety of species.

KEY TO THE TENNESSEE GENERA

Important taxonomic characters in the ictalurids include the armament of the pectoral spines and the anal and caudal fin ray counts. A dissecting needle can be used to separate the soft tissue from the pectoral spine. All anal fin rays (and caudal fin rays in the madtoms), including the tiny anterior rudiments, are included in the counts. Since these fins are quite fleshy, accurate counts may necessitate removing the overlying membranes. This can be done with little damage to the specimen by sliding a dissecting needle along the base of the fin between the bases of the rays and the overlying skin. The skin may then be lifted free from the fin and folded back while counts are being made. When the counts are completed, the flap of skin can be neatly folded back to its original position.

1. Adipose fin with posterior tip not attached to dorsal surface of body (Pls. 128–134, 151) 2
   Adipose fin fused to back along its entire length (Pls. 135–150) . . . . *Noturus* p.308
2. Anal fin rays fewer than 17; tip of dorsal lobe of caudal fin white except in very large specimens . . . . *Pylodictis* p.330
   Anal fin rays 18 or more; tip of dorsal lobe of caudal fin never white 3
3. Caudal fin truncate or rounded (Pls. 129–132) (moderately forked in *A. catus* (Pl. 128)); anal fin rays typically 24 or fewer . . . . *Ameiurus*
   Caudal fin deeply forked (Pls. 133–134); anal fin rays always 24 or more . . . . *Ictalurus* p.305

Genus *Ameiurus* Rafinesque
The Bullheads

Lundberg (1982) presented convincing evidence that the bullheads (white catfish plus six species traditionally called bullheads) are more closely related to several other currently recognized genera of ictalurids than to the fork-tailed catfishes (our channel and blue catfish plus several species from southwestern United States and Mexico) with which they had been included in the genus *Ictalurus* in recent decades, thus creating a paraphyletic grouping (see Systematics and Taxonomy); we therefore revert to *Ameiurus* as the generic name for the bullheads. The genus contains three native Tennessee species that have square or rounded caudal fins and rarely exceed about 1.4 kg (3 lbs). The white catfish, a recent or likely future addition to the Tennessee fauna, is approximately intermediate between bullheads and our two *Ictalurus* catfishes in both caudal fin shape and maximum size, but is osteologically (Lundberg, 1982) a typical bullhead. Three additional species, *A. brunneus* Jordan, *A. platycephalus* (Girard), and *A. serracanthus* Yerger and Relyea, occur in Atlantic and Gulf coastal drainages. *Ameiurus brunneus*, a frequent inhabitant of riffles in streams but tolerant of reservoir conditions, has apparently invaded the upper Etowah River system (Mobile Bay drainage) of northern Georgia (Bryant et al., 1979b) and may eventually disperse to the Conasauga River in Tennessee. E. F. Menhinick (in litt.) informed us that *A. platycephalus* is established in several Tennessee River tributaries in North Carolina, and it is a virtually certain future addition to Tennessee's fish fauna if not present already. In Tennessee, bullheads have received little attention as food or sport fishes. In areas where they are more abundant and commonly exceed weights of a pound, such as the Midwest and northeastern U.S., they are popular food fishes and are often sought by anglers fishing with worms. The colorful common names of horned pout and pollywog are often applied to various species of bullheads. Although the genus contains only seven species, overlapping fin ray counts as well as pigment and morphological changes associated with the breeding season and increasing size have resulted in frequent misidentifications. In our area, problems are most often encountered between the very similar brown and black bullheads. Positive identification should not be attempted without counting the gill rakers (e.g., Burkhead et al., 1980). Calovich and Branson (1964) presented a key to the North American *Ameiurus* and *Ictalurus* based on skull morphology.

Etymology: *Ameiurus* = unforked caudal fin.

KEY TO THE TENNESSEE SPECIES

1. Caudal fin moderately forked (Pl. 128) .... *A. catus*
   Caudal fin truncate, rounded, or very shallowly forked (Pls. 129–132) 2
2. Chin barbels pale yellowish to white; anal, caudal, dorsal, and pelvic fins typically with black margin 3
   Chin barbels with dark pigment; no fins with black margin 4
3. Anal fin rays 24 or more; eye small, its horizontal diameter more than 3.5 times in interorbital width; lower side of body never marbled or mottled; gill rakers (total for anterior arch, one side) 14 or more; widespread .... *A. natalis* p.301
   Anal fin rays 23 or fewer, rarely 24; eye large, its horizontal diameter less than 3.5 times in interorbital width; lower side of body typically marbled or mottled; gill rakers 13 or fewer, rarely 14; anticipated in French Broad River system .... *A. platycephalus* p.303
4. Gill rakers 16–20 (15–21); black membranes of fins contrast sharply with pale rays; posterior pectoral fin serrae (Fig. 98a) usually weak; sides never mottled .... *A. melas* p.300
   Gill rakers 11–15 (rarely 16); fin rays and membranes not sharply contrasting in pigmentation; posterior pectoral fin serrae conspicuous (Fig. 98b); sides often mottled .... *A. nebulosus* p.302

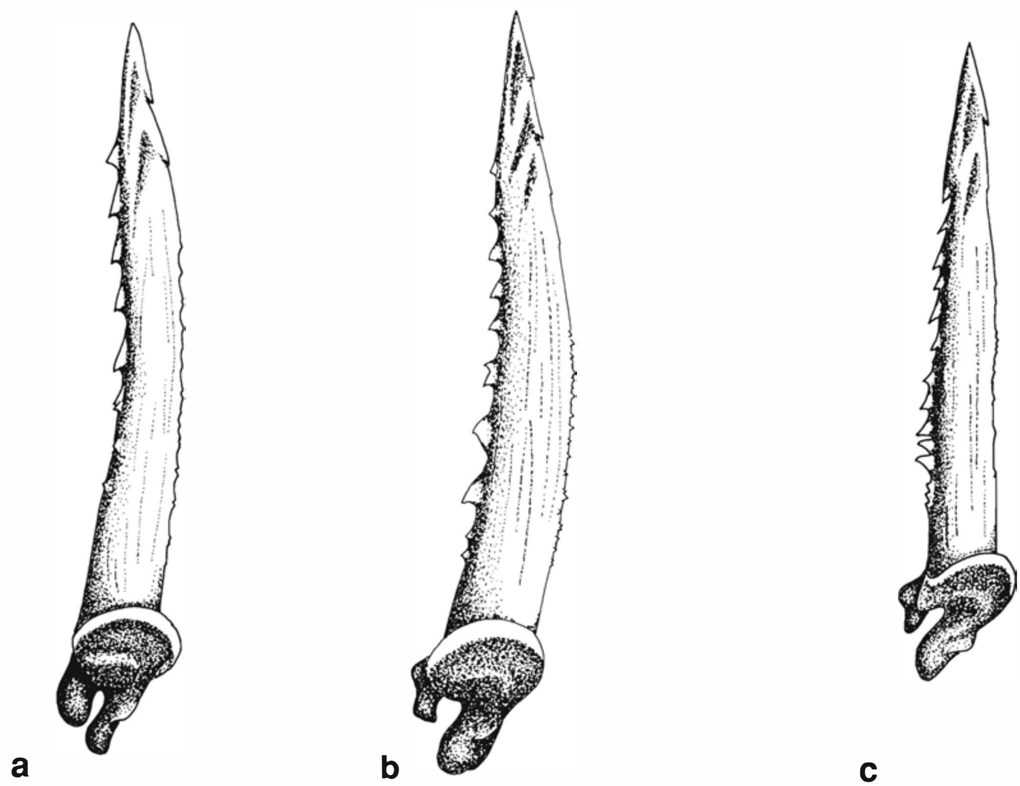


Figure 98. Pectoral spines of bullheads: a) *Ameiurus melas*; b) *A. nebulosus*; c) *A. natalis*.

Ameiurus catus (Linnaeus)

White catfish

Characters: Anal fin rays 21–26, usually 24 or fewer. Caudal fin rays (branched rays plus two) 15–18. Soft pectoral fin rays 9. Soft dorsal fin rays 6. Pelvic fin rays 8. Gill rakers 18–23. Pectoral spine (Fig. 99) with weak posterior serrae. Juveniles are relatively slender but adults are often heavy bodied, exceeding even bullheads in robustness. The caudal fin becomes less forked with maturity. Color pale bluish gray dorsally, white ventrally. All fins except pelvics usually with dusky pigment.

Biology: The following account is abstracted largely from Stevens (1959), and is based on the white catfish population in Santee-Cooper Reservoir, South Carolina. Additional information is from Goodson's (1965) study of an introduced California population and from data summarized in Carlander (1969). Spawning activity peaks in June. Small females produce 2,500–4,000 eggs. Juveniles' (less than 200 mm TL) diet consisted primarily of midge larvae in California. Adults from California and South Carolina populations fed primarily on various fish species. Mayfly nymphs were also extensively utilized, and pond weeds (*Potamogeton*) were abundant in stomach samples from colder months. In South Carolina, white catfish reached total lengths of 81, 137, 206, 272, 325, 366, 399, 437, and 470 mm respectively at the ends of their first 9 years of life. Maximum age was about 11 years, and sexual maturity was reached during the fourth year at a minimum length of 208 mm. The preferred habitat of the white catfish appears to be intermediate between the sluggish water and soft substrates preferred by our bullheads and firmer, current-swept substrates where channel catfish thrive. Maximum size (Stevens, 1959) 566 mm (23.3 in) TL and 3.54 kg (7.8 lb), but considerably larger specimens have been reported (Fishing Hall of Fame, 1982, 10 lbs. 5 oz., Raritan River, New Jersey; Sternberg, 1987, 17 lbs. 7 oz., Success Lake, California, 1981).

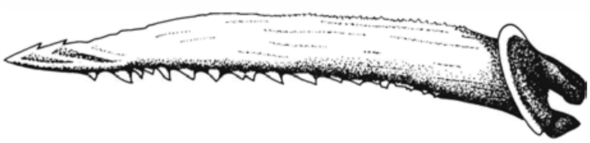


Figure 99. Pectoral spine of *Ameiurus catus*.

Distribution and Status: Native in Atlantic Coastal drainages from New York to Florida panhandle, and widely introduced elsewhere. Since it occurs in the French Broad River in North Carolina very near the Tennessee border (Harned, 1979), the white catfish may already be an overlooked member of the Tennessee fish fauna. Its possible present or almost certain future occurrence in the French Broad River and Douglas Reservoir could remain unnoticed for some time due to its similarity to the channel catfish and our bullheads. Initial suspicion aroused by a large bullhead with a moderately forked tail or a very chunky, unspotted "channel catfish" from this area should prompt examination of characters mentioned in the key and below, which should be adequate to result in positive identification.

Similar Sympatric Species: Since anal fin ray and gill raker counts overlap slightly with those of the channel catfish, the following proportional measurement is included, with ratios for *Ameiurus catus* given first. Interorbital width 1.6–2 versus 2.6–3.5 times in head length

Plate 128. *Ameiurus catus*, white catfish, 230 mm SL, lower Patuxent R., MD.

in specimens less than 11 inches TL; 1.4–1.8 versus 1.8–2.5 in specimens 11–18 inches TL; 1.3–1.6 versus 1.4–2.2 in specimens larger than 18 inches TL.

Etymology: *catus* = a cat.

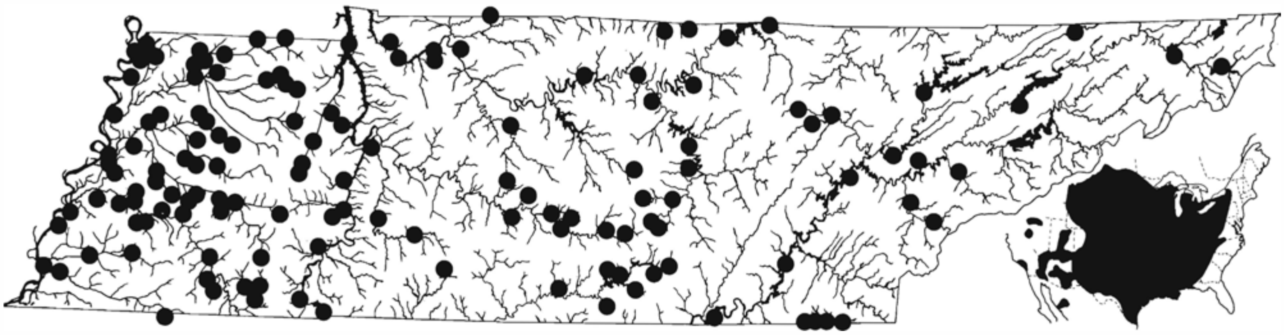
Ameiurus melas (Rafinesque)

Black bullhead

Characters: Anal fin rays 19–25. Other fin ray counts as listed for white catfish. Pectoral spine with weak posterior serrae (Fig. 98a). Gill rakers 16–18. Post-Weberian vertebrae 33–36. Dark fin membranes contrast sharply with paler fin rays. Caudal fin often with pale vertical bar at base. Color dark brown to nearly black dorsally, yellow or white ventrally.

Biology: Black bullheads occur in quiet waters over soft bottoms in habitats ranging from farm ponds to lakes and reservoirs, and small creeks to large rivers. Adults are very secretive during daylight, and are not often caught by anglers or fish collectors until after dusk. Spawning occurs from mid May through July. Wallace (1967) observed reproductive behavior in two pairs that spawned in aquaria. The nest, consisting of a hollowed out depression in the gravel substrate, was constructed by the female using her pelvic and anal fins to sweep out the depression, and pushing larger particles out of the depression with her snout. The male remained near the nest during and after its construction, and courtship was apparently initiated by the female's butting against the abdomen of the male with her snout. Actual mating was preceded by the pair lying side by side, facing opposite directions, and with the male, with mouth open, curling his caudal fin around the face of the female. After several such pairings, spawning was noted by a distinct quivering of the female. The male remained motionless with his mouth agape during this quiver. Spawning occurred five times during a 1-hour interval, and successive spawnings were preceded by fewer of the lateral embraces. The female guarded the nest and eggs during the first day after spawning, with the male assuming this role after the first day. Eggs hatch in 5–10 days, and free-swimming young remain in a tight school, typically guarded by the male, for about 2 weeks, at which time they attain 25 mm TL. Campbell and Branson (1978) provided a detailed summary of biological data for this species in addition to presenting their own results for studies of Kentucky populations. Fecundity ranges from about 2,500–3,800 eggs per female. Young fed primarily on ostracods, amphipods, and copepods, with much of the feeding associated with midday schooling activity. Darnell and Meierotto (1965) indicated that juveniles fed mostly at dawn and dusk in a Wisconsin population. Adults fed almost exclusively after dark and utilized a wide variety of aquatic invertebrates. Midge larvae were predominant food items in all studies reported, and other immature insects, snails, fingernail clams (Sphaeriidae), crustacea, and fish were often eaten. We have found this species to be abundant and very "well fed" around the sewerage outfall of a meat packing plant. Aquatic vegetation was often noted as a food item during spring. Several studies summarized in Carlander (1969) indicated that average growth is to

Plate 129. *Ameiurus melas*, black bullhead, 190 mm SL, Mississippi R. floodplain, TN.



Range Map 127. *Ameiurus melas*, black bullhead (native range extends west to Arizona, Colorado, Wyoming, and Montana, and off inset slightly farther northwest into Saskatchewan and southeastern Alberta; other western populations represent introductions).

about 100, 170, 240, 290, 320, and 350 mm total length by the respective ends of the first 5 years. Variation around these approximate averages is large, and this species tends to stunt under crowded conditions. Sexual maturity is reached at about 160 mm total length. Usual maximum size probably about 1.36 kg (3 lbs), although the accepted angling record is a New York specimen weighing 3.63 kg (8 lbs).

Distribution and Status: Widespread and abundant throughout much of central North America east of the Rocky Mountains and west of the Appalachians, and widely introduced elsewhere. Probably occurs throughout Tennessee in all drainages and provinces, but common only on Coastal Plain.

Similar Sympatric Species: Accurate differentiation between black and brown bullheads can be very challenging. It is likely that confusion between these (and occasionally with the yellow bullhead) species has resulted in more misidentifications than have occurred between any other pair of common Tennessee species. As noted by Burkhead et al. (1980), the number of total gill rakers on the first arch offers virtually complete separation of the two species (see key). The gill rakers can be counted easily by bending the gill cover back after short scissors cuts have been made at its dorsal and ventral attachments. The sharply contrasting black membranes and pale rays of the caudal and anal fin of *melas* are usually sufficient to separate it from both *natalis* and *nebulosus* in all but very small or very large specimens.

Etymology: *melas* = black.

Ameiurus natalis (Lesueur)

Yellow bullhead

Characters: Anal fin rays 24–28. Other fin ray counts modally same as listed for white catfish. Pectoral spine (Fig. 98c) with moderately developed posterior serrae. Gill rakers 12–18. Post-Weberian vertebrae 38–41. Color yellowish brown dorsally, occasionally slightly mottled, pale yellow to white ventrally. Fins uniformly dusky, with black margin typically evident on anal and caudal fins.

Biology: Yellow bullheads are most abundant in sluggish creeks and rivers but occur in virtually all aquatic habitats. Scott and Crossman (1973) and Becker (1983) summarized biological data available for this species. Spawning appears to be somewhat earlier than in brown and black bullheads, probably in April and May in the Tennessee area. Female fecundity ranges from 1,700 to 4,300 eggs per female in 230–330 mm specimens. About 300–700 eggs are laid per spawning act. Both sexes may participate in nest construction, but care of eggs and young is primarily a male function. Schools of young are guarded by the male until they reach a length of about 50 mm. Average growth in the Midwest was 30–66, 180–244, 193–274, and 226–295 mm total length by the respective ends of the first 4 years of life. Schoffman (1955) reported much faster growth in Reelfoot Lake, Tennessee, with total lengths of 332, 370, 402, and 429 mm reached at ages 2+ through 5+. Sexual maturity occurs at age 2 or 3 at a minimum length of about 140 mm, and life span is at least 7 years. Food habits are similar to those described for the black bullhead, but the yellow bullhead has a tendency to consume more vegetation and sewerage or similar sediments. Maximum size (Trautman, 1957) 465 mm (18.3 in) TL and 1.65 kg (3 lbs, 10 oz). State records

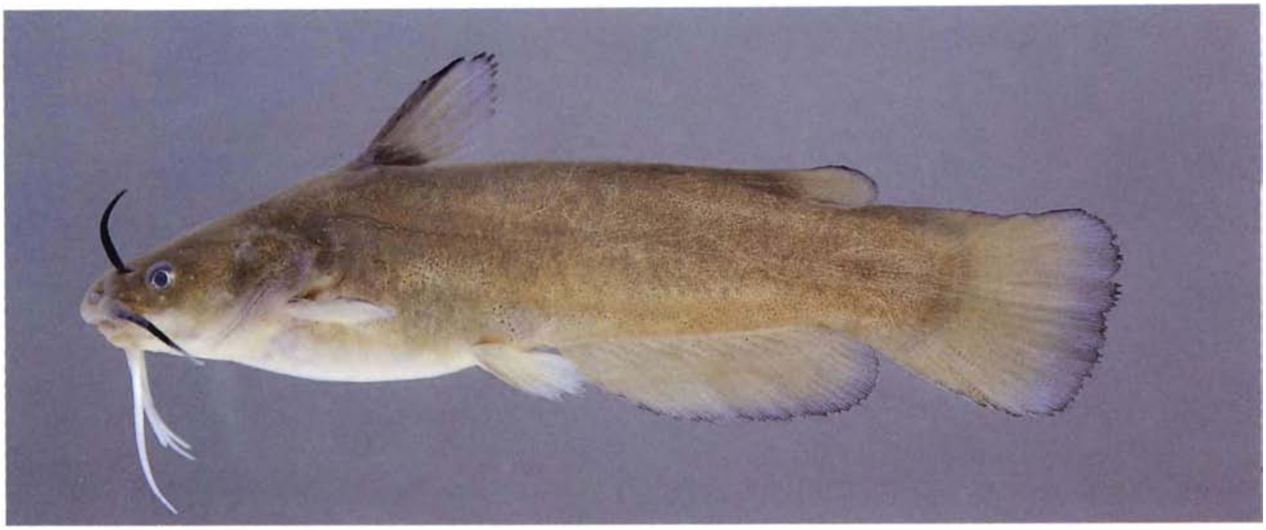
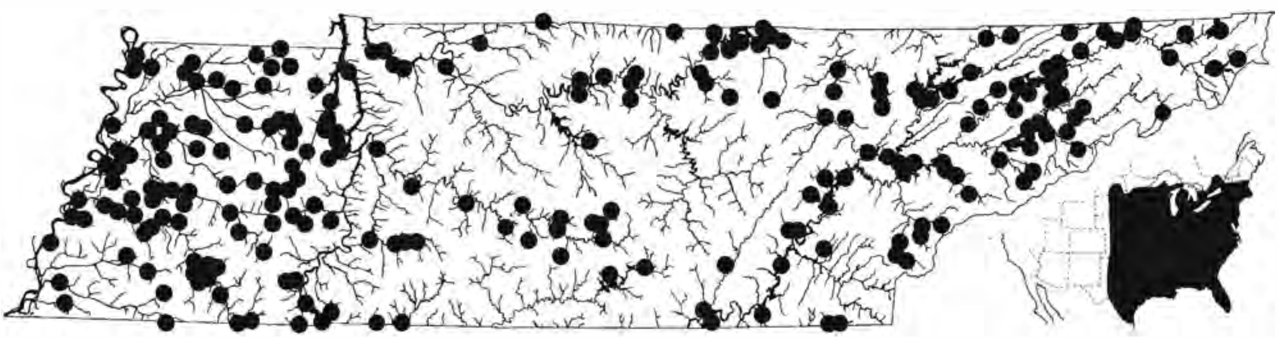


Plate 130. *Ameiurus natalis*, yellow bullhead, 72 mm SL, Obion R. system, TN.



Range Map 128. *Ameiurus natalis*, yellow bullhead.

for Arizona (4 lbs, 4 oz) and Illinois (5 lbs, 4 oz) are reported in Sternberg (1987).

Distribution and Status: Native throughout eastern United States, extending to southeastern Canada, and west to Great Plains and Rio Grande drainage; introduced elsewhere. Common throughout Tennessee except in higher Blue Ridge.

Similar Sympatric Species: The combination of characters mentioned in the key makes this the most easily identifiable Tennessee bullhead.

Etymology: *natalis* = with large buttocks, perhaps in reference to the large nuchal humps of mature males.

Ameiurus nebulosus (Lesueur)

Brown bullhead

Characters: Anal fin rays 18–24. Other fin ray counts as listed for white catfish. Pectoral spine with well developed posterior serrae (Fig. 98b). Gill rakers 12–15 (11–16). Post-Weberian vertebrae 34–39. Color dark brown or gray dorsally; sides usually mottled. Fins uniform dark gray.

Biology: In Tennessee this species appears to be much more restricted to pond and lake habitats than either the black or yellow bullhead, and is rarely taken in pool areas of streams. Spawning occurs (Scott and Crossman, 1973) at water temperatures of about 21 C, suggesting May as the month of maximum spawning activity in our waters. Eggs hatch within 13 days, young spend about 1 week absorbing their yolk sac, and then remain in a tight school for another week or so; both parents are reported as being involved with nest

Plate 131. *Ameiurus nebulosus*, brown bullhead, 275 mm SL, lower Patuxent R., MD.

construction and care of eggs and young (Blumer, 1985). Brown bullheads reach lengths of 81–91, 119–180, 160–259, 201–312, and 272–361 mm total lengths at the ends of their first 5 growing seasons (Carlander, 1969). Females reach sexual maturity at about age 3, and individuals 202–230 mm TL produce about 2,000 to 13,000 eggs yearly. Life span can be at least 11 years (Carlander, 1969). Like our other bullheads, young school under parental protection until they are about 50 mm long, and feed primarily on midge larvae and microcrustacea. Klaberg and Benson (1975) studied food habits of adults in West Virginia populations and found frequent evidence of sewerage ingestion in the form of corn, peas, and other substances in specimens taken near sewerage outfalls. Diet otherwise consists of midge larvae, aquatic annelid worms, a wide variety of immature insects, fingernail clams (Sphaeriidae), snails, other fishes, and aquatic vegetation. Maximum size (Carlander, 1969) about 520 mm (20.5 in) TL and (Scott and Crossman, 1973) 2.7–3.6 kg (6–8 lb).

Distribution and Status: Native to eastern United States and southern Canada west through Mississippi River basin and north to southern portion of Hudson Bay drainage. This is the least common of the three bullheads in Tennessee, but its spotty distribution covers virtually the entire state. It is likely that many previous literature records of this species in Tennessee are based on misidentification of black bullheads.

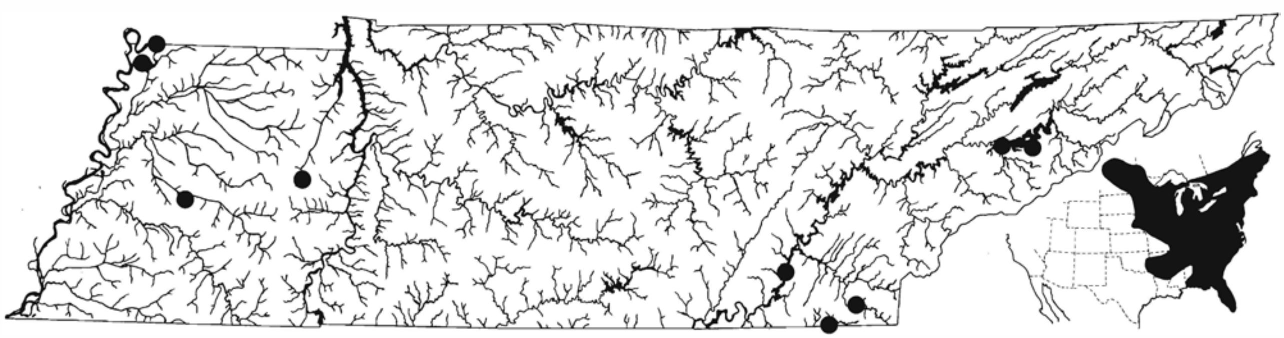
Similar Sympatric Species: See comments under black bullhead.

Etymology: *nebulosus* = clouded, in reference to the mottled sides.

Ameiurus platycephalus (Girard)

Flat bullhead

Characters: Anal fin rays 21–23 (20–24). Principal caudal fin rays 17 (11 UT specimens). Pectoral fin rays 8–9. Gill rakers 10–13 (9–15). Vertebrae 37–41. Pectoral spine (Fig. 100) with numerous weak posterior serrae. Other counts as listed for white catfish. All rayed fins with straw-colored background with narrow dark margins on median fins, and often on paired fins,



Range Map 129. *Ameiurus nebulosus*, brown bullhead (several introduced populations in western North America not shown).

Plate 132. *Ameiurus platycephalus*, flat bullhead, juvenile, 76 mm SL, Roanoke R. system, VA (photo N.M. Burkhead & R.E. Jenkins).

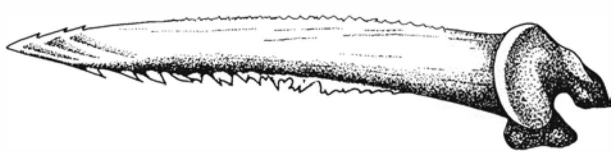


Figure 100. Pectoral spine of *Ameiurus platycephalus*.

especially in young. Dorsal fin with prominent dark blotch at base. Adipose fin same color as adjacent dorsum. Lower sides typically marbled or mottled with dark gray and pale yellow. Dorsum uniformly dark gray, ventral surface immaculate from pelvic fin bases anteriad. Maxillary and nasal barbels darkly pigmented, often with pale leading edges; chin barbels typically lacking dark pigment.

Biology: Yerger and Relyea (1968) reported flat bullheads to typically occur in gentle currents to quiet waters in medium to large rivers, ponds, and reservoirs, usually over soft substrates; they also show considerable tolerance for Piedmont streams with moderate currents and firm substrates, especially as juveniles. Olmsted and Cloutman (1979) have studied the biology of this bullhead in Lake Norman, North Carolina. Spawning occurred in that area in June and July at water temperatures of 21–24 C (70–75 F). Females contained about 200–1,750 eggs depending on body size and age. No spawning habitat was identified. Growth was estimated to be similar in both sexes through age 3, with growth in subsequent years slower in females, which attained sexual maturity at that age. Average total lengths for ages 1–5 were calculated as (males first): 97 and 100 mm, both 152, 191 and 190, 225 and 217, 255 and 238; no females over 5 years old were found; the largest specimen seen was a male 286 mm TL and 7 years old. The diet apparently consists mainly of aquatic insects, small fishes, and snails. Maximum total length 286 mm (11.2 in).

Distribution and Status: Native range of *A. platycephalus* includes Atlantic Coast drainages from Roanoke River, Virginia, south through Altamaha River drainage, Georgia, where it occurs both in the Piedmont and Coastal Plain. It is apparently well established in the French Broad River system, and present in the Nolichucky, Little Tennessee, and Hiwassee river systems in North Carolina very near the Tennessee border (E. F. Menhinick, in litt.) and will doubtless be taken from one or more of these systems in Tennessee in the near future.

Similar Sympatric Species: The flat bullhead is most likely to be confused with the brown bullhead, *A. nebulosus*, which shares the marbled pigment pattern of the lower sides and has similar anal fin ray counts. Brown bullheads typically have 14 or more gill rakers, whereas flat bullheads rarely have as many as 14 (specimens we have examined from French Broad River had 12), and larger and fewer (usually 15 or fewer vs. 25 or more) posterior serrae on the pectoral spine. The flat bullhead differs from all *Ameiurus* thus far occurring in Tennessee in its flat predorsal and head profile and in its larger eye (horizontal eye diameter stepped into interorbital width is less than 3.5 vs. more than 3.5 in other

Tennessee *Ameiurus*). It is extremely similar to *A. brunneus* with which it is sympatric over much of its native range and which could also be a future introduction to Tennessee. These species are difficult to distinguish, but a modal count of 13 or fewer (vs. 14 or more) gill rakers and 20 (vs. 18–19) anal fin rays would favor a determination as *platycephalus*.

Etymology: *platy* = flat; *cephalus* = head.

Genus *Ictalurus* Rafinesque

With bullheads removed to genus *Ameiurus*, *Ictalurus* is left with two species in Tennessee and most of the United States. Several additional species, all similar to the channel catfish, occur in Mexico, and the ranges of two of these, *I. lupus* (Girard), and *I. pricei* (Rutter), barely extend into the southwestern United States. Both Tennessee species reach large size, are excellent food fishes, and are commonly exploited by fish farming in ponds or in commercial and sport fisheries. Reproductive behavior is similar to that reported for *Ameiurus*, but nest sites are typically associated with some sort of cavity.

Etymology: *Ictalurus* = fish cat.

KEY TO THE TENNESSEE SPECIES

1. Edge of anal fin straight, anal fin rays 30 or more; never with dark spots on sides . . . . *I. furcatus*
   Edge of anal fin rounded, anal fin rays fewer than 30; often with dark spots on sides . . . . . *I. punctatus* p.306

Ictalurus furcatus (Lesueur)

Blue catfish

Characters: Anal fin rays 30–36. Other fins with counts as listed for white catfish. Gill rakers 14–21 in our specimens. Pectoral spine with well-developed posterior serrae, similar to that of channel catfish (Fig. 101). Air bladder very constricted. Back sloping steeply and in straight line from dorsal fin to snout, giving head a wedge-shaped appearance. Color pale gray to dark blue dorsally, white ventrally. Fins with dusky margins.

Biology: The blue catfish is an inhabitant of our largest rivers, and is successful in some reservoirs. It typically occurs in deep waters with firm substrates and considerable current. Biological information is summarized from accounts in Carlander (1969) and Pflieger (1975). Spawning occurs in spring, beginning as early as April in Louisiana and extending into June farther north. Growth in Tennessee (averaged from Watts Bar, Chickamauga, and Kentucky reservoirs) was 141, 212, 260, 308, 355, 407, 477, 585, and 666 mm total length after the first through ninth years. Hale and Timmons (1989), studying 13 year classes from Kentucky Reser-

Plate 133. *Ictalurus furcatus*, blue catfish, 445 mm SL, Kentucky Res., TN.

voir, found growth generally exceeding that reported above through age 7 and less thereafter; growth increments increased markedly after the second year. At age 13, fish in this study had attained an average 813 mm TL. Specimens from Alabama (Kelly, 1968) and Oklahoma (Jenkins, 1956) reached about 1 m total length by the end of their ninth year. Life span is unknown, but surely exceeds 20 years. Young under 125 mm feed primarily on zooplankton, while adults feed on burrowing mayflies, crayfishes, fingernail and unionid clams, and other fishes. The blue catfish is as highly esteemed as the channel catfish for its eating qualities, but it has received less attention in pond culture than that species. There has been some experimentation with blue x channel catfish hybrids for aquaculture. Maximum size conjectural, and reported up to 315 lbs.; largest reasonably confirmed record is a 150 lb specimen taken in 1879 (see Pflieger, 1975). Tennessee record is a 130 lb (59 kg), 1.55 m (5 ft) specimen from the Prater Flats area of Ft. Loudon Reservoir, taken by J. C. Garland, Bill Norman, and Richard Reagan on 18 December 1976.

Distribution and Status: Widespread in Mississippi Basin, and in Gulf drainages from Mobile Basin west and south through Texas, Mexico, and northern Guatemala. Widely introduced elsewhere. The blue catfish has decreased in abundance and range in recent years, presumably due to the effects of impoundments and siltation. One possible reason for its lack of tolerance of impounded rivers is associated with its being more migratory than other catfishes (Pflieger, 1975). In Tennessee, healthy populations persist in the French Broad River and Douglas Reservoir, main channel impoundments of the Tennessee River, and the Mississippi River and the lower reaches of its largest tributaries. Even in its preferred habitats the blue catfish is typically much less common than the channel catfish.

Similar Sympatric Species: Adult channel catfish tend to lose their dark spots and are often misidentified as blue catfish. Characters utilized in the key should be adequate to separate the species. In addition, the swimbladder of the channel catfish is not constricted, the profile from the dorsal spine to the snout is rounded (straight to concave in the blue catfish), and the channel catfish has a larger and more dorsally placed eye than the blue catfish.

Etymology: *furcatus* = forked, referring to the deeply forked caudal fin.

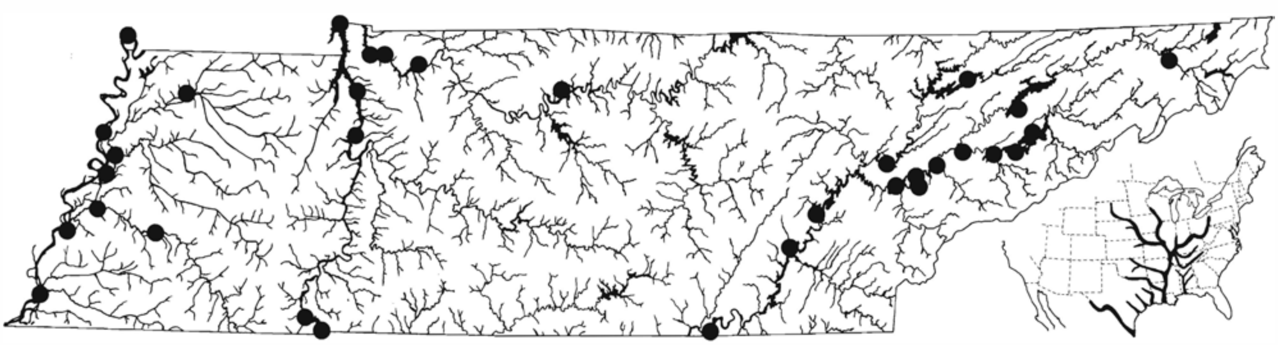
Ictalurus punctatus (Rafinesque)

Channel catfish

Characters: Anal fin rays usually 24–27. Other fin rays as listed for white catfish. Gill rakers 14–18. Post-Weberian vertebrae 42–45. Pectoral spine with well-developed posterior serrae (Fig. 101). Color pale gray to olive dorsally, white to yellowish ventrally. Sides of young and often of adults with scattered dark spots. Median fins with dusky to black borders.

Biology: The channel catfish is most typically an inhabitant of medium to large warm rivers with alternating pool and riffle habitats where it spends daylight hours associated with some cover in quiet pool areas and forages in both pools and swifter waters from dusk until dawn. It is perhaps the most versatile catfish and has

Figure 101. Pectoral spine of *Ictalurus punctatus*.



Range Map 130. *Ictalurus furcatus*, blue catfish (native range extends off inset south to Guatemala; introduced populations east and west of native range not shown).

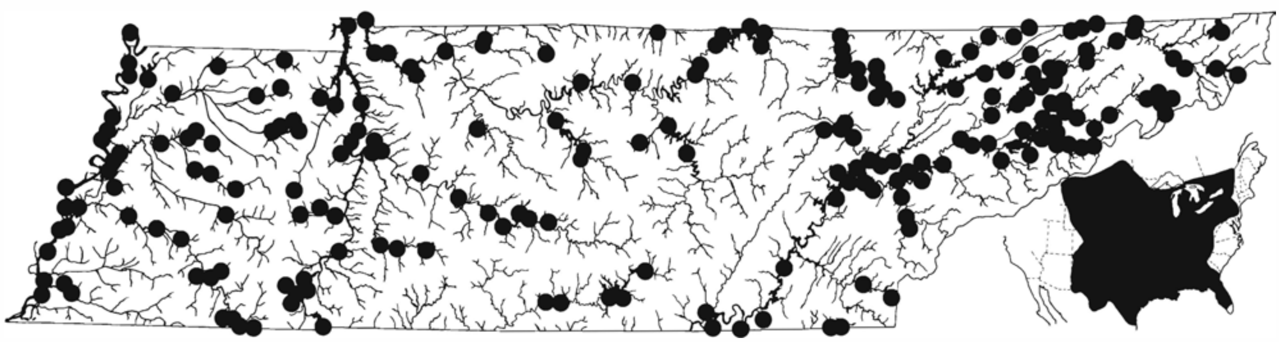
Plate 134a. *Ictalurus punctatus*, channel catfish, 410 mm SL, Reelfoot L., TN.

Plate 134b. *Ictalurus punctatus*, channel catfish, juvenile, 148 mm SL, Mississippi R., TN.

adapted to additional habitats such as reservoirs, natural lakes, farm ponds, and even larger trout streams. Because of its adaptability, excellent food quality, and value to commercial fisheries, its biology has been extensively studied both in natural environments and in relation to pond and cage culture. Methods and techniques for rearing marketable channel catfish vary with area of the country and are typically available free of charge from state agricultural extension services. Catfish aquaculture is extremely important in the economies of such areas as the Mississippi Delta region of Mississippi, and many tons of fillets are produced and exported to distant markets, including overseas.

The voluminous literature concerning the biology of the channel catfish has been well summarized in Carlander (1969), Scott and Crossman (1973), and Becker (1983). Spawning typically occurs during late spring or early summer at water temperatures of 22–30 C. Females may lay from 2,000 to 70,000 eggs per year, depending on fish size. Breeding behavior is apparently very similar to that described for bullheads. Natural reproduction in clear ponds often requires the addition of various spawning shelters such as submerged tires, small barrels, or other such cover. The male is apparently responsible for guarding the nest and young. Juveniles are insectivores, feeding on midge and caddis larvae in addition to a wide variety of other small aquatic invertebrates. Adults may feed almost exclusively on other fish, but typically also consume crayfish, mollusks, immature mayflies and caddisflies, and occasional aquatic vegetation. The imaginative array of typically smelly baits used by anglers, ranging from shad and chicken innards to soap, bananas, cheese, and doughballs, suggests that any sort of organic material is potential food. Adults are often taken unintentionally on various artificial lures. Channel catfish are fast and powerful swimmers and provide excellent sport when taken by angling. Growth is extremely variable, with the following respective ranges of total lengths (Carlander, 1969) expected through the first 8 years of life in our area: 86–163, 170–239, 206–290, 241–333, 269–366, 295–404, 325–427, and 462–495 mm. Sexual maturity is attained at about 270 mm, usually at age 3. Maximum age is about 24 years, but in southern populations normal life expectancy is probably about 15 years. Carroll and Hall (1964) recorded specimens to 8 years of age in Norris Reservoir attaining 540 mm TL. Maximum size (Stevens, 1959) attained in recent specimens from Santee-Cooper Reservoir in South Carolina, with specimens of 62, 60, 55, and 52 lbs. (23.6–28.2 kg) reasonably well documented, and a 34 kg (75 lb) specimen witnessed by several people. Since blue and flathead catfish were at that time unknown from this reservoir, we are inclined to accept this record. Undocumented hearsay records of channel catfish in this size range from the Kentucky Reservoir area are not uncommon, but the possibility of misidentified blue catfish or blue x channel catfish hybrids must be considered. Tennessee record is a 18.6 kg (41 lb) fish from Fall Creek Falls Lake, Clint Walters Jr., 30 July 1982.

Distribution and Status: Native range uncertain, but including all central drainages of United States and



Range Map 131. *Ictalurus punctatus*, channel catfish (approximate native range shown in inset; widely introduced both east and west of this range).

southern Canada, and probably some Atlantic slope drainages of northern and southern United States; widely introduced. Widespread and abundant throughout Tennessee.

Similar Sympatric Species: Most similar to and often confused with the much less common blue catfish. This is especially true of adults during the breeding season, who often lose their dark lateral spots and develop a bluish color. The number of anal fin rays and shape of the anal fin are diagnostic at all sizes.

Etymology: *punctatus* = spotted.

Genus *Noturus* Rafinesque
The Madtoms

Taylor's (1969b) monographic treatment of the genus *Noturus*, commonly called the madtoms, contains a great deal of information concerning this interesting group of fishes. Much of the information to follow appears in Dr. Taylor's treatise. Grady (1988) has recently been investigating interrelationships through biochemical studies. The closest relative to madtoms is considered to be the highly derived subterranean form, *Prietella phreatophila* Carranza, of Mexico (Lundberg, 1982). Madtoms are generally too small to be of any food value, but *N. phaeus* and *N. stigmosus* reach total lengths of 175–200 mm (7–8 in), while specimens of *N. flavus* from the Midwest may exceed a foot in length (Trautman, 1981). Madtoms can be extremely difficult to collect. Streams that will not yield a single madtom to seining during daylight hours occasionally produce madtoms in abundance when seining after dark. They may actually bury themselves under several inches of gravel and rely on interstitial water during daylight hours (Stegman and Minckley, 1959). The madtoms, like the other ictalurids, are presumably rather opportunistic feeders, preying on aquatic invertebrates and small fishes, as well as scavenging. Feeding is primarily nocturnal.

There are three recognized subgenera in the genus *Noturus* (but see Systematics comments under *Noturus flavus*). Members of the subgenus *Rabida* are typically boldly patterned in black and yellow, have curved pectoral fin spines that are heavily armed with recurved posterior serrae, and often occupy gravel substrates swept by currents. Of the 15 species included in the subgenus, nine occur in Tennessee; others are *N. albater* Taylor, *N. flavater* Taylor, *N. placidus* Taylor, and *N. taylori* Douglas of the Ozark-Ouachita region, *N. trautmani* Taylor, known from a single stream in Ohio, and *N. furiosus* Jordan and Meek of the Tar and Neuse drainages of North Carolina. The subgenera *Schilbeodes* and *Noturus* (considered a single subgenus by LeGrande, 1981, who studied chromosomes) are not boldly patterned, and have straight pectoral fin spines and reduced serrae. Members of the subgenus *Schilbeodes* frequently occupy quiet waters with soft substrates. Six of the ten species allocated to *Schilbeodes* occur in Tennessee; others are *N. gilberti* Jordan and Evermann from the Roanoke River in Virginia, *N. funebris* Gilbert and Swain from eastern Gulf coastal drainages, *N. lachneri* Taylor from the Ouachita region, and an undescribed form from Lake Waccamaw, North Carolina. Subgenus *Noturus* contains only *N. flavus*.

Etymology: *Noturus* = back tail, in reference to the fusion of the adipose fin to the caudal fin.

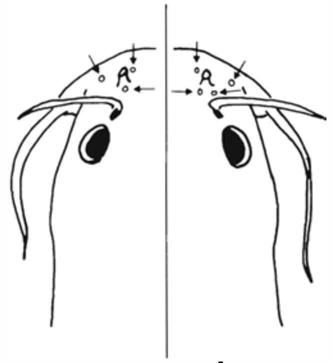
KEY TO THE TENNESSEE SPECIES

1. Dorsal surface marked with 3 or 4 pale saddles (located behind head, under dorsal fin, anterior to adipose fin, and posterior to adipose fin) except in *N. eleutherus*; posterior serrae on pectoral fin spine as long as diameter of the spine; pectoral spine with posterior margin concave and the posterior serrae recurved toward the body (Figs. 104–106): Subgenus *Rabida* 8
   Dorsal surface uniform gray, lacking pale saddles, or with only two pale saddles (posterior to head and under posterior edge of dorsal fin in *N. flavus* and *N. exilis*); posterior pectoral fin serrae not nearly as long as diameter of spine (except in *exilis*, *insignis*, and *phaeus*); pectoral fin spine with posterior margin straight and with posterior serrae, if present, not recurved toward body (Figs. 107, 109) 2
2. Pale dorsal areas behind head and at posterior end of dorsal fin; premaxillary tooth patch with posterior extensions (Fig. 102a); posterior pectoral fin serrae less developed than anterior serrae .... *N.* (*Noturus*) *flavus* p.317
   Dorsum uniform gray (except in *N. exilis*); premaxillary tooth patch lacking posterior extensions (Fig. 102b); anterior pectoral fin serrae never longer than posterior serrae; subgenus *Schilbeodes* 3

Figure 102. Premaxillary tooth patches of madtoms: a) *Noturus flavus*; b) *N. insignis*.

3. Pectoral fin spine with prominent posterior serrae (Figs. 107, 112, 117) 4
   Pectoral fin spine lacking distinct posterior serrae (Figs. 113, 116) 6
4. Dorsal, caudal, and anal fins with dark submarginal bands; east and middle Tennessee 5
   Dorsal, caudal, and anal fins with dark pigment extending from base to pale marginal band; west Tennessee .... *N. phaeus* p.326

5. Preoperculomandibular canal pores 10; 3 pores surrounding anterior nostril (Fig. 103a); middle Tennessee and Cumberland River drainage, east Tennessee . . . . *N. exilis* p.314
Preoperculomandibular canal pores 11; 4 pores surrounding anterior nostril (Fig. 103b); North Fork Holston and Watauga river systems of east Tennessee . . . . *N. insignis* p.320



a b

Figure 103. Pores surrounding anterior nostril of madtoms: a) *Noturus exilis*; b) *N. insignis*.

6. Upper and lower jaws equal (Pl. 141) . . . . *N. gyrinus* p.318
Upper jaw extending well past lower jaw 7
7. Pelvic fin rays 8, rarely 7 or 9; total caudal fin rays 54 or fewer, rarely 55 or 56; Conasauga River and its tributaries . . . . *N. leptacanthus* p.321
Pelvic fin rays 9, rarely 8 or 10; total caudal fin rays 55–64; Tennessee, Cumberland, and Mississippi river drainages . . . . *N. nocturnus* p.325
8. Dorsal fin without pigment except on spine (and on posterior rays in *N. baileyi*) 9
Dorsal fin well pigmented throughout, or with a conspicuous dark blotch posterior to spine 12
9. Adipose fin virtually lacking pigment 10
Adipose fin with broad, dark bar in middle that extends at least halfway to margin of fin 11
10 Anterior serrae well developed on pectoral fin spine (Fig. 118), known only from Clinch and Duck rivers . . . . *N. stanauli* p.327
Anterior serrae virtually absent on pectoral fin spine (Fig. 111); direct tributaries to Mississippi River in west Tennessee . . . . *N. hildebrandi* p.319
11. Anal fin rays 12–13 (rarely 14); pelvic fin rays usually 8; pale dorsal saddles not extending down sides, scarcely visible in lateral view (Pl. 135); Citico Creek and formerly from Abrams Creek, both tributaries to the Little Tennessee River . . . . *N. baileyi* p.311
Anal fin rays 15 or more (rarely 14); pelvic fin rays usually 9 or 10; pale dorsal saddles extend down sides and are easily visible in lateral view (Pl. 136); east and middle Tennessee, but not known from Little Tennessee River system . . . . *N. elegans* p.312
12. Adipose fin with dark vertical bar in middle that extends to or nearly to fin margin (Pls. 139, 145, 146); dorsum and caudal fin boldly patterned with pale and dark areas 13
Adipose fin lacking dark vertical bar (Pl. 137), but may range from being uniformly darkly pigmented to having a dark band along much of base of fin; dorsum and caudal fin mottled, not boldly marked except in occasional juveniles . . . . *N. eleutherus* p.313
13. Black bar under middle of adipose fin extends down and back to connect with the basicaudal dark blotch; caudal fin typically with two black bands (Pls. 146, 150); total caudal fin rays 54 or fewer 14
Black bar under middle of adipose fin separate from basicaudal blotch; caudal fin typically with a single submarginal band (Pl. 139, 145); caudal fin rays 56 or more 15
14. Confined to the Conasauga River; head length contained 2.8–3.2 times in standard length . *N. munitus* p.324
Confined to the Mississippi River and its direct tributaries in west Tennessee; head length contained 3.2–3.5 times in standard length . . . . *N. stigmosus* p.328

15. Basicaudal bar does not reach dorsal or ventral margins of caudal fin (Pl. 145); middle and west Tennessee and Cumberland River drainage of east Tennessee .... *N. miurus* p.322
Basicaudal bar extends to or nearly to dorsal and ventral margins of caudal fin (Pl. 139); extremely rare, upper Tennessee River drainage .... *N. flavipinnis* p.315

Noturus baileyi Taylor

Smoky madtom

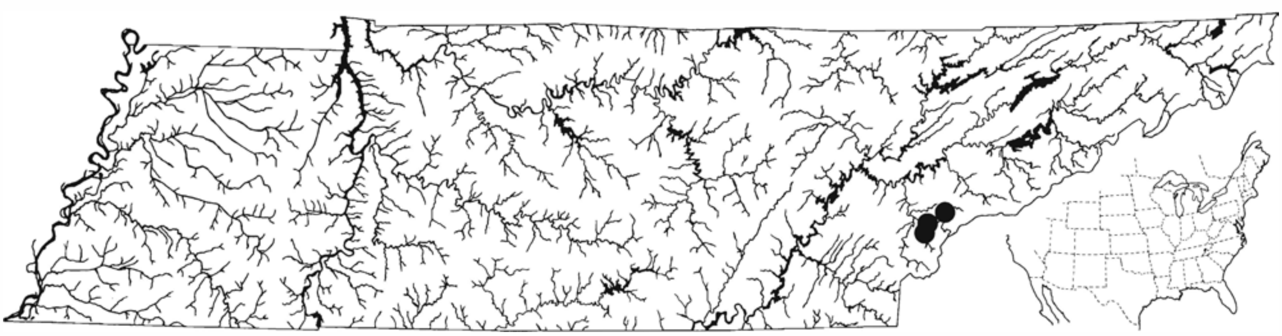
Plate 135. *Noturus baileyi*, smoky madtom, 40 mm SL, Little Tennessee R. system, TN.

Characters: Anal fin rays 12–13 (12–14). Soft pectoral fin rays 8. Pelvic fin rays 8 (7–9). Total caudal fin rays 42–49. Internasal pores usually 2, preoperculomandibular canal pores 11. Gill rakers 5–8. Post-Weberian vertebrae 33–34. Pectoral fin spine (Fig. 104) with anterior serrae virtually absent, posterior serrae moderately developed. Dorsal fin virtually immaculate except for brown pigment on spine. Adipose fin with broad dark bar extending to or nearly to dorsal margin. Pale yellow areas on dorsal midline (at posterior dorsal fin base and both ends of adipose fin) extend little on sides and are barely noticeable in lateral view. Caudal fin with vague pale and dark vertical bands.

Figure 104. Pectoral spine of *Noturus baileyi* (drawn by G. Dinkins).

Biology: The smoky madtom is currently known from only a 4.2-km portion of Citico Creek in Monroe County, Tenn., where in the summer and fall it inhabits areas transitional between pools and riffles with depths of about 25 cm and gravel substrates interspersed with rounded cobbles and small boulders. In the winter and spring it inhabits gentle runs and pools. It is a very secretive species, quickly fleeing after being exposed by a flashlight beam at night, and typically retreating under a boulder. Dinkins (1984) provided life history information. As is typical for madtoms, eggs are deposited in a cavity beneath a large rock or other shelter, and are guarded by the male. Active nests were found from early June to late July, at water temperatures of 19–24 C (64–74 F). Estimated averaged number of eggs per nest is about 36. Length-frequency distribution of Citico Creek specimens indicated first year's growth to be about 36 mm, sexual maturity at age 2 at about 50 mm SL, and a life span of 4 years. Maximum total length 73 mm (2.9 in).

Distribution and Status: Until its recent rediscovery in Citico Creek, Monroe County, Tenn. (Bauer et al., 1983), the smoky madtom was known only from the five original types collected from the lower portion of Abrams Creek on 8 June 1957. The specimens were collected in a "rough fish" removal project designed to remove competition for trout. Numerous additional collections from lower Abrams Creek and from other similar habitats in the Little Tennessee River system have been conducted with the purpose of locating additional populations, but have failed. The Abrams Creek population is believed to be extirpated. Since *N. baileyi* is



Range Map 132. *Noturus baileyi*, smoky madtom.

known only from a 4.2-km portion of Citico Creek (estimated population about 700), it certainly warrants its Endangered status. The entire watershed of Citico Creek above and including the smoky madtom habitat is in the Cherokee National Forest, a circumstance affording it considerable protection. Forest Service officials are cognizant of its Endangered status, but an accidental chemical spill or increased acidity due to run-off from sulfate rich Anakeesta shales in the watershed could quickly eliminate the only known population. A recovery plan (Biggins, 1985) has been conceived to try to improve the species's status. Attempts to reestablish a population in Abrams Creek, using Citico Creek specimens and captive-reared progeny, are underway.

Similar Sympatric Species: *Noturus eleutherus* and *N. flavipinnis* have prominent anterior serrae on the pectoral fin spine (Figs. 106, 108) and extensive dark pigment on dorsal fin rays. Also, potentially sympatric with both *N. stanauli* and an *N. elegans* form that occurs in the upper Tennessee drainage. Both of these have more prominent anterior pectoral spine serrae (Figs. 105, 118) and 14 or more anal fin rays (12–13 in *N. baileyi*, with only 1 of 15 specimens with 14 rays).

Systematics: Subgenus *Rabida*. *Noturus baileyi* is thought to be allied with *N. hildebrandi* and *N. stanauli* (Taylor, 1969b; Etnier and Jenkins, 1980); Grady (1988) hypothesized *stanauli* to be its closest relative.

Etymology: The species epithet is a patronym for Dr. Reeve M. Bailey, eminent ichthyologist at the University of Michigan.

Noturus elegans Taylor

Elegant madtom

Plate 136. *Noturus elegans*, elegant madtom, 53 mm SL, Barren R. system, TN.

Characters: Anal fin rays 14–19. Soft pectoral fin rays 8 (8–9). Pelvic fin rays 9 (8–10). Total caudal fin rays 46–55. Internasal pores usually 2 (1–2), preoperculomandibular canal pores 11 (10–12). Gill rakers 4–8.

Figure 105. Pectoral spine of *Noturus elegans* (drawn by G. Dinkins).

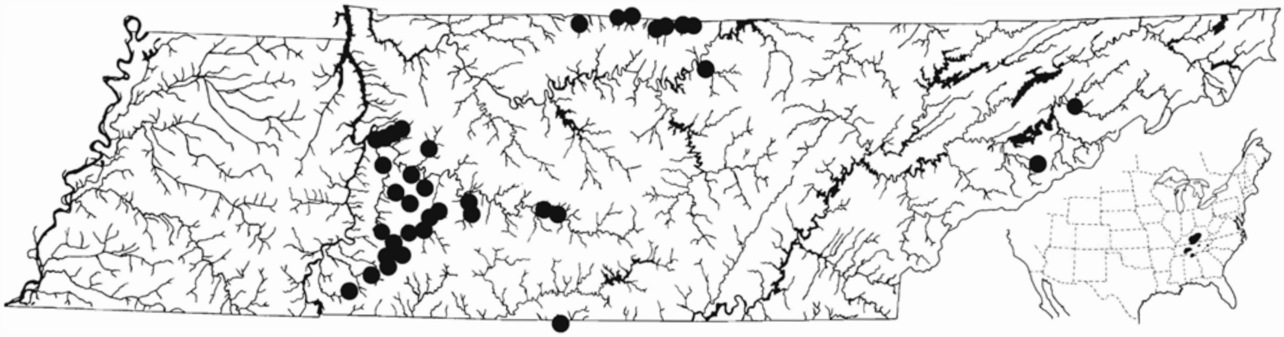
Post-Weberian vertebrae 34–37. Pectoral fin spine with prominent posterior serrae and very small anterior serrae (Fig. 105). Color dark brown to gray dorsally with four pale saddles; mottled brown or gray on sides; yellow to white on belly. Distinct crescent-shaped pale areas at caudal fin base and middle of fin.

Biology: *Noturus elegans* is an inhabitant of gravel shoal or shallow pool areas in habitats ranging from small creeks to small rivers. R. W. Bouchard (pers. comm.) noted the tendency of specimens from the Duck and Buffalo river systems to concentrate in areas of darkened gravel particles. Burr and Dimmick (1981) located three nests in Barren Co., Ky., on 22 June, with water temperature 20 C (68 F). The nests, located under slabrocks in gently flowing pools, were each attended by a male. Two of the nests contained 20–30 sac fry, and the third had a clutch of 25 eggs. Maximum length 81 mm (3.15 in).

Distribution and Status: Occurs in Ohio, Cumberland, and Tennessee drainages. The elegant madtom is extremely rare except in Highland Rim streams of lower Duck and Buffalo rivers, smaller tributaries to the Tennessee River in southern Tennessee and northern Alabama, and Barren River system of Tennessee and Kentucky where it is locally abundant.

Similar Sympatric Species: No other members of the subgenus *Rabida* are typically found in areas where *elegans* occurs. Occasionally sympatric with *eleutherus*, which lacks distinct pale dorsal saddles and has prominent anterior pectoral fin serrae (Fig. 106); *miurus*, which has prominent anterior pectoral fin serrae (Fig. 114) and 56 or more caudal fin rays; and *stanauli*, which typically has eight pelvic rays and lacks dark pigment in the adipose fin. Both *eleutherus* and *miurus* have extensive dark pigment on dorsal fin rays.

Systematics: Subgenus *Rabida*, probably closely related to *N. hildebrandi* species group (LeGrande, 1981). *Noturus elegans* may actually be a complex of several species. Specimens from the Duck and Buffalo river tributaries and adjacent Indian Creek (Wayne County) are boldly marked with sharply contrasting



Range Map 133. *Noturus elegans*, elegant madtom.

pale yellow and chocolate brown dorsal saddles. Specimens from the Barren River system in Clay and Macon counties are similar in body shape, but have much more subdued pigmentation. Additional University of Tennessee (UT) and University of Michigan Museum of Zoology (UMMZ) specimens tentatively identified as *N. elegans* are known from the Flint River system, Madison County, Alabama (UT 48.8); Piney Creek system, Limestone County, Alabama (UMMZ 165887); Dunn Creek at mouth of Yellow Breeches Creek, Sevier County, Tennessee (UMMZ 131386); Little Chucky Creek mile 4, Greene County, Tennessee (UT 48.724); Roaring River 2 miles above mouth, Jackson County, Tennessee (UMMZ 168262); and Ruin Creek, Elliott County, Kentucky (UT 48.283). All of these appear to have the subdued pigmentation typical of the Barren River specimens but tend to be heavier bodied. In addition, two specimens that have subdued pigmentation and are markedly different in appearance from the boldly patterned specimens from Duck River tributaries are available from the main channel of the Duck River in Bedford County (UT 48.299). So far, conventional meristic, morphometric, and pigmentation comparisons have provided insufficient information to determine the taxonomic status of these populations. A biochemical investigation of the problem is in progress by J. M. Grady and B. M. Burr.

Etymology: *elegans* = elegant, referring to the handsome pigment pattern.

Noturus eleutherus Jordan

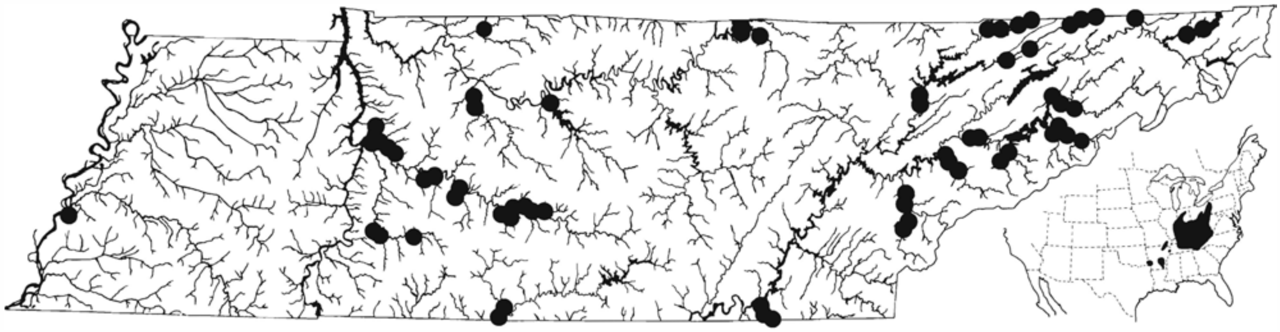
Mountain madtom

Characters: Anal fin rays 12–16. Soft pectoral fin rays 8 (7–9). Pelvic fin rays 9 (8–10). Total caudal fin rays 42–50. Internasal pores 2, preoperculomandibular canal pores 10 (8–11). Post-Weberian vertebrae 31–32. Pectoral fin spine with both anterior and posterior serrae well developed (Fig. 106). Color mottled brown dorsally with dark blotches beneath the dorsal-fin origin, behind dorsal fin, and in base of adipose fin; blotches variable, indistinct in some populations. Fins mottled.

Plate 137. *Noturus eleutherus*, mountain madtom, 37 mm SL, Red R., TN.

Biology: The mountain madtom is an inhabitant of coarse gravel and rubble riffle areas in moderate to large rivers. It avoids small streams and reaches peak abundance in shoal areas in rivers such as the Clinch above Norris Reservoir, the lower Duck River, and the middle and lower Wabash River in Indiana and Illinois. Starnes and Starnes (1985) studied biology of east Tennessee populations. Spawning occurred primarily in June. Females 51–59 mm SL (62–73 TL) produced 55–115 eggs per year, with an average of 91 over all size groups of mature females. A single nest, guarded by a large male and found under a flat rock in a shaded pool on 2 July, .7 m deep, water temperature 24 C (75 F), contained 70 eggs nearly ready to hatch. Development through 14 days was described. Food of both young and adults was exclusively larvae of aquatic insects, domi-

Figure 106. Pectoral spine of *Noturus eleutherus* (drawn by G. Dinkins).



Range Map 134. *Noturus eleutherus*, mountain madtom.

nated in both number and biomass by mayflies (mostly Baetidae). Diptera (midges and blackflies), hydropsychid caddisflies, and stoneflies were also important food items. Feeding commenced at dusk, and most individuals had full stomachs within 4 hours. At the end of 1, 2, and 3 years of growth, the largest specimens were 27 mm SL (35 mm TL), 37 (47), and 47 (58), respectively. A life span of 4 years was indicated. Trautman (1957) indicated that Ohio specimens reached lengths of 36–64 mm TL after 1 year's growth, were sexually mature at 56 mm TL, and maximum length was 127 mm (5 in). We have not seen specimens larger than 85 mm TL from Tennessee.

Distribution and Status: Ohio, Cumberland, and Tennessee river drainages, and, west of the Mississippi River, in the White, Ouachita, and Red river systems of Missouri, Arkansas, and Oklahoma. We have a single specimen from the main channel of the Mississippi River. In Tennessee, the mountain madtom is locally common in unimpounded rivers of the Ridge and Valley and Highland Rim.

Similar Sympatric Species: *Noturus miurus* and *N. flavipinnis* both have 54 or more caudal fin rays and have a vertical black band in the adipose fin that extends to or nearly to the margin of that fin. In *eleutherus*, dark pigment in the adipose fin forms a horizontal bar along its base. Differs from *N. stanauli* in several merisitic characters and in having a distinctly curved pectoral spine, darkly pigmented lower sides, and dark pigmentation covering most of the dorsal fin. Also see *N. baileyi*.

Systematics: A member of the subgenus *Rabida*, hypothesized to be closest related to *N. taylori* of the Ouachita system (LeGrande, 1981). Based on biochemical evidence Grady (1988) and chromosomal studies (LeGrande, 1981), this pair was hypothesized to have a close relationship to a group comprised of *N. munitus*, *N. stigmosus*, and *N. placidus*.

Etymology: *eleutherus* = free, in reference to the rather incomplete fusion of the posterior portion of the adipose fin to the body in this species.

Noturus exilis Nelson

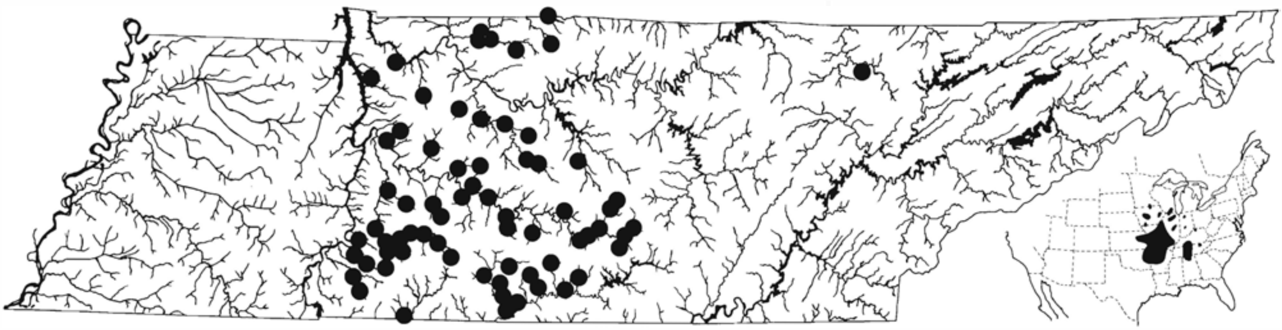
Slender madtom

Plate 138. *Noturus exilis*, slender madtom, 68 mm SL, Red R., TN.

Characters: Anal fin rays 17–22. Soft pectoral fin rays 9 (8–10). Pelvic fin rays 9 (8–10). Total caudal fin rays usually 46–55. Internasal pores 1 (1–2), preoperculomandibular canal pores 10 (10–11). Gill rakers 5–8. Post-Weberian vertebrae 36–41. Pectoral fin spine (Fig. 107) with well-developed posterior serrae. Color gray dorsally, pale yellowish or white ventally. Dorsal, anal, and caudal fins pale at base and margined with black.

Biology: The slender madtom is an inhabitant of gentle riffles and flowing pools in small streams with coarse gravel to slabrock substrates. Mayden and Burr (1981)

Figure 107. Pectoral spine of *Noturus exilis* (drawn by G. Dinkins).



Range Map 135. *Noturuxs exilis*, slender madtom.

provided detailed biological information from a southern Illinois population. Reproductive activity was concentrated from mid June through July at water temperatures of 23.5–29 C. Spawning sites were cavities excavated under large rocks, usually in pool areas. Each nest was guarded by a male (a female was occasionally present during early stages of nesting), who remained with young until after yolk sac absorption. Nests contained an average of 51 eggs (27–74), about half the number of mature eggs produced per female per year (26–150, mean = 84), suggesting multiple spawning by females. Standard lengths of 50, 70, and 76 mm were reached at the end of 1, 2, and 3 years of growth. Sexual maturity normally occurred after 2 years in both males and females, but some age class 0 females were thought to be sexually mature at lengths of as little as 46 mm. A life span of 5 years was indicated. Feeding activity was primarily just before dawn and just after dusk. Diet consisted primarily of aquatic insect immatures (midges, mayflies, caddisflies) and small crustacea (isopods, amphipods, copepods). In northeastern Oklahoma (Vives, 1986), biology was similar but growth was somewhat slower (46, 57, and 68 mm SL at ages 1, 2, and 3), a larger percentage of females matured during their first year, eggs were somewhat larger, and mayfly and midge larvae were more dominant in stomachs examined. Maximum total length (Pflieger, 1975) about 6 in. We have an Arkansas specimen 137 mm (5.4 in) long.

Distribution and Status: Central portion of the Mississippi River basin, but most abundant in Ozarkian streams. Generally uncommon in Tennessee, where most records are from the Highland Rim and Nashville Basin.

Similar Sympatric Species: *Noturus flavus* and *N. nocturnus* are rather similar in shape and coloration. Both of these species lack well-developed posterior serrae on the pectoral fin spine and usually lack dark marginal bands on the median fins.

Systematics: Subgenus *Schilbeodes*. *Noturus exilis* is most similar in appearance to the allopatric *N. insignis*, and presumably closely related to that species (LeGrande, 1981); however, Grady (1988) hypothesized a close relationship to *N. nocturnus*.

Etymology: *exilis* = slender.

Noturus flavipinnis Taylor

Yellowfin madtom

Plate 139. *Noturus flavipinnis*, yellowfin madtom, 60 mm SL, Clinch R. system, VA (photo N.M. Burkhead & R.E. Jenkins).

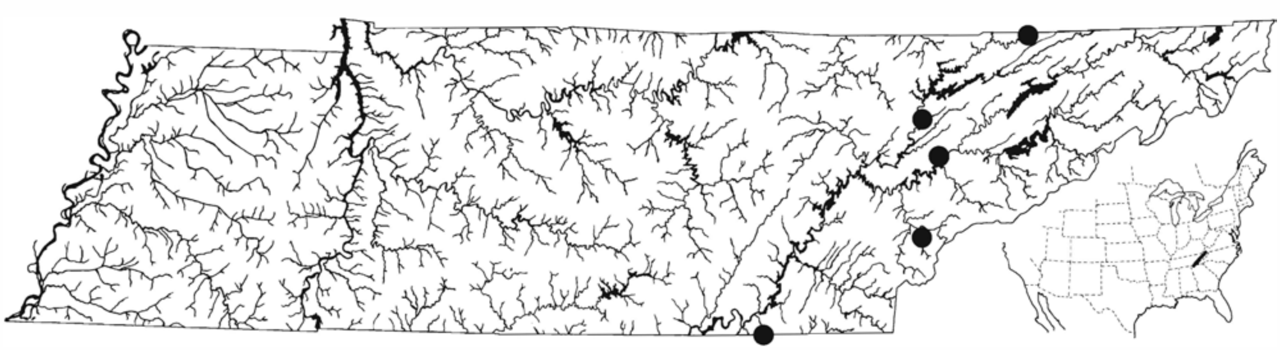
Characters: Anal fin rays 14–16. Soft pectoral fin rays 7–8. Pelvic fin rays 8, rarely 7. Total caudal fin rays 54–63. Internasal pores 2, preoperculomandibular canal pores 10–11 (9–12). Gill rakers 4–8. Post-Weberian vertebrae 34–35. Pectoral spine (Fig. 108) with both

Figure 108. Pectoral spine of *Noturus flavipinnis* (drawn by G. Dinkins).

anterior and posterior serrae well developed. Color yellowish dorsally, white ventrally. Nape area dark; dark blotches beneath dorsal-fin origin, behind dorsal fin, and in adipose fin base; crescent-shaped blotch traversing caudal-fin base. Median fins banded with dark mottling.

Biology: Habitat differs considerably in the three known localities where this madtom persists, ranging from the small, pristine, silt-free trout waters of Citico Creek in Monroe Co., Tenn., to the much larger, warm, and very silty Powell River near the Virginia border in Hancock County, Tenn. The historical range of the yellowfin madtom also suggests considerable habitat plasticity. It occupies pool areas and is associated with cover in the daytime in the form of brush piles, sunken leaves, bedrock crevices, and water willow beds. In Citico Creek it is virtually invulnerable to daytime collection by seining or electrofishing, but is easily located and captured in open areas of pools with handnets (or bare hands!) while snorkeling at night (Bauer et al., 1983). Daytime seining in the more abundant cover in Copper Creek, Virginia, and in Powell River, has produced specimens. Additional biological information for the Citico Creek population was provided by P. W. Shute (1984). Spawning is as described for other madtoms, with males guarding clutches of 30 to over 100 eggs in cavities under large flat slab-rocks from late May to mid July with water temperatures of 18–21 C (65–70 F). Females may spawn at least twice per season, since their complement of mature eggs is about twice the average number per nest. Young reach lengths of about 50 mm after one summer's growth. Sexual maturity occurs at about 100 mm, and life span is estimated to be 3 to 4 years. Maximum total length 134 mm (5.25 in).

Distribution and Status: *Noturus flavipinnis* was apparently widespread in the upper half of the Tennessee River drainage prior to 1893, with records available from North Fork Holston River at Saltville, Virginia; Clinch River at Walkers Ford, Union County, Tennessee (now Norris Reservoir); Lyons Creek at Tennessee River, Knoxville, Tennessee (now Fort Loudon Reservoir); Hines Creek, Anderson County, Tennessee; and Chickamauga Creek in north Georgia. Burkhead and Jenkins (1982b) have questioned the validity of the Clinch River and Lyons Creek records. The occurrence of the closely related *N. miurus* in the Elk River system may indicate that the range of *flavipinnis* was confined upstream of that system in the Tennessee River drainage. The yellowfin madtom was considered as "possibly extinct" by Taylor (1969b). In 1968 Richard Fitz and TVA biologists collected a single specimen in Powell River at Alanthus Hill, Hancock County, Tennessee (Taylor et al., 1971). Two additional specimens have recently been collected from that area. In 1969 Robert E. Jenkins discovered a healthy population in Copper Creek, a large Clinch River tributary in Scott County, Virginia, and specimens were quite easily taken in Copper Creek for the next 5 years or so. The number of specimens taken by ichthyologists over this time span (probably fewer than 100 specimens) was certainly not enough to result in depletion. In 1979 we were able to collect only a single large adult after considerable effort at several choice Copper Creek localities. Hopefully, this is the result of long-term population fluctuation, but its continued rarity in Copper Creek (Burkhead and Jenkins, 1982b; pers. comm. R. E. Jenkins, 1992) suggests that this population may be disappearing. The population represented by the three Powell River specimens is apparently a very small one, and it continues to be threatened by coal- and gravel-mining operations in and near the upper Powell River. The November 1983 capture of a single specimen from that area (P. W. Shute, 1984) is encouraging. Several attempts to visually search for specimens there with night-time snorkeling were very inefficient due to constant high turbidity



Range Map 136. *Noturus flavipinnis*, yellowfin madtom.

relative to Citico Creek waters, so the strength of this population continues to be difficult to assess. Mark-and-recapture population estimates in Citico Creek (P. W. Shute, 1984) suggested a population of about 500 adults in the 1.5-km stretch of the creek occupied by *N. flavipinnis*. Its relict distribution is difficult to explain in view of its wide habitat tolerance, and it may be the victim of "olfactory noise" (Etnier and Jenkins, 1980; Morison, 1983). The yellowfin madtom certainly deserves protection under endangered species legislation, and is listed as Threatened by the U.S. Dept. of Interior. Should current trends continue in Copper Creek, Endangered status would seem more appropriate. A recovery plan (USFWS, 1983b) has been devised for the species in hopes of upgrading its status. Young reared from nests taken from Citico Creek have been introduced into lower Abrams Creek in an effort to establish a population there, and captive rearing and additional transplant efforts are underway.

Similar Sympatric Species: *Noturus eleutherus* has 50 or fewer caudal fin rays, has indistinct dorsal saddles, and lacks the vertical black bar at the caudal base and vertical black bar extending from the mid base of the adipose fin to its margin.

Systematics: A member of the subgenus *Rabida*, probably most closely related to *N. miurus* (Taylor, 1969b; LeGrande, 1981).

Etymology: *flavipinnis* = yellow fin.

Noturus flavus Rafinesque

Stonecat

Plate 140. *Noturus flavus*, stonecat, 130 mm SL, Mississippi R., TN.

Characters: Anal fin rays 15–18. Soft pectoral fin rays 10 (9–11). Pelvic fin rays 9 (8–10). Total caudal fin rays 55–67. Internasal pores 2 (rarely 1), preoperculomandibular canal pores 11 (10–12). Gill rakers 6–7. Post-Weberian vertebrae 37–41. Pectoral fin spine lacking posterior serrae and with 3 or 4 anterior barbs near tip (Fig. 109). Color tan to gray dorsally with pinkish or yellowish to white lower sides and belly. Dorsum with

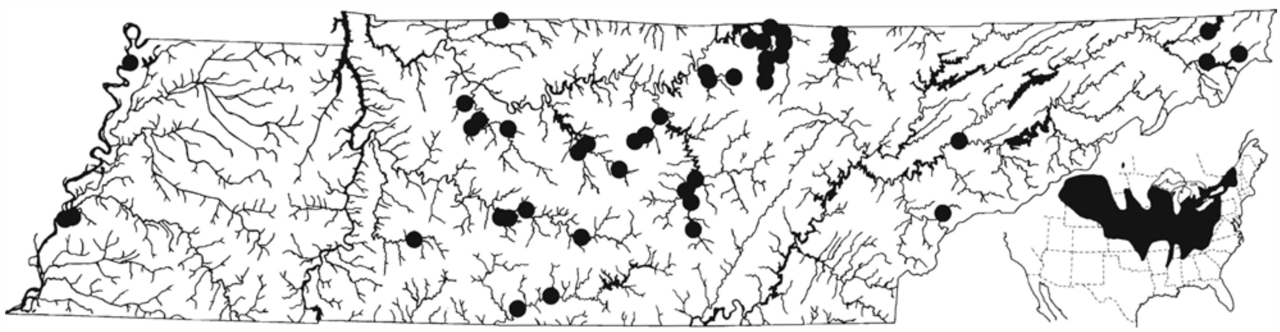
Figure 109. Pectoral spine of *Noturus flavus* (drawn by G. Dinkins).

pale areas usually present immediately behind head and at posterior end of dorsal fin base. Pale margin of caudal fin enlarged at posteriodorsal corner.

Biology: The stonecat typically occurs in moderate-sized warmwater creeks to small rivers and occupies gentle riffle areas with coarse substrates. It occasionally occurs both in tiny streams and in rivers as large as the lower Mississippi. Scott and Crossman (1973), Pflieger (1975), and Walsh and Burr (1985) summarized available biological information. Spawning in our area may occur from April to as late as July. Scott and Crossman (1973) listed peak spawning temperature in Canada as 27.8 C (82 F); Walsh and Burr (1985) recorded spawning temperatures of 25 C (77 F) and above in Missouri. Females produce 200 to 1,200 eggs per year, about 100–500 of which are laid in each nest in compact clusters beneath flat stones or similar structures. One of the parents, presumably the male, guards the nest. Young reached lengths of about 79 mm at the end of their first year in South Dakota and averaged 99, 114, and 137 mm at the ends of their second through fourth years; life span was 7 to 9 years. In Illinois and Missouri streams (Walsh and Burr, 1985) stonecats averaged 49, 100, and 123 mm SL at ages 1, 3, and 4. In these populations, sexual maturity occurred at age 3 at about 90 (males) and 100 (females) mm SL, and life span was only 5–6 years. Walsh and Burr (1985) found a wide variety of aquatic insect larvae (mayflies, stoneflies, caddisflies, midges, blackflies) in smaller specimens, while larger adults had consumed mostly mayfly larvae and crayfish. Maximum total length (Trautman, 1957) 313 mm (12.3 in).

Distribution and Status: Occurs throughout the upper Mississippi Basin, much of the Great Lakes drainage, and in the Hudson Bay drainage in the Red River. In Tennessee it is abundant only in Big South Fork of the Cumberland River, and has apparently been extirpated from much of the upper Tennessee River drainage, although it persists in the North Fork Holston and Clinch river systems in Virginia.

Similar Sympatric Species: Both *N. exilis* and *N. insignis* are very similar in shape and appearance, but have black marginal bands on median fins and well de-



Range Map 137. *Noturus flavus*, stonecat.

veloped posterior serrae on the pectoral fin spine. Somewhat similar to *N. phaeus* and *N. nocturnus*, both of which lack the pale areas behind the head, at the posterior base of the dorsal fin and at the posteriodorsal corner of the caudal fin that are typically present in *flavus*. In addition, *N. phaeus* has well-developed posterior pectoral serrae, and all four of these species lack the posterior extensions of the premaxillary tooth patch (Fig. 102) that are diagnostic for the madtom subgenus *Noturus*.

Systematics: The stonecat is the only member of the subgenus *Noturus*. However, it consistently differs from the subgenus *Schilbeodes* only in the shape of the premaxillary tooth patch. LeGrande (1981) found no convincing karyological differences between the subgenera *Noturus* and *Schilbeodes*, placed *flavus* in a phylogenetic position well within *Schilbeodes*, and questioned the validity of their continued separate recognition. We are inclined to concur with LeGrande's position. Since *Noturus* is the older name, it has priority over *Schilbeodes*. Populations in the main channel of the Mississippi and lower Missouri rivers differ noticeably from other populations in having tiny, nearly vestigial eyes. Taylor (1969b) could find no other consistent differences between these specimens and those from other populations and noted considerable variation in eye size in the latter. Additional taxonomic problems in this widespread species have surfaced subsequent to chromosome analysis based on studies of LeGrande and Cavender (1980) and Burr and Warren (1986), the latter who consider Cumberland River drainage populations to represent a distinct taxon.

Etymology: *flavus* = yellow.

Noturus gyrinus (Mitchill)

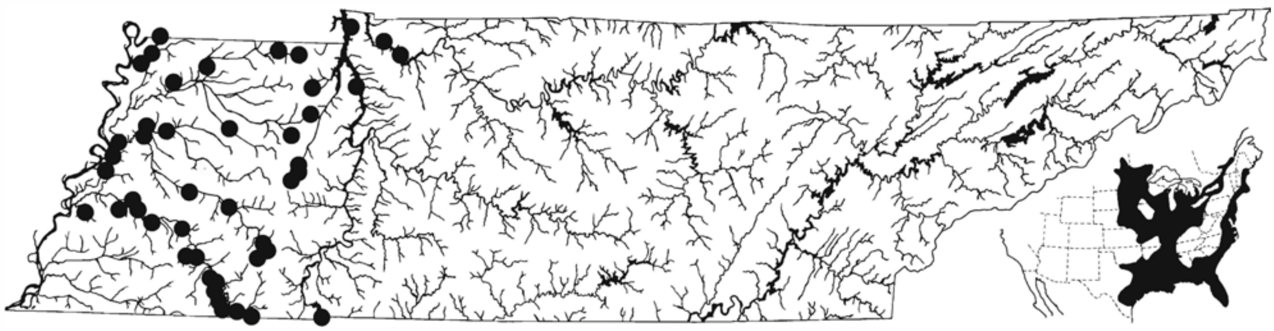
Tadpole madtom

Plate 141. *Noturus gyrinus*, tadpole madtom, 57 mm SL, Obion R. system, TN.

Characters: Anal fin rays 13–18. Soft pectoral fin rays 5–10. Pelvic fin rays 5–10. Total caudal fin rays 50–66. Internasal pores 2 (rarely 1), preoperculomandibular canal pores usually 10 (8–12). Gill rakers 5–10. Post-Weberian vertebrae 32–37. Pectoral fin spine lacking serrae (Fig. 110). Upper and lower jaws equal, as opposed to other Tennessee madtoms which have the upper jaw projecting past the lower jaw. Myosepta conspicuous as dark horizontal and oblique lines on body. Color dark gray to nearly black. Adults occasionally with a wash of orange pigment on lower jaw and throat.

Biology: The tadpole madtom is unique among madtoms in being restricted to current-free habitats with soft, highly organic substrates. It is often found in lakes, oxbows, swamps, and in quiet waters in pools or along the edges of drainage ditches and low-gradient streams. Biological information available is summarized by Scott and Crossman (1973), Pflieger (1975), and

Figure 110. Pectoral spine of *Noturus gyrinus* (drawn by G. Dinkins).



Range Map 138. *Noturus gyrinus*, tadpole madtom.

Whiteside and Burr (1986). Peak spawning month in our area is probably June. Egg clusters, averaging 50 per nest but numbering up to 117, have been found in tin cans, or under boards or other flat objects. A southern Illinois population averaged 41, 50, and 56 mm SL at ages 1–3. Maturity normally occurs at age 2, but a few males and females are sexually mature at age 1. Females in southern Illinois produced 48–323 (mean 151) eggs per year. Normal life span is 3 to 4 years. Food consists primarily of midge larvae, isopods and amphipods, and mayfly and caddis larvae; small specimens utilized cladocerans, copepods, and ostracods as well. Maximum total length 114 mm (4.5 in), but Jordan and Evermann (1896:146) indicate lengths to 5 in.

Distribution and Status: Widespread on Atlantic and Gulf coastal plain from New England to Texas, and above Fall Line in Mississippi Basin and Great Lakes and southern Hudson Bay drainages. Fairly common in and near Coastal Plain in west Tennessee, but not occurring elsewhere in the state.

Similar Sympatric Species: Most similar in shape and coloration to *N. phaeus* and *N. nocturnus*, but these species differ in having the upper jaw longer than the lower jaw, in lacking conspicuous darkened myosepta along the sides, and in having at least a few posterior serrae or anterior barbs on the pectoral fin spine.

Systematics: A member of the subgenus *Schilbeodes* whose closest relative, among described species, is presumably *N. lachneri* of central Arkansas (Grady, 1988). An undescribed species from Lake Waccamaw, North Carolina, is very similar in appearance.

Etymology: *gyrinus* = tadpole in Greek, in reference to the similarity in shape and texture of this species to tadpoles.

Noturus hildebrandi (Bailey and Taylor)

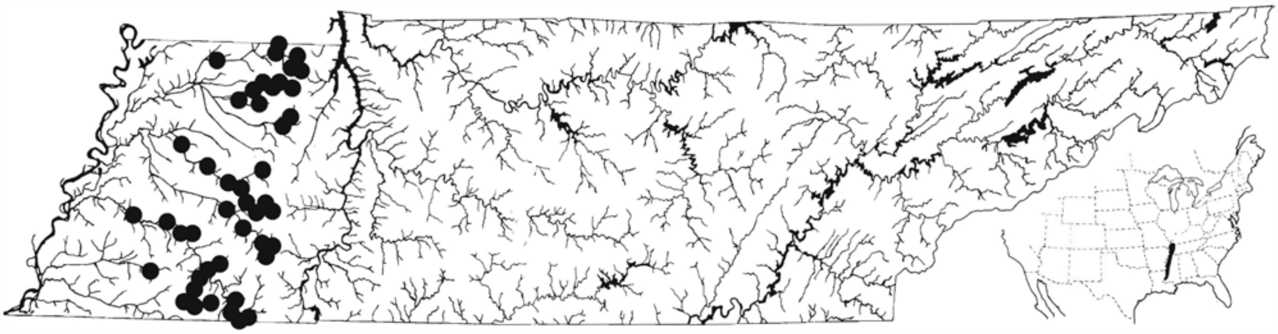
Least madtom

Plate 142. *Noturus hildebrandi*, least madtom, 35 mm SL, Obion R. system, TN.

Characters: Anal fin rays 12–17. Soft pectoral fin rays 8–9 (7–10). Pelvic fin rays 8 (7–9). Total caudal fin rays 43–50 (40–51). Internasal pores 2 (1–2), preoperculomandibular canal pores 10–11 (9–12). Gill rakers 4–8. Post-Weberian vertebrae 32–35 (30–36). Pectoral fin spine (Fig. 111) with well-developed posterior serrae but with anterior serrae weak or absent. Color brown dorsally with pale areas before dorsal fin, behind dorsal fin, and beneath anterior and posterior adipose fin. Caudal fin with basal and submarginal dark bars. Pectoral fins mottled. Adipose fin and rays of dorsal fin virtually unpigmented.

Biology: The least madtom is restricted to coastal plain habitats in west Tennessee and western Mississippi. It occurs both in small streams and in the main channels of larger rivers. It is typically found in shallow, current swept areas over shifting sand or fine gravel substrates and is associated with cover in the form of detritus accumulations and overhanging banks. It may be locally

Figure 111. Pectoral spine of *Noturus hildebrandi* (drawn by G. Dinkins).



Range Map 139. *Noturus hildebrandi*, least madtom.

abundant. Mayden and Walsh (1984) recorded life history information from a population from the North Fork Obion River, Henry County, Tenn. Breeding activity was inferred to be from mid June through early July. No nest sites were located, but aquarium-held females produced clutches of 11–27 (mean = 19) eggs which were guarded by a single male in cavities under mussel shells. Since potential nesting cover in the form of slabrocks, mussel shells, and discarded beverage containers is sparse in most *N. hildebrandi* habitats, it seems likely that nests are built under snags or similar organic cover. Females probably spawn more than once, as annual egg production per female was 17–38 (mean = 30), and one partially spent female was found in July with about half of her predicted egg complement remaining. Young reach lengths of about 35 mm SL by December of their first year, grow little over the winter, and are about 39 mm SL and sexually mature at the onset of the June spawning period. Mortality is apparently very high after the spawning period. Those specimens that survive through their second summer average about 50 mm SL in late fall. Survival through a second winter was not noted, and life span is perhaps only 18 months or so. Food consists primarily of midge and caddis larvae, supplemented with mayfly and stonefly nymphs. Maximum total length 64 mm (2.5 in).

Distribution and Status: Eastern tributaries to the lower Mississippi River from the Obion River system of Kentucky and Tennessee south through the Homochitto River of southern Mississippi. Common in Tennessee in relatively swifter waters of upper Coastal Plain.

Similar Sympatric Species: Other *Rabida* species that occur in west Tennessee are *N. miurus* and *N. stigmosus*. Both of these species have prominent serrae on the anterior edge of the pectoral fin spine (Figs. 114, 119), a distinct black bar extending from the midbase of the adipose fin to near its margin, well pigmented lower sides, and dark pigmentation on dorsal fin rays (Pls. 145, 150).

Systematics: A member of the subgenus *Rabida* that, together with *N. baileyi* and *N. stanauli*, comprises the *hildebrandi* species group (Etnier and Jenkins, 1980; Grady, 1988). Taylor (1969b) recognized two subspecies, *N. h. lautus* from the Obion through the Hatchie river systems, and *N. h. hildebrandi* from southwestern Mississippi. He considered populations from northwestern Mississippi and the Loosahatchie River in southwest Tennessee to represent intergrades.

Etymology: *hildebrandi* is a patronym in honor of the prominent American ichthyologist Samuel F. Hildebrand; *lautus* = washed or clean, referring to the virtually unpigmented lower sides.

Noturus insignis (Richardson)

Margined madtom

Plate 143. *Noturus insignis*, margined madtom, 49 mm SL, Potomac R. system, VA.

Characters: Anal fin rays 15–21. Soft pectoral fin rays 9 (8–10). Pelvic fin rays 9 (8–10). Total caudal fin rays 56–65 (54–67). Internasal pores 2, prepoperculomandibular canal pores 11 (10–12). Gill rakers 6–10. Post-Weberian vertebrae 38–40 (37–42). Pectoral fin spine with moderately developed posterior serrae and a few weak anterior barbs near tip of spine (Fig. 112). Color gray or tan. Median fins with broad dark margins.

Figure 112. Pectoral spine of *Noturus insignis* (drawn by G. Dinkins).

Biology: The margined madtom reaches greatest abundance in Piedmont rivers and is typically associated with coarse gravel or boulder substrates, moderate to swift currents, and moderate depths. Clugston and Cooper (1960) reported on various aspects of the biology of this species in Pennsylvania. Spawning occurred in late June and early July. Total lengths of about 45, 98, 115, and 135 mm were attained by the ends of the first through fourth growing seasons. Sexual maturity typically occurred during the third summer, and life span was about 5 years. A 122-mm female contained 107 eggs. Several other studies, summarized in Clugston and Cooper (1960) and in Carlander (1969), indicated a diet of aquatic insect immatures and some small fish, and that males were responsible for guarding the nest and eggs. Maximum total length 158 mm (6.2 in) in specimens seen by us, but Jordan and Evermann (1896:147) indicate lengths of "nearly a foot."

Distribution and Status: Native populations occur along the Atlantic Coastal drainages and in the New (upper Ohio) River system of Virginia and West Virginia in Blue Ridge, Piedmont, and Coastal Plain habitats. It is highly unlikely that it occurred naturally in the Tennessee River drainage. Recently this species has appeared in two localities in the Tennessee River drainage, both in the upper Holston River system. It is abundant in Watauga River above Watauga Reservoir in Tennessee and North Carolina and in the North Fork Holston River in Virginia. Taylor (1969b) was aware of these populations and suspected their origin to have been unintentional introductions, most likely from the emptying of bait buckets containing live specimens. *Noturus flavus*, an ecologically similar madtom of the upper Holston River system, has not been collected from Tennessee portions of that system in recent years, and its possible extirpation may in part be related to the recent invasion of *N. insignis*.

Similar Sympatric Species: *Noturus flavus* is very similar in appearance, but lacks posterior pectoral spine serrae (Fig. 109) and black margins on median fins, and has posterior extensions of the premaxillary tooth patch (Fig. 102a).

Systematics: Subgenus *Schilbeodes*. LeGrande (1981) suggested, based on their virtually identical karyotypes, that the morphological similarities between *N. insignis* and *N. exilis* are due to a close relationship rather than to convergence, as was suggested by Taylor (1969b). Systematics of both species was treated by Hubbs and Raney (1944).

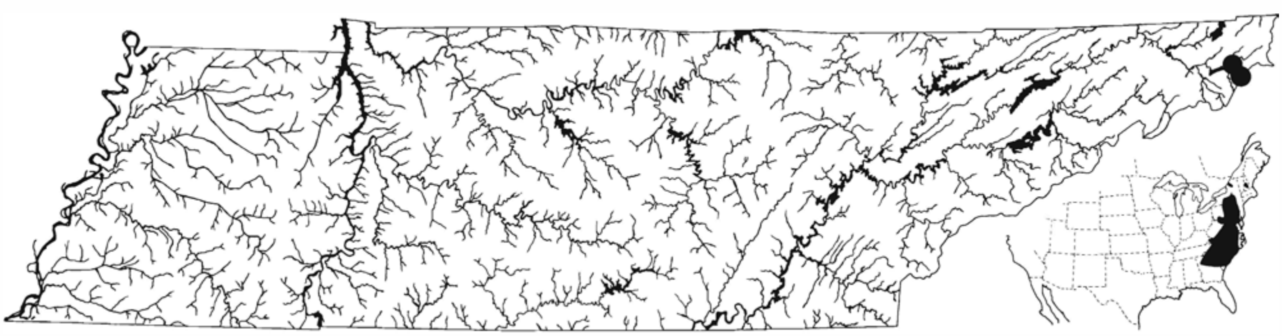
Etymology: *insignis* = remarkable, probably referring to some aspect of the appearance of this fish.

Noturus leptacanthus Jordan

Speckled madtom

Plate 144. *Noturus leptacanthus*, speckled madtom, 62 mm SL, Etowah R., GA.

Characters: Anal fin rays 14–18. Soft pectoral fin rays 8–9 (7–10). Pelvic fin rays 8 (7–9). Total caudal fin rays 47–57. Internasal pores 2, preoperculomandibular



Range Map 140. *Noturus insignis*, margined madtom (New Hampshire and Tennessee River drainage populations presumably represent introductions).

Figure 113. Pectoral spine of *Noturus leptacanthus* (drawn by G. Dinkins).

canal pores 11 (10–12). Gill rakers 5–8. Post-Weberian vertebrae 32–37. Pectoral fin spine (Fig. 113) lacking both anterior and posterior serrae. Body color dark reddish brown in life. Caudal fin dusky or mottled with pale border; pectoral fins often dusky basally.

Biology: We have found this species to inhabit swift, gravel or boulder riffle areas to a much greater extent than do other species of the subgenus *Schilbeodes*. It is most abundant in habitats ranging from small to medium-sized rivers. Clark (1978) studied a population in the Pascagoula River drainage in southern Mississippi. Breeding time varied in her two-year study, and extended from May through August, generally slightly later than for syntopic *N. funebris* and *N. gyrinus*. Spawning sites were discarded cans and bottles that were free of debris, apparently due to nest-preparation activities of the male. Cans and bottles used as nest sites had their openings directed downstream or perpendicular to the current. Both females and males were sexually mature in their second summer, and these 1-year-old fish comprised the majority of the reproductive population. Females 33–35 mm SL produced an average of 24 (14–45) mature eggs per year. Average clutch size in 8 nests was 17.6 (15–25) eggs. Average diameter of eggs found in nests was 5.5 mm, considerably larger than reported for other madtoms. Average standard lengths of 39 and 50 mm were reached at age 1 and 2, respectively, and life span was only 2.5 years. Food was judged to be primarily midge larvae. Two *N. leptacanthus* were found in the stomachs of *N. nocturnus*. Maximum total length 110 mm (4.3 in).

Distribution and Status: Atlantic and Gulf drainages from the Edisto River, South Carolina, to Amite-Comite system of Louisiana. Rohde's (1980) apparent records of *N. leptacanthus* from the Bear Creek (Tennessee drainage) system of Alabama and Mississippi are misplotted, and are meant to represent Gulf rather than Tennessee drainage records (Rohde, pers. comm.). In Tennessee it occurs only in the Conasauga River system, where it is common.

Similar Sympatric Species: In Tennessee confined to the Conasauga River and its larger tributaries where the only other madtom is the boldly patterned *N. munitus*.

Systematics: A member of the subgenus *Schilbeodes* that lacks obvious close affinities with other members of the subgenus (Taylor, 1969b; LeGrande, 1981).

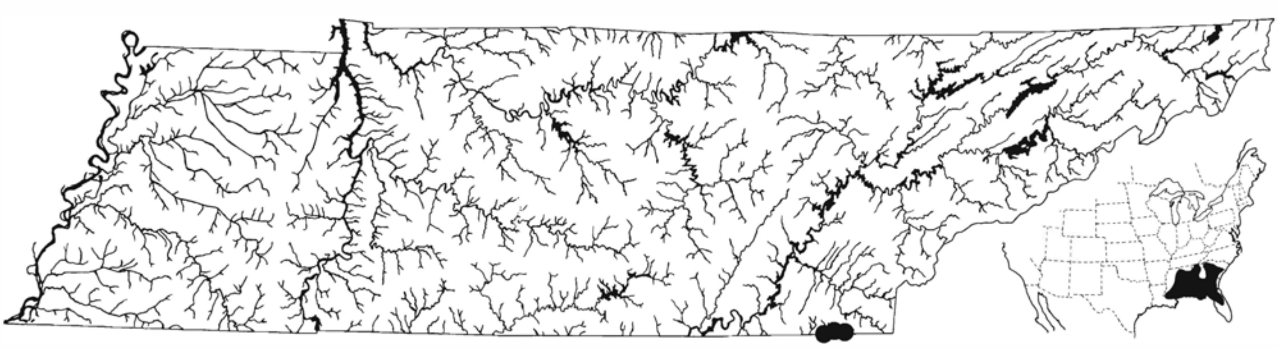
Etymology: *leptos* = slender, *canthos* = spine.

Noturus miurus Jordan

Brindled madtom

Plate 145. *Noturus miurus*, brindled madtom, 61 mm SL, lower Tennessee R. system, TN.

Characters: Anal fin rays 13–17. Soft pectoral fin rays 8 (7–9). Pelvic fin rays 9 (8–10). Total caudal fin rays 54–64. Internasal pore single (rarely double), preoperculomandibular canal pores 11 (10–12). Gill rakers 6–



Range Map 141. *Noturus leptacanthus*, speckled madtom.

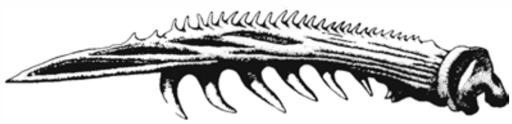


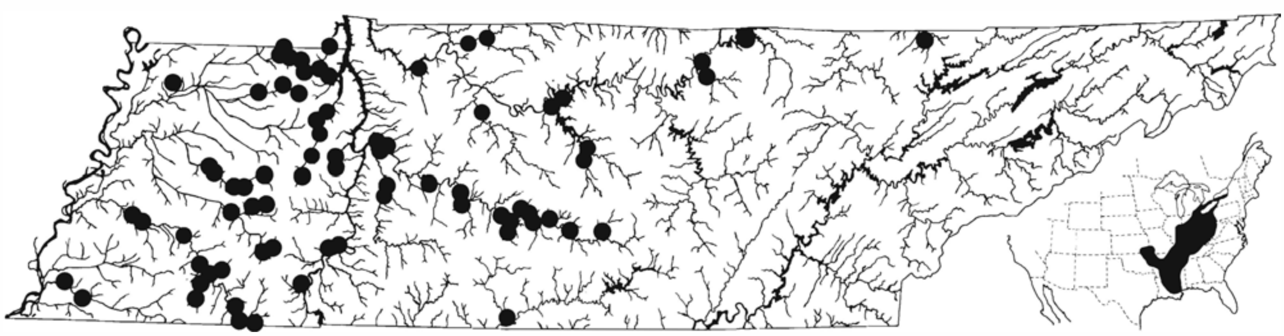
Figure 114. Pectoral spine of *Noturus miurus* (drawn by G. Dinkins).

7. Post-Weberian vertebrae 34–37 (32–37). Pectoral fin spine (Fig. 114) with both anterior and posterior serrae well developed. Color pale yellowish or tan. Dark on top of head except for conspicuous pale areas behind eyes. Dark saddles beneath dorsal fin origin, behind dorsal fin, and at base of adipose fin. Anterior tip of dorsal fin with conspicuous black blotch. Caudal fin with dark submarginal band.

Biology: The brindled madtom typically occurs in pools or areas with little current over substrates composed of mud, detritus, or silty gravel. Habitats vary from small creeks to large rivers. Specimens are usually associated with some sort of cover during daytime. Life history information is summarized from studies on Michigan (Taylor, 1969b) and southern Illinois (Burr and Mayden, 1982a) populations. Spawning occurs at water temperatures of 24–27 C, corresponding to late June in Illinois and from late July to mid August in Michigan. Nest sites were often discarded beer and soda cans, with preference shown for containers with "pop-top" size openings, and with the openings oriented downstream. Flat rocks and pieces of wood provide the ceiling for the nest cavity in the absence of these cultural artifacts. Females were found with males only in nest cavities lacking eggs, with males assuming parental duties after egg deposition. Females produced 42–90 (mean = 66) eggs in Illinois, which was identical to average clutch size. In Michigan, clutch size was 28–46. Multiple spawning of females may be absent in this species, or less frequent than in other madtoms. In Illinois, standard lengths of about 55 mm and 62 mm were reached at ages 1 and 2. Many females were mature during their second summer (age 1), but nest-guarding males (Illinois) were in their third or fourth summer (age 2 and 3). Nest-guarding males in Michigan were 51–71 mm SL, and some were presumably age 1. Life span in Illinois was 3 years. Food consisted of dipteran larvae (midges and blackflies), mayflies (*Potamanthus* and *Stenonema*), hydropsychid caddisflies (*Cheumatopsyche*), and isopods in Illinois. Maximum total length (Trautman, 1957) 132 mm (5.2 in).

Distribution and Status: Widespread in Mississippi Basin in Coastal Plain, and extending into upland areas in Ohio, Cumberland, and Tennessee river drainages. Also in uplands west of Mississippi River in White, Arkansas, and Ouachita river systems; and in southern Great Lakes tributaries. Gulf Coastal populations occur in the Pearl and Lake Ponchartrain drainages of Louisiana and Mississippi. In Tennessee most common in Coastal Plain streams, but also occurs in Highland Rim and Nashville Basin habitats. Known from the upper Cumberland drainage from a single specimen (UT 48.280) reportedly collected in No Business Creek, Campbell County, Tenn., by TVA biologists.

Similar Sympatric Species: In west Tennessee often occurring with both *N. stigmosus* and *N. hildebrandi*. In these species dark dorsal fin pigment, if present, is subterminal rather than terminal. Further differing from *hildebrandi* in having well-developed anterior pectoral spine serrae and in having a vertical black band in middle of adipose fin that extends to or nearly to edge of fin. Further differing from *stigmosus* in having more caudal fin rays and in lacking a median dark vertical band of pigment in the caudal fin. In middle Tennessee *miurus* occurs with *elegans*, *eleutherus*, and *stanauli*. None of these has a terminal black blotch at the tip of the dorsal fin, and of these three, only *elegans* has a vertical dark bar in the middle of the adipose fin (rarely



Range Map 142. *Noturus miurus*, brindled madtom.

reaching the margin). Further differing from *elegans* in having only a single inter-nasal pore and in number of caudal fin rays. Range approaches that historically held by the very similar *N. flavipinnis*.

Systematics: A member of the subgenus *Rabida*, most closely related to *N. flavipinnis* (Taylor, 1969b; LeGrande, 1981).

Etymology: *miurus* = curtailed, perhaps referring to its rather short and stocky appearance.

Noturus munitus Suttkus and Taylor

Frecklebelly madtom

Characters: Anal fin rays 12–14. Soft pectoral fin rays 8 (7–8). Pelvic fin rays 9 (8–9). Total caudal fin rays 45–52. Internasal pores 2, preoperculomandibular canal pores 11 (9–12). Gill rakers 5–7. Post-Weberian vertebrae 30–33. Pectoral fin spine with both anterior and posterior serrae very well developed (Fig. 115). Color mottled brown on yellowish background. Bold dark saddles under dorsal fin origin, behind dorsal fin, and at adipose fin base. Dorsal, caudal and pectoral fins mottled or banded.

Figure 115. Pectoral spine of *Noturus munitus* (drawn by G. Dinkins).

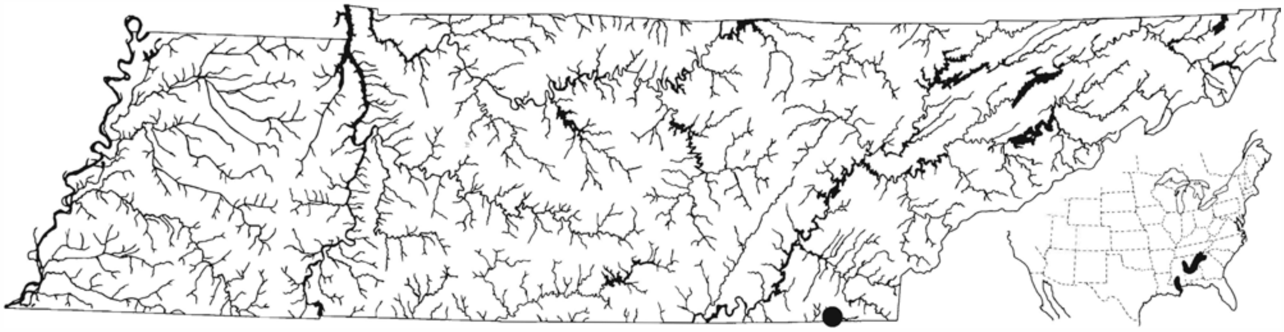
Biology: The frecklebelly madtom is a Gulf Coast drainage species typically inhabiting rivers with moderate to swift currents over substrates ranging from coarse gravel to boulders, submerged trees, and brush. Many inhabited rocky riffles have abundant growths of riverweed (*Podostemum*) (Suttkus and Taylor, 1965). It reaches maximum abundance in large rivers and also occurs in smaller rivers, but it is virtually unknown from small creeks. Trauth et al. (1981) reported a June–July breeding season and fecundity of 100–140 ova per female in the Tombigbee River, Mississippi. G. Miller (1984) reported a diet comprised principally of hydropsychid caddisfly larvae, ephemerellid mayfly nymphs, and blackfly and midge larvae. Other aspects of the biology of *N. munitus* have not been reported. Maximum total length 99 mm (3.9 in).

Distribution and Status: Widely scattered populations occur both above and below the Fall Line in the Pearl River drainage and Mobile Basin. In Tennessee, *N. munitus* is known only from several specimens from the main channel of the Conasauga River. It is considered to be a Threatened Species throughout its range by the U.S. Department of Interior Office of Endangered Species, and as Endangered or Threatened in states in which it occurs.

Similar Sympatric Species: The only other madtom in the Conasauga River system is the unpatterned *N. leptacanthus*.

Systematics: Subgenus *Rabida*. Closest relatives are presumed to be *N. stigmosus* and *N. placidus* (Grady, 1988).

Plate 146. *Noturus munitus*, frecklebelly madtom, 75 mm SL, Etowah R., GA.



Range Map 143. *Noturus munitus*, frecklebelly madtom.

Etymology: *munitus* = armed, referring to the excessive development of both anterior and posterior pectoral fin serrae.

Noturus nocturnus Jordan and Gilbert

Freckled madtom

Plate 147. *Noturus nocturnus*, freckled madtom, 41 mm SL, lower Tennessee R. system, TN.

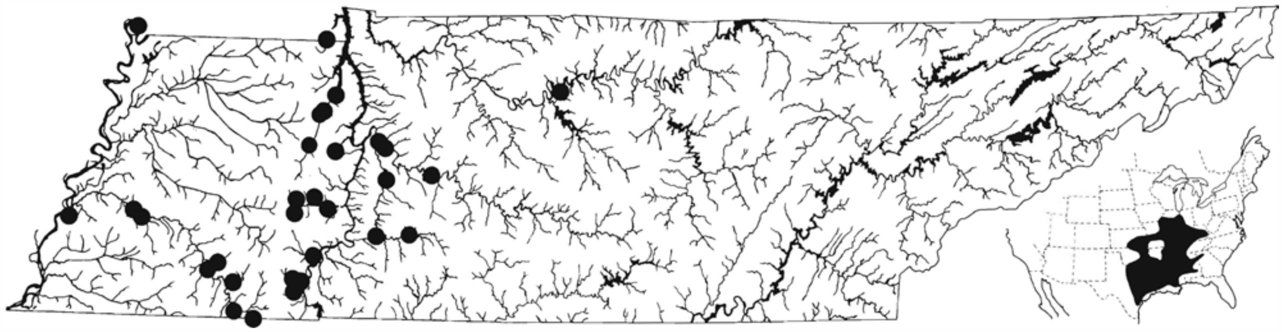
Characters: Anal fin rays 15–19. Soft pectoral fin rays 9 (8–10). Pelvic fin rays 9 (8–10). Total caudal fin rays 55–64. Internasal pores 2, preoperculomandibular canal pores 10–11 (9–12). Gill rakers 5–7. Post-Weberian vertebrae 35–38. Pectoral fin spine with a few weak posterior serrae and several small anterior barbs (Fig. 116). Color rather uniformly dark gray. See further comments under Similar Sympatric Species.

Biology: The freckled madtom occurs in habitats ranging from medium-sized creeks to large rivers. We have typically found it associated with cover in the form of brush, logs, and roothair masses along overhanging banks in areas with moderate to gentle currents over silty gravel substrates. Burr and Mayden (1982b) presented life history information from a southern Illinois population. Their habitat description of riffles and areas of strong current deviates from our observations in the lower Duck River and coastal plain streams of the Mississippi River Embayment. Spawning in Illinois was probably in June and July, with three nests containing 47, 139, and 154 eggs located on 25 June, water temperature 25 C (77 F), in beer cans in a shaded area 10–15 cm deep, with "some current." Five females 67–75 mm SL contained an average of 102 mature eggs (85–116). Perhaps occasional polygamy, rather than, or in addition to the more normal polyandry, occurs in this species. Standard lengths were about 65 mm at age 1 and 78 mm at age 2 in the Illinois population. Females were sexually mature by their second summer, but all sexually active males encountered were in their third or fourth summer (ages 2 or 3). Life span was 4.5 years. Diet consisted of aquatic insect immatures dominated by mayflies, caddisflies, midges, and blackflies. Maximum total length 150 mm (5.9 in), but usually much smaller.

Figure 116. Pectoral spine of *Noturus nocturnus* (drawn by G. Dinkins).

Distribution and Status: Widespread above and below Fall Line in central and lower Mississippi drainage, and in Gulf Coastal drainages from Mobile Basin to the San Jacinto River, Texas. The freckled madtom is uncommon in Tennessee, with most of our collections from tributaries to the lower Tennessee River and from the Hatchie River system.

Similar Sympatric Species: Very similar in appearance to *N. exilis*, *N. phaeus*, and *N. flavus*. Differing from *exilis* and *phaeus* in lacking distinct posterior serrae on pectoral fin spine. Differing from *N. flavus* in lacking posterior extension of the premaxillary tooth patch, modal number of soft pectoral fin rays, and in pigmentation. In *nocturnus* melanophores are conspicuous on the ventral portion of the head and on the belly just anterior to the pelvic fin bases, and the median fins are usually uniformly dark gray. In *flavus* the belly and lower head



Range Map 144. *Noturus nocturnus*, freckled madtom.

are immaculate, and median fins are either immaculate or dark with pale margins. The occasional specimens of *nocturnus* (Plate 147) that have dark marginal bands on median fins resemble *exilis*, but they differ in lacking the prominent posterior pectoral spine serrae of that species. Also similar to *N. gyrinus*, in which the tip of the upper jaw does not project beyond the lower jaw.

Systematics: Subgenus *Schilbeodes*. Taylor's (1969b) treatment of *nocturnus* and *insignis* as a species pair is not supported by karyological studies of LeGrande (1981) or biochemical studies of Grady (1988) who hypothesized *N. exilis* as closest relative to *insignis*.

Etymology: *nocturnus* = nocturnal, referring to its dark coloration.

Noturus phaeus Taylor

Brown madtom

Characters: Anal fin rays 19–24. Soft pectoral fin rays 8–9 (7–10). Pelvic fin rays 9 (7–10). Total caudal fin rays 50–58. Internasal pores 2, preoperculomandibular canal pores 11 (10–12). Gill rakers 6–9. Post-Weberian vertebrae 34–37. Pectoral fin spine (Fig. 117) with well-developed posterior serrae. Uniformly gray to brown in coloration with pinkish orange tint in life.

Figure 117. Pectoral spine of *Noturus phaeus* (drawn by G. Dinkins).

Biology: The brown madtom is an inhabitant of coastal plain streams tributary to the lower Mississippi River. It typically occurs in tiny to medium-sized creeks and occupies areas ranging from moderate currents over sandy substrates to pool areas with silty bottoms. Like many other madtoms, it is most likely to occur associated with cover such as brush, log jams, or overhanging banks. Other aspects of its biology are unknown. Maximum total length (Douglas, 1974) up to nearly 150 mm. Our largest specimen is 135 mm (5.3 in).

Distribution and Status: Below the Fall Line in eastern tributaries to Mississippi River from Obion system of Kentucky and Tennessee southward, and west of Mississippi River in Red and Ouachita river systems.

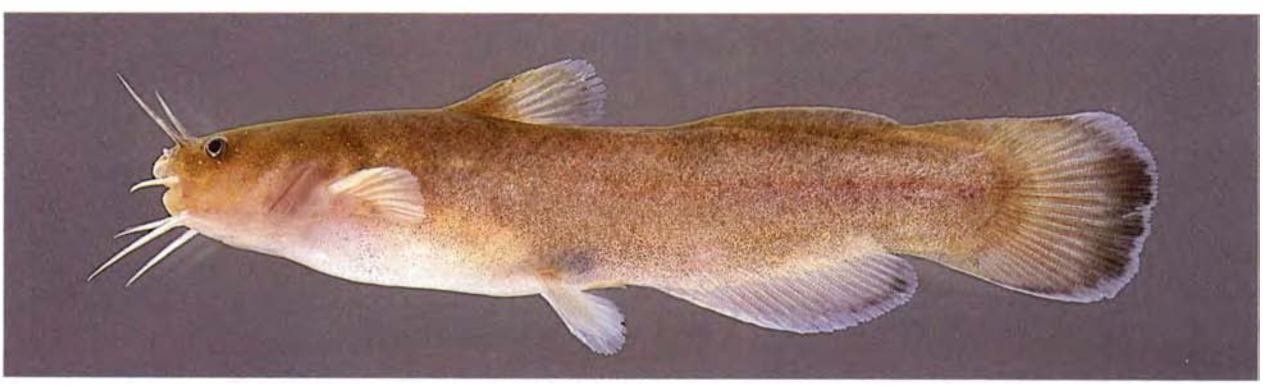
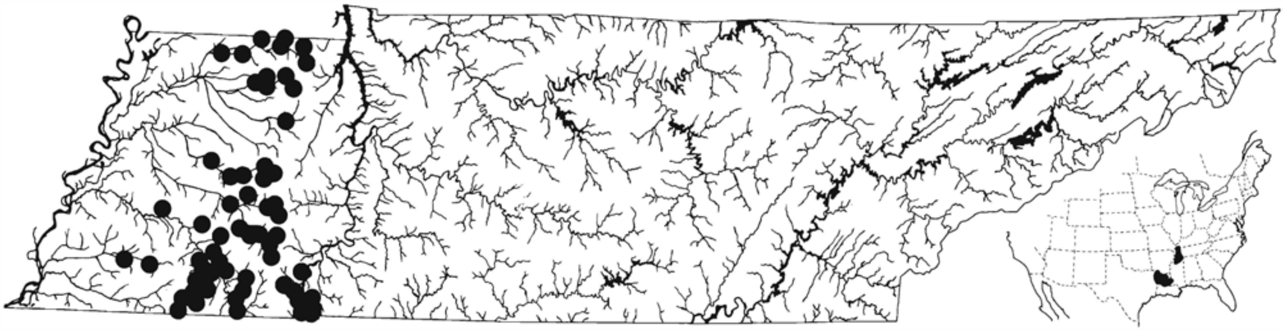


Plate 148. *Noturus phaeus*, brown madtom, 78 mm SL, Hatchie R. system, TN.



Range Map 145. *Noturus phaeus*, brown madtom.

Also present in several western tributaries to lower Tennessee River, perhaps as a result of headwater exchange from the Hatchie River system. Common in tributaries to Mississippi River in west Tennessee on upper Coastal Plain.

Similar Sympatric Species: Very similar to *N. nocturnus* in shape and coloration. The brown madtom has well-developed posterior serrae on the pectoral fin spine (Fig. 117), whereas these serrae are virtually absent in *nocturnus* (Fig. 116). In addition, there is little overlap in anal fin ray counts between the two species.

Systematics: A member of the subgenus *Schilbeodes* closely related to and formerly considered conspecific with *N. funebris* of Gulf Coast drainages (Taylor, 1969b; Grady, 1988).

Etymology: *phaeus* = the color of twilight, referring to the overall dusky color of this species.

Noturus stanauli Etnier and Jenkins

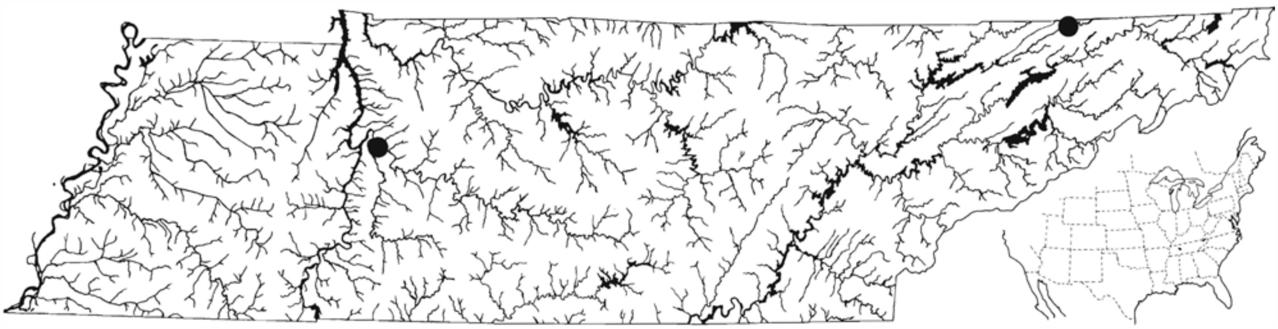
Pygmy madtom

Plate 149. *Noturus stanauli*, pygmy madtom, 31 mm SL, Clinch R., TN.

Characters: Anal fin rays 14–17. Soft pectoral fin rays 8 (7–9). Pelvic fin rays 8 (8–9). Total caudal fin rays 45–51 (44–57). Internasal pores 2, preoperculomandibular canal pores 11 (10–11). Post-Weberian vertebrae 33–34. Pectoral fin spine with well-developed posterior serrae and small but conspicuous anterior serrae (Fig. 118). Color dark brown to nearly black on top of head and dorsally on body, sharply contrasting with white ventrally. Pale areas present before and behind dorsal and adipose fin bases. Pectoral spine area black. Caudal fin broadly banded. Dorsal fin rays and adipose fin immaculate.

Figure 118. Pectoral spine of *Noturus stanauli* (drawn by G. Dinkins).

Biology: The pygmy madtom is apparently one of the rarest of North American fishes. Fewer than fifty specimens are known from the two widely separated localities. Etnier and Jenkins (1980) described the habitat at the type locality, Clinch River at River Mile 181.1, Frost Ford, 11.8 air km WSW of Kyles Ford, Hancock County, Tennessee, as follows: "Most specimens have been taken in a single area along the north bank about 30 m below the most downstream of two bedrock shelves that extend across the river, and just above and at the head end of a prominent bed of water willow (*Justicia americana*). In this area substrates are of medium gravel, water depths are typically 0.5 m or less, and current is about 0.3 m/sec. Several specimens have been taken in similar habitats directly across the river along the south bank, and in swifter water adjacent to the water willow bed mentioned above." In the lower Duck River just above the mouth of Hurricane Creek, Duck River Mile 17.5, Humphreys County, Tennessee, "The former gravel shoal just across and slightly upstream from the mouth of Hurricane Creek produced several specimens over fine gravel substrates, depths of 1 m, and current velocity of about 0.6 m/sec. Recent physical changes in flow pattern at this locality have re-



Range Map 146. *Noturus stanauli*, pygmy madtom.

duced current and allowed considerable silt accumulation. All recent Duck River specimens have been collected along the north bank of the river about 300 m above the mouth of Hurricane Creek over fine gravel substrates with 20–30 cm depths and current velocity of about 0.6 m/sec." Other aspects of its biology are unknown. Maximum total length 44 mm (1.75 in).

Distribution and Status: Known only from single localities in the Clinch and Duck rivers (see Biology). *Noturus stanauli* was collected from the Clinch locality as recently as 1991. It is considered to be a Threatened Species by the Tennessee Wildlife Resources Agency and will presumably be afforded Protected status by the U.S. Department of Interior Office of Endangered Species. Should Columbia Dam be completed on the Duck River, its tailwaters could result in extirpation of the *N. stanauli* population, about 100 river miles below the dam site. In this eventuality, the status of the species would likely be Endangered.

Similar Sympatric Species: Sympatric with *eleutherus* in the Clinch River and *miurus* and possibly *elegans* in the lower Duck River. It differs from both *miurus* and *elegans* in lacking a vertical dark band in the adipose fin, from *eleutherus* and *miurus* in lacking a darkly pigmented dorsal fin, and from all three species in having virtually unpigmented lower sides.

Systematics: A member of the *N. hildebrandi* species group of the subgenus *Rabida* (Etnier and Jenkins, 1980), believed by Grady (1988) to be closest related to *N. baileyi*.

Etymology: *stanauli* is derived from the Cherokee words "oostanauli" (a shoal area in a river) and "tsulistanauli" (catfish).

Noturus stigmosus Taylor

Northern madtom

Characters: Anal fin rays 13–16. Soft pectoral fin rays 8 (7–9). Pelvic fin rays 9 (8–10). Total caudal fin rays 47–55. Internasal pores 2, preoperculomandibular canal pores 11 (9–12). Gill rakers 4–7. Post-Weberian vertebrae 31–35. Pectoral fin spine (Fig. 119) with both anterior and posterior serrae very well developed. Color pale yellowish with dark brown to black saddles. Caudal fin base with characteristic "skeleton key" pattern. Pectoral fins mottled anteriorly.

Biology: This beautifully marked species occurs in large creeks and rivers where it is usually found associated with moderate to swift currents, clean sand or gravel substrates, and cover in the form of brush, logs, or larger boulders. It seems unfortunate that a common name more appropriate than "northern madtom" was not coined for this spectacular fish. It is occasionally taken on trot lines by catfish fishermen. Taylor (1969b) indicated that reproduction in Michigan occurred slightly earlier than in *N. miurus*, and that clutch sizes ranged from 61 to 141 eggs or young. As in *N. miurus*, males guarded the nest, and the nest site was associated with submerged cans (larger than those normally used by *miurus*), milk bottles, boxes, or large rocks. Males guarding the nests also developed secondary sexual characters similar to those of *miurus*, including flattening of the head, diffusion of dark pigment, and conspicuous swellings behind the eyes, on the nape, and on the lips and cheeks. Other aspects of its biology are unknown. Maximum total length (Trautman, 1957, as *N. furiosus*) 132 mm (5.2 in).

Distribution and Status: Above the Fall Line in Ohio River drainage and eastern tributaries to Lake Erie, and below Fall Line in eastern tributaries to Mississippi River from Obion through Wolf River systems of Ten-

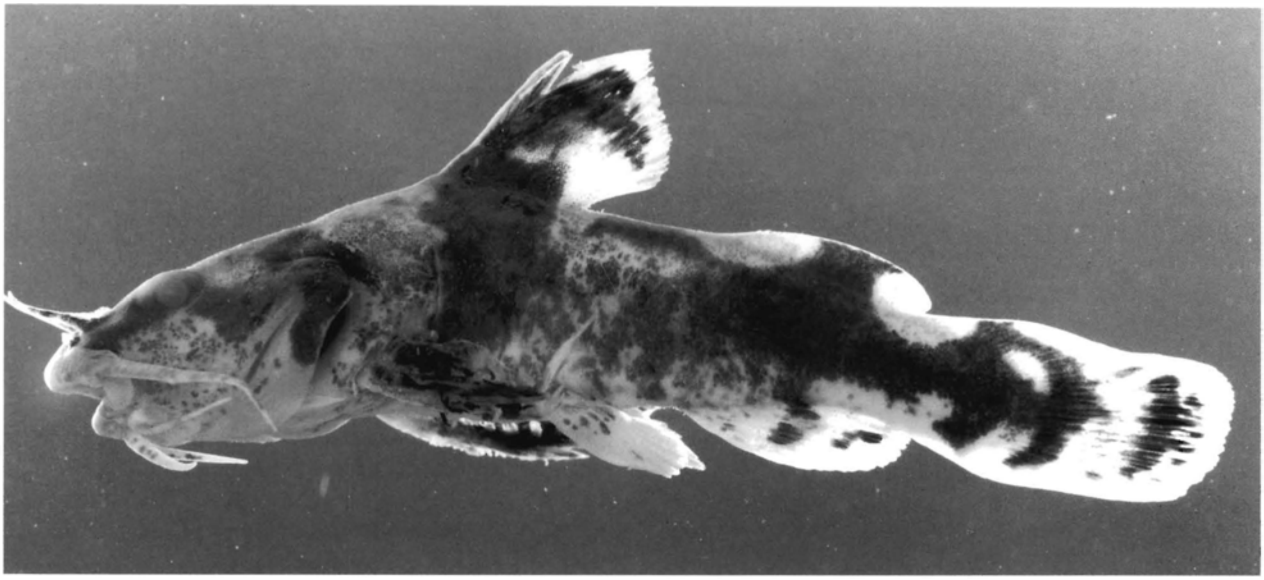


Plate 150. *Noturus stigmosus*, northern madtom, 50 mm SL, Hatchie R., TN.

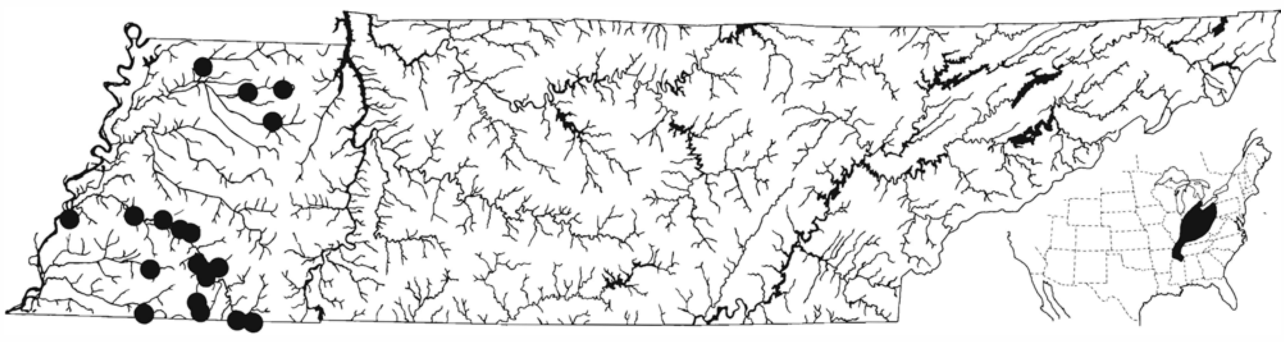
Figure 119. Pectoral spine of *Noturus stigmosus* (drawn by G. Dinkins).

nessee and northern Mississippi. The northern madtom is locally fairly common in Hatchie River, but rare elsewhere in Tennessee. It is listed as a Species of Special Concern in Tennessee by the Tennessee Heritage Program (Starnes and Etnier, 1980).

Similar Sympatric Species: Both *miurus* and *hildebrandi* have a similar color pattern. In *miurus* (Pl. 145) the dorsal fin has a terminal black blotch and the caudal fin lacks a vertical dark bar midway between its base and posterior margin. In *stigmosus* the median caudal dark bar is present and dark dorsal fin pigment is definitely below the margin. *Noturus hildebrandi* (Pl. 142) differs in lacking a vertical bar of pigment in the adipose fin, in having an immaculate dorsal fin, and in virtually lacking anterior serrae on the pectoral spine (Fig. 111).

Systematics: A member of the *N. furiosus* group of the subgenus *Rabida* of Taylor (1969b) along with *placidus* and *munitus*. However, Grady (1988) did not hypothesize a close relationship of *furiosus* to these species. See also comments under *N. munitus*. Very similar to the allopatric *N. munitus*, but Tennessee *stigmosus* differ consistently from this species in having the pale basicaudal areas separated into two lunate blotches separated by a median dark mark.

Etymology: *stigmosus* = marked or branded, referring to the two light spots typically present just anterior to the dorsal spine.



Range Map 147. *Noturus stigmosus*, northern madtom.

Genus *Pylodictis* Rafinesque

The genus *Pylodictis* contains a single species, *P. olivaris* (Rafinesque), characterized below. Its closest relative (Taylor, 1969b; Lundberg, 1982) is considered to be *Satan eurystomus* Hubbs and Bailey, an amazing blind, non-pigmented species from artesian wells as deep as 1,250 ft deep in the vicinity of San Antonio, Texas (Hubbs and Bailey, 1947). Fossil *Pylodictis* essentially indistinguishable from *P. olivaris* date to the mid Miocene (Lundberg, 1975b).

Pylodictis olivaris (Rafinesque)

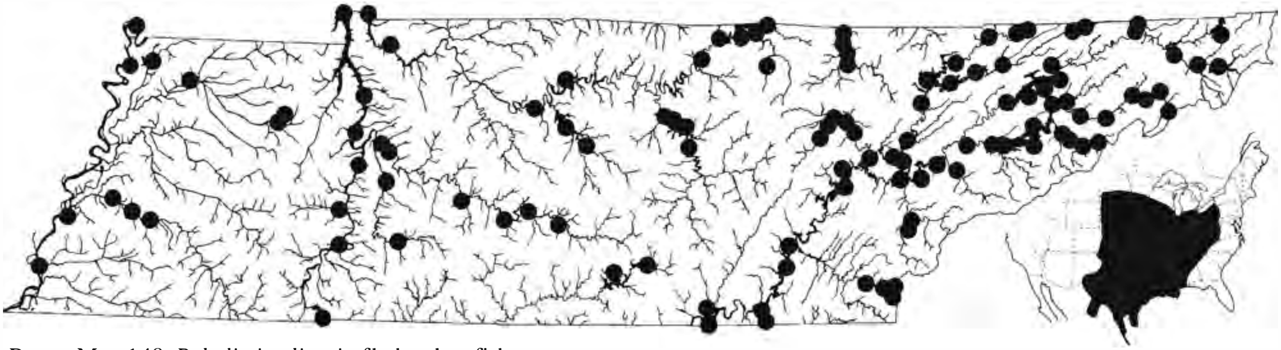
Flathead catfish

Characters: Anal fin rays 13–17. Soft pectoral fin rays modally 11. Pelvic fin rays modally 9. Caudal fin rays (branched rays plus 2) modally 17. Internasal pores 2, preoperculomandibular canal pores modally 12. Gill rakers 9–11 in 28 specimens 42–256 mm TL. Pectoral fin spine with both anterior and posterior serrae very well developed (Fig. 120). Premaxillary tooth patch with posterior extensions similar to those of *Noturus flavus*. Color yellowish with brown mottling. Fins dusky. Juveniles often nearly black dorsally. Juveniles and young adults with white blotch on tip of dorsal lobe of caudal fin.

Biology: The flathead catfish is a solitary and secretive species of medium to large rivers and reservoirs where it typically spends daylight hours associated with cover such as caves, undercut banks, brush piles, or log jams. Juveniles are commonly encountered in riffle areas. It forages at night in a wide variety of habitats, including riffles so shallow that the dorsal fin may be exposed (Trautman, 1957). Additional biological information has been abstracted from accounts in Trautman (1957), Minckley and Deacon (1959), Carlander (1969), Pflieger (1975), and Becker (1983). Spawning takes place in cave-like depressions in the bank or in a cavity hollowed out by one or both parents under a board, boulder, log, or similar object. Spawning in Tennessee probably takes place from June into July. The compact egg masses may contain 4,000 to 100,000 eggs. After spawning, the nest and newly hatched young are guarded by the male, who becomes aggressive toward the female. The large amount of age and growth data available for the species indicates respective total lengths for the first 8 years to be about 64–239, 127–353, 185–475, 259–579, 320–648, 376–780, 421–907, and 465–985 mm. Growth data available for Tennessee populations is at or near the top of these ranges. In Norris Reservoir, Carroll and Hall (1964) recorded flatheads up to 16 years old and over a meter in length. Sexual maturity may be attained at sizes as small as 380 mm, usually at age 3 or older. Life span is at least 19 years. Juveniles feed mostly on aquatic insect immatures in riffle areas. At lengths of 100 mm and larger food shifts almost exclusively to other fishes, with crayfish also taken occasionally. Flatheads feed heavily on shad in reservoirs (Turner and Summerfelt, 1971). Trautman (1957) indicated that a possible feeding strategy of adults is to lie motionless with the mouth open until another cover-seeking species swims into this apparent refuge. Minckley and Deacon (1959) observed flatheads to lunge and seize prey after lying motionless. This is an important commercial species, with most specimens taken with trot lines, set lines, and trammel nets. It is also actively sought by anglers where it is

Figure 120. Pectoral spine of *Pylodictis olivaris*.

Plate 151. *Pylodictis olivaris*, flathead catfish, 133 mm SL, Nolichucky R., TN.



Range Map 148. *Pylodictis olivaris*, flathead catfish .

abundant, with live or fresh fish the preferred bait. It is apparently not as likely to scavenge as are the blue or channel catfish, and the so-called "stink baits" used for these species are not particularly effective for flatheads. The flathead is an active predator and is occasionally taken on artificial lures. This catfish is highly esteemed as a food fish throughout its range. Common names used locally for this species include mudcat, yellow cat, and shovelnose cat. This last name is also applied to the unrelated paddlefish, *Polyodon spathula*. This is one of our largest species, and earlier reports in excess of 100 lbs are quite likely valid. Pflieger (1975) reports a 42.5 kg (94 lb) specimen from Missouri taken in 1971. The current Tennessee record is a 82 lb specimen taken from Big Sandy River by Jim Dardin on a trotline in 1977.

Distribution and Status: Widespread in large rivers of central United States west of Appalachian divide, and in Gulf drainages from Mobile Basin to Mexico. The flathead catfish has adapted to reservoir habitats, and continues to be abundant in Tennessee.

Similar Sympatric Species: Juveniles might be mistaken for one of the madtom species, especially *Noturus flavus*, which may have a pale dorsal margin on the caudal fin. The free posterior end of the adipose fin of *Pylodictis* is apparent even in small sizes.

Etymology: *Pylodictis* = mud fish; *olivarus* = olive colored.

ORDER SALMONIFORMES

FAMILY ESOCIDAE
The Pikes

The pikes are northern-hemisphere freshwater fishes usually classified in the order Salmoniforms. Under various classifications, this order provisionally has included, in addition to the pikes, the mudminnows (Umbridae), salmons (Salmonidae), smelt (Osmeridae), a few families of anadromous and freshwater fishes of Asia and southern-hemisphere regions (e.g., Plecoglossidae, Salangidae, Galaxiidae), and possibly several families of deep-sea midwater fishes, including several bizarre forms (Greenwood et al., 1966; Rosen, 1974; Nelson, 1984). However, the inclusiveness of this order, particularly with regard to esocoids, has been questioned recently (Fink and Weitsman, 1982; Williams, 1987), and in a most recent work (Sanford, 1990), escoids are not included within Salmoniformes. When classified with Salmoniformes, the pikes, together with the mudminnows (Umbridae), constitute the suborder Esocoidei (Nelson, 1972; Reist, 1987). Esocid fossils are known from the Oligocene (23–38 million years ago) of Europe, the Paleocene and probably the Cretaceous (54–75 mya) of western Canada, and the Miocene (5–23 mya) of Oregon (Cavender et al., 1970; Wilson, 1980; Wilson et al., 1988). In the United States today, the natural range of esocids is confined to regions east of the Rocky Mountains, but introductions have occurred in the West. The only genus, *Esox* Linnaeus, contains but five species. Three of these are confined to North America, one (*E. reicherti* Dybowski, the Amur pike) is restricted to Siberia but has been sporadically introduced into North America, and the northern pike, *E. lucius*, occurs in both North America and Eurasia. Early collection records and fossils (Cavender et al., 1970) indicate that the ranges of some pike species may be shrinking, mainly in the Southwest. The taxonomy and distribution of North American esocids was summarized by Crossman (1978). Nelson (1972) provided a phylogenetic study of Esocidae, and recognized two subgenera of *Esox*: *Esox* s.s. includes *E. lucius*, *E. reicherti*, and *E. masquinongy*; *Kenoza* Jordan and Evermann contains the pickerels, *E. americanus* and *E. niger*.

Pike are characterized by produced, "duck-bill-like" snouts, and posteriorly positioned dorsal fins, and relatively small cycloid scales embedded in slimy mucous. A lateral line is present. They are swift, aggressive predators that prey primarily on other fishes. Along with fish, birds, small mammals, turtles, frogs, leeches, and other suitable-sized prey items are taken occasionally. Pike are considered to be so efficient as predators that their value as controllers of centrarchid populations is often considered to surpass their value as sport and food fishes. Biology of our four species is very similar. Spawning occurs primarily in the early spring and is random. A single female is often escorted by several males, with spawning occurring in heavily vegetated and often silty shallows. The eggs are sticky immediately after fertilization, and hatching success is probably dependent on the eggs adhering to vegetation or other structures that prevent their settling into the silt. The rather large (2–3 mm in diameter) eggs hatch within 10–12 days, and larvae, which have an adhesive organ at the tip of their snout, attach to the vegetation and are inactive for about another week while the yolk sac is absorbed. Young pike usually feed on invertebrates until about 50 mm (2 in) long, after which they are piscivorous. Crowded conditions often result in considerable cannibalism. Pike are "lie-in-wait" predators which may remain motionless in concealment for long periods of time until unwary prey is near. A sudden lunge secures the prey which is usually grasped in the midsection, killed, and swallowed head-first (Parsons, 1959). Pike are active diurnally and remain so throughout the winter months. Growth is very fast, and under favorable conditions the larger species may reach total lengths of 304–457 mm (12–18 in) during their first year. Females grow faster, live longer, and reach larger sizes than males.

Although the intermuscular bones or "dorsal ribs" are bothersome in smaller fish, the flesh of pike is excellent in flavor and texture. Fried pike is very tasty, and large fish are superb when baked. Before baking, remove head, entrails, and fins; scrape vigorously to remove scales and mucous; stuff with any poultry dressing; baste with melted butter and lemon juice; wrap in aluminum foil, and bake for about 45 minutes at 350 F, or until flesh flakes easily. The flavor is reminiscent of salmon, but lighter, more flaky, and less rich.

Etymology: *Esox* is a European vernacular name for the pike.

KEY TO THE TENNESSEE SPECIES

1. Opercles fully scaled (Fig. 121); 8 or fewer pores (Fig. 122) on ventral surface of lower jaw (both sides) .. 2

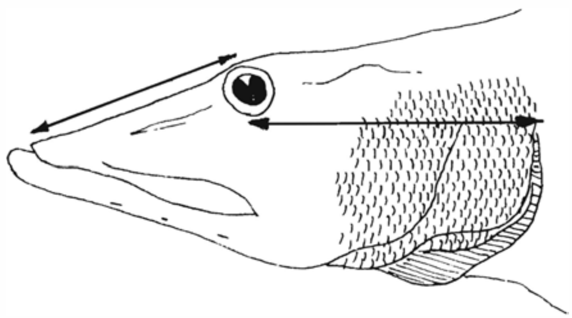


Figure 121. Cheek and opercular scalation of *Esox americanus* (drawn by C. Justis).

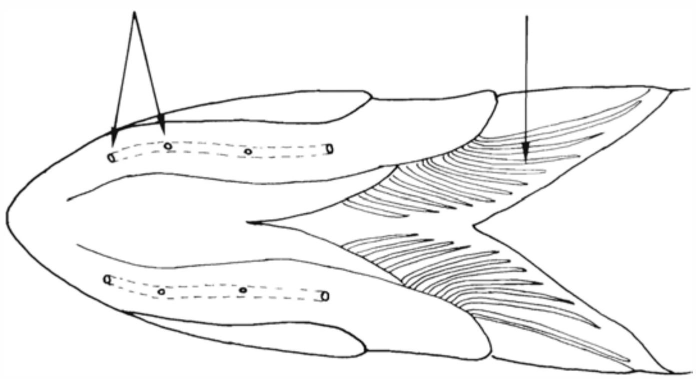


Figure 122. Ventral view of head of *Esox americanus* (showing 8 total pores on mandibles and 11 branchiostegal rays on each side).

Only upper half of operculum scaled (Figs. 123, 124); 10 or more pores on ventral surface of lower jaw ... 3

2. Branchiostegal rays (Fig. 122) usually 12 or fewer, occasionally 13; distance from center of eye to tip of snout less than or equal to distance from center of eye to posterior border of gill cover (Fig. 121) .... *Esox americanus*

Branchiostegal rays 14 or more, rarely 13; snout longer, with distance from center of eye to tip of snout greater than distance from center of eye to posterior border of gill cover .... *E. niger* p.339

3. Lower half of cheek naked (Fig. 123); pores on lower jaw total 12 or more; branchiostegal rays usually 17 or more on each side . . . . *E. masquinongy* p.337

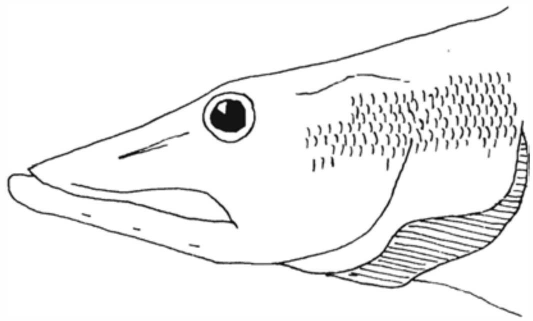


Figure 123. Cheek and opercular scalation of *Esox masquinongy* (drawn by C. Justis).

Entire cheek scaled (Fig. 124); pores on lower jaw 11 or fewer; branchiostegal rays usually 15 or fewer . . . . *E. lucius* p.335

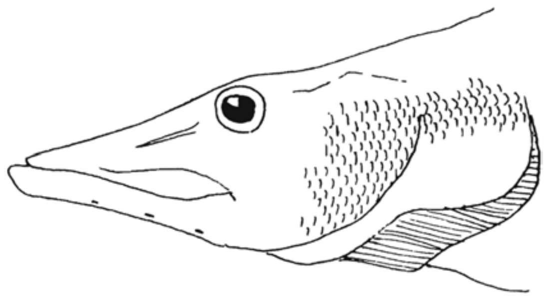


Figure 124. Cheek and opercular scalation of *Esox lucius* (drawn by C. Justis).

Esox americanus Gmelin

Grass or redfin pickerel

Characters: Lateral-line scales 92–118. Dorsal fin rays 14–17. Anal fin rays 13–15. Pectoral fin rays 14–15. Pelvic fin rays 10–11. Principal caudal fin rays 19. Branchiostegal rays 11–12 (10–14). Lower jaw with 8 (7–9) total pores. Vertebrae 42–47. Greenish gray to bronze on back continuing on upper sides where dark pigment is often interrupted by pale areas to form broad, oblique vertical bars; a pale midlateral streak may be present. Fins are unspotted and greenish.

Biology: This smallest of the pike family is abundant in west Tennessee where it occurs in sluggish waters from ponds and swamps to pools in rivers and creeks. Its disappearance from portions of its range in the Southwest suggests that it is not tolerant of excessive turbidity.

Plate 152. *Esox americanus*, grass pickerel, 103 mm SL, Lake Isom, TN.

Unlike the other pikes, it does not often get sufficiently large to attract interest as a sport or food fish. Biological information pertinent to the nominate subspecies is summarized in Scott and Crossman (1973). Ming (1968), Pflieger (1975), and Becker (1983) summarized the information available concerning our subspecies, *E. a. vermiculatus* Lesueur. Grass pickerel prefer areas of dense submerged vegetation. In winter they may burrow in mats of fallen leaves. Spawning occurs at temperatures of about 10 C (50 F), corresponding to early March in our area. An additional spawning may occur during fall. Gravid females in Wisconsin contained 843–4,584 mature eggs at 160–325 mm TL. Eggs hatch within 2 weeks. Natural hybrids with chain pickerel and northern pike are known to occur (McCarraher, 1960). Food of grass pickerel smaller than 50 mm is primarily invertebrates, but larger specimens are piscivorous, feeding principally on sunfish, darters, and minnows, plus occasional crayfish. Sexual maturity may be reached after 1 year's growth at total length of about 120 mm. Lengths at the ends of the second through fourth years in Oklahoma averaged 200, 250, and 260 mm, and a 4-year life span was indicated. Comparable data for Wisconsin, ages 1–5, were 145, 208, 251, 287 and 356 mm TL. The population of *E. a. americanus* studied in North Carolina did not reach 250 mm until their fifth year and had 6-year life spans. Females grow faster and live longer than males. Trautman (1981) reported a maximum TL of 381 mm (15 in). This specimen weighed only 14 oz (397 g), so it would appear that state records of 1.5 lb for Georgia and Louisiana and 1 lb 9 oz for North Carolina represent considerably larger specimens.

Distribution and Status: Atlantic Coastal region and Gulf Coastal Plain from New England to Brazos River, Texas; central Mississippi River basin, and southern Great Lakes tributaries. The range of the grass pickerel has apparently decreased in the Southwest within the past century (Ming, 1968). Common in west Tennessee in Coastal Plain, but much less abundant in western Highland Rim habitats of Barren, Cumberland, and Tennessee river systems. Spread of vegetation, such as milfoil, in mainstream reservoirs of the state may promote range expansion.

Similar Sympatric Species: Commonly occurs with the chain pickerel in west Tennessee. It differs from that species, in addition to characters mentioned in the key, in typically having the suborbital bar extending obliquely down and back (usually more vertical in chain pickerel), and in usually having fewer than 115 lateral-line scales. Counts for dorsal, anal, pectoral, and pelvic fins overlap, but may be useful in identifying troublesome specimens. Hybrids with the chain pickerel have been reported. Differences in branchiostegal ray counts provide excellent separation of the two species in our area, but broadly overlap in Atlantic Coast drainages.

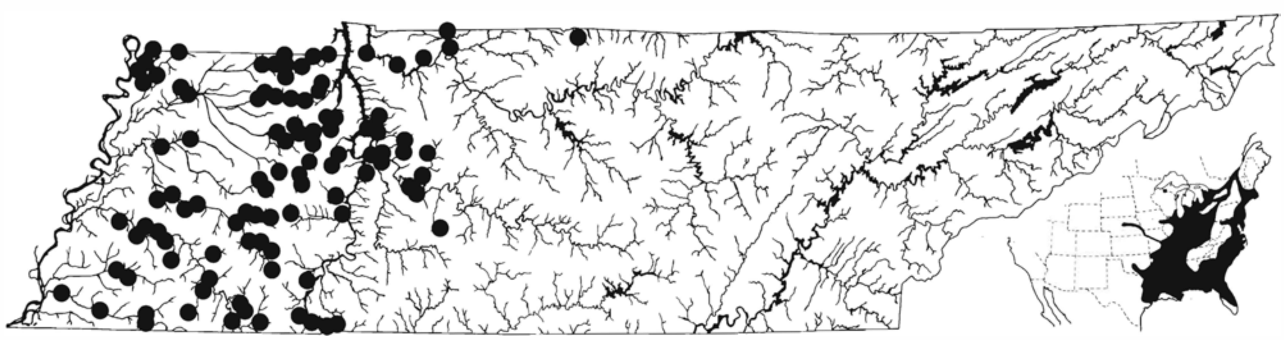
Systematics: Crossman (1966) reviewed the systematics of *E. americanus*, and recognized populations in central North America as the subspecies *E. a. vermiculatus* Lesueur, commonly called the grass pickerel. The nominate subspecies (redfin pickerel) occurs along the Atlantic Coast, with the Gulf Coastal area inhabited by intergrades between the two subspecies.

Etymology: *americanus* = of America; *vermiculatus* = with worm-like, or wavy markings.

Esox lucius Linnaeus

Northern pike

Characters: Lateral-line scales 105–148. Dorsal fin rays 15–19. Anal fin rays 12–15. Pectoral fin rays 14–17. Pelvic fin rays 10–11. Principal caudal fin rays 19. Branchiostegal rays 14–16. Lower jaw with 10 (8–11)



Range Map 149. *Esox americanus*, grass or redfin pickerel.

Plate 153. *Esox lucius*, northern pike, adult, colored pencil rendition of J.R. Tomelleri.

total pores. Vertebrae 57–65. Color dark gray-green on back and sides, white to yellowish on lower sides and belly. Adults with about eight longitudinal rows of yellowish, bean-shaped spots on side. Juveniles with dark of sides interrupted by narrow, oblique pale areas ventrally that tend to form vermiculations or vertically elongate spots on upper side. Median fins with dark blotches; all fins may show amber, orange, or red color.

Biology: The northern pike may not be native to Tennessee, but it has been widely introduced south of its original range in North America. It is abundant in vegetated lake habitats in northern states and also occurs in rivers. Within its native range, spawning occurs shortly after spring break-up, and adults typically begin their upstream movements toward spawning areas before rivers are ice-free. Spawning occurs in vegetated shallows at water temperatures of about 4.5–11 C (40–52 F). The eggs are large (2.5–3 mm in diameter), and about 3,000 to 120,000 are produced per female, depending on size. The adhesive eggs hatch in about 2 weeks, and larvae are inactive for about an additional week during yolk-sac absorption. Early food consists of invertebrates, but the diet shifts to fish within 2 weeks, when the pike fry are about 50 mm TL. Early spawning makes fry of later spawners such as suckers (and muskellunge) available as prey. Young pike reach total lengths of about 15–30 cm (6–12 in) during their first year, and under exceptional conditions may reach 46–51 cm (18–20 in). Sexual maturity occurs in about 3–5 years, and life span is probably about 25 years. Scott and Crossman (1973) and Becker (1983) provided additional information and literature references for this extensively studied species.

Although very similar to the muskellunge in maximum size, strength, and flavor, northern pike are not nearly so popular with anglers, perhaps due to a combination of their averaging smaller, being easier to catch, and tending to fight deep rather than on the surface as is typical of the musky. In Melton Hill Reservoir, northerns are sought by anglers around the milfoil beds. Pike often concentrate, along with other predators, near the heated effluent of the Bull Run Steam Plant to take advantage of the forage fishes congregated there. Spoons, large plugs, and live minnows are favorite baits. Many large northerns are lost by inexperienced anglers unfamiliar with their typical behavior after being hooked. After only a very few, often feeble efforts to escape, they usually allow themselves to be reeled in, apparently ready to be landed. The first attempt to net or gaff them invariably results in a tremendous burst of power, and often leads to broken lines and rod tips. Their sharp teeth can quickly cut monofilament leaders, and wire is recommended unless very large artificial lures are being used. Melton Hill Reservoir northerns are growing rapidly, and the Tennessee record will probably climb steadily for some time. At this writing it is 20 lb 12 oz, 1987, John Hammond. The world angling record of 62.5 lb was caught in Switzerland in 1979. The North American angling record of 46 lb 2 oz, from Sacandaga Reservoir, New York, has held since 1940. Specimens from 75 to nearly 150 lbs have been reported from Europe, but these are unverifiable old records usually treated with considerable skepticism.

Distribution and Status: Native to northern North America and Eurasia, but widely stocked elsewhere. Crossman (1978) considered the native range in North America to include virtually all of Canada, and the United States from Vermont to Montana and southward into Missouri and Ohio. In the colder climate of the Pleistocene, *E. lucius* probably ranged much further south. As a result of a recent stocking program by Virginia biologists, an occasional northern pike is taken in both the Tennessee and Virginia portions of South Holston Reservoir. A specimen of unknown origin was recently captured in Little River, Blount County; and

Melton Hill Reservoir is currently being stocked on a regular basis. Reproduction has not been demonstrated in Tennessee. It is not unreasonable to expect native northern pike to occur sporadically in the Mississippi River in west Tennessee, as they have been reported from that river as far south as southern Illinois.

Similar Sympatric Species: Any record of *Esox lucius* from the Mississippi River in west Tennessee would be of extreme interest. *Esox americanus* and *E. niger* both occur there, but differ from *E. lucius* in having fully scaled opercles and usually eight versus ten mandibular pores. Potentially sympatric with the muskellunge throughout east Tennessee; muskies have a naked lower cheek, typically 12 or more mandibular pores, and generally higher meristic counts (see Characters).

Etymology: *lucius* is a Latin name for pike.

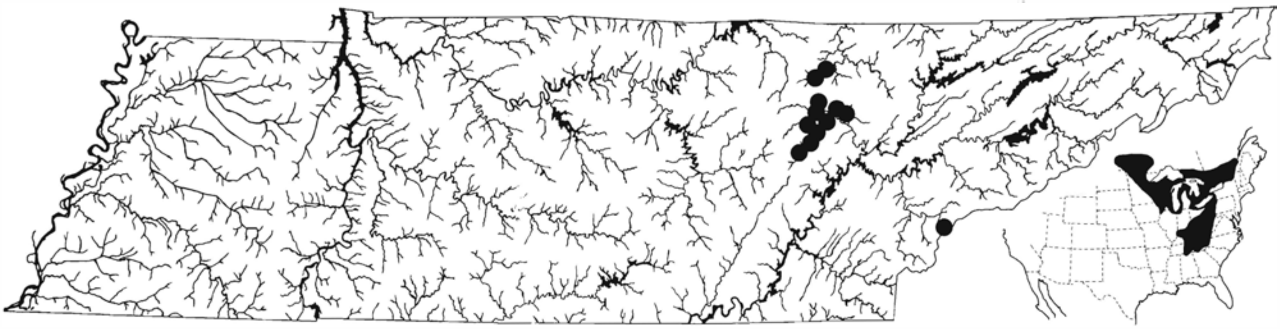
Esox masquinongy Mitchill

Muskellunge

Characters: Lateral-line scales 130–167. Dorsal fin rays 15–19. Anal fin rays 14–16. Pectoral fin rays 14–19. Pelvic fin rays 11–12. Principal caudal fin rays 19. Branchiostegal rays 16–19. Lower jaw with 12 or more (11–19) total pores. Vertebrae 64–66. Color silvery with dark broken vertical bars, less apparent in larger individuals. Dorsal, anal, and caudal fins gray to reddish, often with large dark spots; these fins orange in juveniles. A black horizontal streak through eye.

Biology: Muskellunge are inhabitants of pool areas in rivers, and larger northern lakes. In Tennessee they are native to relatively clear upland rivers where they occur in large rocky pool habitats and serve as top predators, feeding on a variety of other fishes, including other "muskies" nearly half their own size, and salamanders. As top predators, they probably were never overly abundant. Musky are very aggressive and have been observed to attack one another on occasion (Parsons, 1959). Biology of the musky is similar to that of the northern pike, but spawning occurs somewhat later, at water temperatures of 9.4–15 C (49–59 F). Because of their depleted status, southern riverine populations (*E. m. ohioensis*) are not well studied. In eastern Kentucky rivers, Brewer (1980) found musky to be extremely sparse with only one adult fish per 12–14 acres of pool habitat; nowadays Tennessee populations may be even more sparse. Axon and Kornman (1986) found optimum habitat to be pools about 1 m in depth in stream reaches with gradients of .6–1.2 m/km with plenty of fallen trees. Spawning occurs in April and May at water temperatures of 13–15 C. Spawning habitat was believed to be shallow waters near the ends of pool areas. Upstream movement and migration into smaller tributaries prior to spawning was detected. Following spawning, musky move considerable distances (up to 20 km) away from spawning areas. Parsons (1959) noted that musky would only spawn in the upper 12–17% of the inhabited stream area. Spawning is indiscriminate, with eggs strewn over the bottom (thus vulnerable to siltation), and up to 180,000 may be extruded by a single female (Oehmcke et al., 1965). Natural hybrids with northern pike occur, and this hybrid, often called the tiger musky, has been intentionally cultured in fish hatcheries. Development requires 8–14 days at spawning temperatures. In Kentucky, musky averaged 26 cm TL (10 in) at age 1, 46 cm at age 2, 60 at 3, 73 at 4, 84 at 5, and 90 at 6; sexual maturity was reached at age 4 (Brewer, 1980). In Tennessee, Parsons (1959) estimated growth at about 15 cm per year with sexual maturity reached at 3 years and 56 cm in males and 3–4 years and 64 cm in females. Few muskies were believed to live beyond 6 years. Most adults were under 2.3 kg (5 lb) and 68 cm (30 in). The record for the Tennessee riverine form is 10.2 kg (22.5 lb) and 103.5 cm (46 in)

Plate 154. *Esox masquinongy*, muskellunge, adult, colored pencil rendition of J.R. Tomelleri.



Range Map 150. *Esox masquinongy*, muskellunge (widely introduced outside of native range shown on Tennessee map and inset).

caught in Emory River in 1947. In northern populations, life span estimates are 24–30 years (Becker, 1983). Additional biological information, primarily on northern populations, is presented in Scott and Crossman (1973) and Becker (1983); Crossman and Goodchild (1978) have compended a large bibliography on muskellunge biology, and Hall (1986) edited a treatise on their biology and propagation.

Lake-adapted northern muskellunge have been stocked into some Tennessee reservoirs, but there is no indication that natural reproduction has occurred in these habitats. The "stockers" grow rapidly to catchable size, but tremendous fishing effort is expended for each one caught. Trolling with very large lures is the prevalent technique. The Tennessee record is 42 lb 8 oz, caught by Kyle Edwards from Norris Reservoir in 1983. The former world angling record of 69 lb 15 oz, St. Lawrence River, 1957, has been disqualified; its replacement is a 69 lb 11 oz fish from Chippewa Flowage, Wisconsin, 1949 (pers. comm. Bob Kutz, National Fresh Water Fishing Hall of Fame). Older reports of muskellunge weighing about 100 pounds are poorly documented but generally accepted as possible.

Distribution and Status: Native to Ohio River drainage (including Cumberland and Tennessee rivers), upper Mississippi River drainage, the Great Lakes, southern Hudson Bay tributaries, and some northern Atlantic Coastal drainages. Fossils indicate that ancestral forms may have occurred in the Pacific Northwest in the Miocene and that musky occurred well into the Southwest in the Pleistocene (Cavender et al., 1970). This largest of the pikes occurred in both the Cumberland and Tennessee river systems of east and middle Tennessee until recently. Our native populations are virtually extinct, and are treated as Endangered by both the Wildlife Resources Agency and the Heritage Program (Starnes and Etnier, 1980). Pfitzer (1954) reported the former occurrence of the native muskellunge in the French Broad, Little Tennessee, and Hiwassee rivers. Dickinson (1986) recorded remains of late Pleistocene or Holocene age from caves along the Duck River. It was known to be in jeopardy several decades ago (Parsons, 1959). It is likely that this species was once widespread in larger streams and rivers of both the Tennessee and Cumberland drainages, with hearsay records extending downstream to the Harpeth River in the Cumberland drainage and about to the Chattanooga area in the Tennessee drainage. According to Kuhne (1939), there was a former sport fishery for musky in the Cumberland River near Nashville. Impoundments have destroyed most of these populations, and siltation from coal surface-mining has doubtless impacted Cumberland Plateau stream populations. Tiny native populations persist in several streams in the Big South Fork and Obed river systems of the Cumberland Plateau, according to Parsons (1959) and Riddle (1975), who reported them from Clear Fork, Crooked, Daddys, Clear, Rock, and White creeks in these systems, as well as the lower Obed and Emory rivers. Progeny from northern muskellunge populations have been and continue to be introduced, as hatchery and brood stock availability allow, into Tennessee reservoirs, where growth has been excellent.

Similar Sympatric Species: See account for *E. lucius*.

Systematics: Many Tennessee reservoirs receive annual plantings of young, hatchery-reared muskellunge that are descended from brood stock from non-native strains of northern lakes (i.e., *E. m. masquinongy*). The muskellunge of the Ohio River system has been regarded as a distinct subspecies, *E. m. ohioensis* Kirtland. It has been assumed that muskellunge native to the Tennessee and Cumberland River systems are identical with those of the Ohio. Juveniles of our native muskellunge differ from those of other areas in having a broad, unbroken band of iridescent silver along each side, but Jim Little, TWRA, indicates that this trait is not consistent (pers.

comm.). Trautman (1957) described juvenile pigmentation for *E. m. ohiensis* to be very similar to that of more northerly populations—vertically banded or with these bands broken into rows of spots that angle anteriad from the dorsum. The recent tendency has been to treat the muskellunge as a variable but monotypic species (Crossman, 1978). It is possible that the Tennessee and Cumberland river populations represent a race distinct from that of the Ohio River. Unfortunately, native muskellunge are now so rare that this important question may never be answered. There is considerable sympathy in the state for saving our native muskellunge by protecting extant populations from poaching and environmental damage. In addition, attempts have been made to culture these native, stream-inhabiting forms (Garavelli, 1977), but so far success has been limited. Since it is presently very difficult to capture enough specimens to serve as a brood stock in our state, our southern muskellunge may be doomed to extinction, genetic swamping from Great Lakes populations, or genetic blending with the supposedly identical populations from the Ohio River.

Etymology: *masquinongy* stems from an Ojibwa (Chippewa) Indian name for this fish.

Esox niger Lesueur

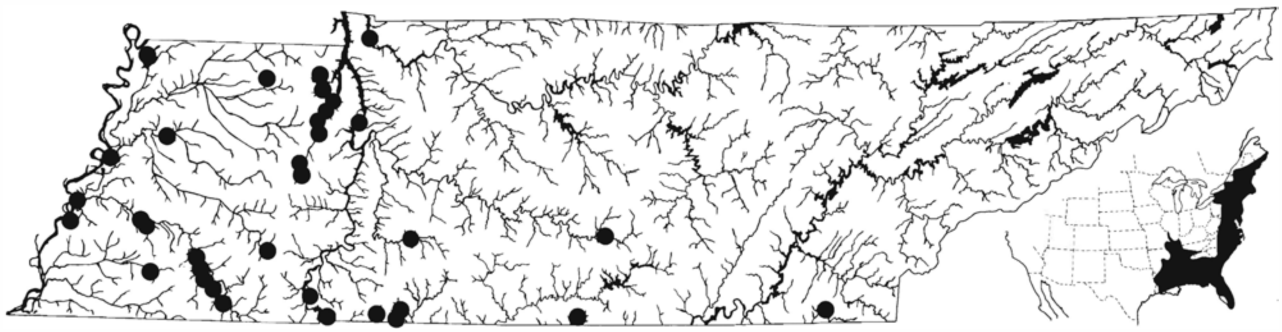
Chain pickerel

Characters: Lateral-line scales 110–138. Dorsal fin rays 14–15. Anal fin rays 11–13. Pectoral fin rays 12–15. Pelvic fin rays 9–10. Principal caudal fin rays 19. Branchiostegal rays 14–17 (rarely 13). Lower jaw with 8–9 total pores. Vertebrae 52–54. Color of adults dark green on back and sides; sides with pale reticulations forming chain-like markings. Fins not blotched or brightly colored. Juveniles lack the chain-like markings, with green of sides interrupted by narrower pale areas; a pale middorsal streak is often evident.

Biology: This is the well-known pickerel of the East Coast, where it is a popular food and game fish. It is fairly common in portions of west and middle Tennessee, but receives little fishing pressure in our state. It occurs in weedy, still water habitats from oxbow lakes and spring outflows to quiet areas in creeks and rivers. The chain pickerel would appear to prefer relatively clearer and more vegetated habitats than the sympatric redfin pickerel. Young feed predominantly on insects and crustacea until they reach about 100 mm TL, and then switch to a piscivorous diet (Meyers and Muncy, 1962). Spawning occurs in early spring at water temperatures of 8–11 C (47–52 F) and lasts for about 1 week (Scott and Crossman, 1973). As is the case with *E. americanus*, it has been suggested that an additional fall spawning may occur. Females 30–35 cm long contained about 6,000–8,000 mature eggs. Young reached lengths of about 175 mm TL (7 in) after 1 year's growth in Massachusetts (Scott and Crossman, 1973), and were 370 mm (15 in) long after 4 years. In Maryland, young-of-the-year attained an average 160–170 mm at 4–5 months of age (Meyers and Muncy, 1962). Sexual maturity may be reached after 1 year in the southern part of its range, but is normally delayed until after 2 or 3 years in the north. Life span in northern states is 8 or 9 years. The accepted world angling record of 4.3 kg (9 lb 6 oz) is from Georgia, 1961. The largest specimen caught in Tennessee, 3.4 kg (7 lb 7 oz), was from Kentucky Reservoir, Burke Williams, 1991.

Distribution and Status: Primarily on the Coastal Plain and Piedmont of Atlantic and Gulf coastal drainages from the New England area to western Louisiana, and introduced in numerous areas to the north and west. Occurring well above the Fall Line in the eastern Great Lakes and Mississippi River and Mobile basins, including the Conasauga River in Bradley County, Tennesssee. Rare in rivers of the western Highland Rim, but abundant in some of the larger, heavily vegetated spring outflows in that area. Less common than the

Plate 155. *Esox niger*, chain pickerel, 103 mm SL, lower Tennessee R. system, TN.



Range Map 151. *Esox niger*, chain pickerel.

grass pickerel in Coastal Plain areas of west Tennessee except in well-vegetated ponds and oxbows with clear waters.

Similar Sympatric Species: See *E. americanus* account.

Etymology: *niger* = black.

FAMILY UMBRIDAE

The Mudminnows

Mudminnows comprise a small family of strictly freshwater northern-hemisphere fishes. They are considered closely related to the esocids and are included with them in the salmoniform suborder Esocoidei (Nelson, 1972). Relationships were further discussed by Cavender (1969), Wilson and Veilleux (1982), Banarescu et al. (1983), and Reist (1987). Fossils date to the Oligocene of Eurasia and North America (Cavender, 1969). Umbrids are characterized by a short snout, posterior dorsal fin placement, and lack of a lateral line. Four of the six species occur in North America, as follows: *Umbra pygmaea* (DeKay), the eastern mudminnow, occurs along the Atlantic Coast lowlands; *Umbra limi* (Kirtland), the central mudminnow, occurs in north central North America; *Novumbra hubbsi* Schultz, the Olympic mudminnow, is restricted to western Washington; and *Dallia pectoralis* Bean, the Alaska blackfish, occurs in Alaska and adjacent Siberia; an additional *Dallia* species was recently described from eastern Siberia (Chereshnev and Balushkin, 1980). A third *Umbra* species, *U. krameri*, occurs in Europe. There is not a consensus among the above workers on the interrelationships of these fishes except that *U. limi* and *U. pygmaea* are closest relatives. Alaska blackfish may reach lengths of up to 8 in (205 mm) and are used for dog food and occasionally for human food in areas where they are abundant. The other species are much too small to be used as food fishes, but *Umbra limi* has some economic value as a bait fish, and occasionally mudminnows are shipped into Tennessee along with shipments of fathead minnows (*Pimephales promelas*) from the Midwest.

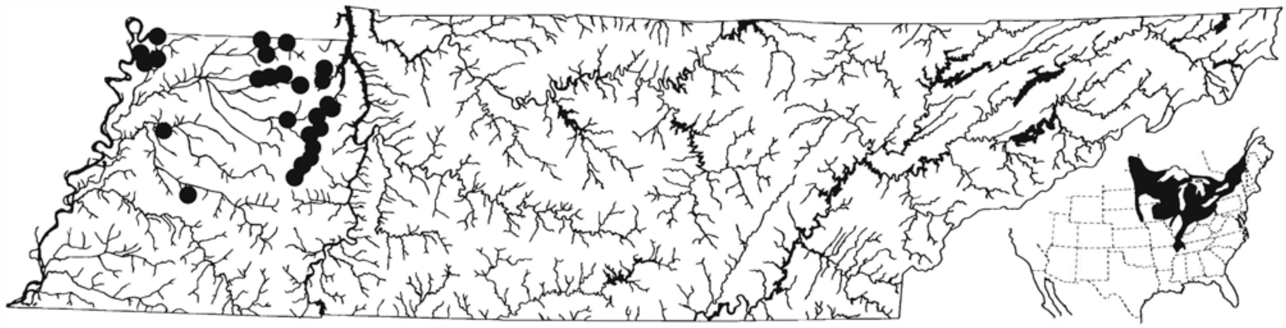
Genus *Umbra* Scopoli

Umbra limi (Kirtland)

Central mudminnow

Plate 156. *Umbra limi*, central mudminnow, 63 mm SL, Reelfoot L., TN.

Characters: Lateral line absent, scales in lateral series 34–37. Dorsal fin rays 13–15. Anal fin rays 7–9. Pectoral fin rays 14–16. Pelvic fin rays 6–7. Principal caudal fin rays 12–13. Branchiostegal rays 4. Vertebrae 35–37. Color dark brown on back and sides, often with



Range Map 152. *Umbra limi*, central mudminnow.

greenish tints; dark of sides interrupted by narrow pale areas extending upward from the buff-colored lower sides. Fins uniformly pale to dark brown. Conspicuous dark vertical bar at caudal fin base.

Biology: The central mudminnow is an inhabitant of swamps or sluggish creeks where it is usually associated with dense vegetation, detritus, or other cover. Biological information is summarized from Gill (1904), Rice (1942), Peckham and Dineen (1957), Carlander (1969), and Scott and Crossman (1973). Spawning occurs in spring when water temperatures reach about 13 C (55 F), or about mid March in our area. Adults move into shallow waters, where the adhesive eggs are deposited on vegetation. Females produce from about 200 to over 2,000 eggs per year, which hatch in about a week. Young specimens up to about 25 mm have the developing vertebral column extending above and free from the caudal fin (see Breder, 1933), a condition shared by the gars. In northern populations, average total lengths of 50–70 mm were estimated after the first year's growth, with averages of 64–79, and 76–86 in succeeding years. Sexual maturity may be reached at age 1, but is usually delayed in females until they are 2 years old. Life span has been suggested to be as little as 4 and as much as 9 years. Food of smaller specimens is primarily ostracods, with larger specimens consuming aquatic insects, amphipods, isopods, and snails. Behavior in aquaria suggests that mudminnows lie motionless and ambush or slowly stalk their prey. They also are known to leap from the water to take prey perched overhead. Mudminnows are very adept at surviving in habitats with periodic oxygen depletion, and are, along with brook sticklebacks and fathead minnows, often the only fish species encountered in shallow, organic midwestern lakes. They have been observed to periodically rise to the surface and gulp air, one possible adaptation to these conditions. Early naturalists (e.g., Abbott, 1870) contended that mudminnows burrow into the mud to "hibernate" over winter, but this was not found to be the case by Peckham and Dineen (1957). Maximum total length 132 mm (5.2 in).

Distribution and Status: Upper Mississippi River basin, Great Lakes tributaries, and southern headwaters of Hudson Bay drainage. Common in northern glacial regions but uncommon southward. Northwestern Tennessee represents the southern extent of the range, where the central mudminnow is restricted to Coastal Plain habitats of the Obion and Forked Deer river systems, and a western tributary to the lower Tennessee River, the Big Sandy.

Similar Sympatric Species: The posterior position of the single dorsal fin readily separates *Umbra* from all Tennessee fishes likely to be encountered in west Tennessee except the killifishes and topminnows. *Umbra* differs from these in having a vertical black bar at the base of the caudal fin, a less modified jaw structure, and in having the dorsal fin origin distinctly anterior to the anal fin origin.

Etymology: *Umbra* = a shadow; *limi* = of the mud.

FAMILY OSMERIDAE
The Smelts

Smelts are salmoniform fishes that differ noticeably from salmonids in lacking axillary processes associated with the pelvic fins (Fig. 11). Smelt are further characterized by their small, slender body, silvery-color, large mouth with well-developed teeth, and adipose fin. Some have a characteristic odor very much like that of a cucumber, as do several of the temperate southern hemisphere galaxioid fishes. Osmerid fossils date to at least the Paleocene Epoch over 55 million years ago. They were included in the suborder Salmonoidei with salmonids and related families (G. Nelson, 1970b; J. Nelson, 1984), but, in more recent works, Begle (1991, 1992) hypothesized the galaxioid fishes as the closest relatives to smelts and placed them together in a separate suborder, Osmeroidei; the marine argentinoid fishes are the hypothesized sister group to that suborder. McAllister (1963), Begle (1991), and Wilson and Williams (1991) reviewed their systematics. The distribution of the family (seven genera, eleven or so species) is circumboreal. Two species of the genus *Hypomesus* (western North America and eastern Asia) are virtually confined to fresh waters, but other smelts are normally marine inhabitants as adults, either spawning on ocean beaches or in freshwater streams. Landlocked populations are established for many of the anadromous species. Most species occur in the North Pacific, with only the capelin (*Mallotus villosus*) and the familiar rainbow smelt (*Osmerus m. mordax*) occurring in the western North Atlantic. The anadromous "ayu" (*Plecoglossus*) of eastern Asia, formerly placed in a separate family, was the hypothesized closest relative to *Osmerus* by Begle (1991), but Wilson and Williams (1991) hypothesized their new freshwater Paleocene fossil genus, *Speirsaenigma*, to be the ayu's closest relative in a sister lineage containing *Osmerus* plus *Allosmerus*, *Thaleichthys*, and *Spirinchus*; *Mallotus* and the freshwater *Hypomesus* were considered even more primitive members of the family than the Paleocene fossil genus.

Genus *Osmerus* Linnaeus

Taxonomy of the genus *Osmerus* has been problematic. According to the revision of McAllister (1963), in addition to the rainbow smelt, *O. m. mordax*, the genus includes a North Pacific subspecies *O. mordax dentex*, and the very similar *O. eperlanus* of the eastern North Atlantic. However, some localized landlocked populations have, at times in the past, been accorded taxonomic status (e.g., the pygmy smelt, *O. spectrum* Cope, of Maine) and studies of landlocked populations in Canada by Copeland (1977) indicated that a separate taxon might be involved.

Osmerus mordax (Mitchill)

Rainbow smelt

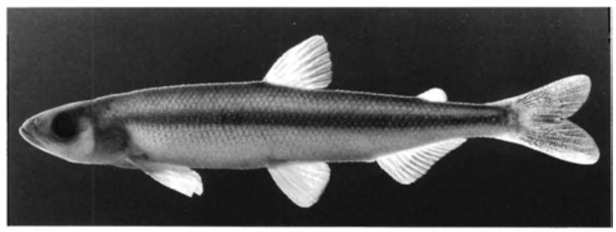
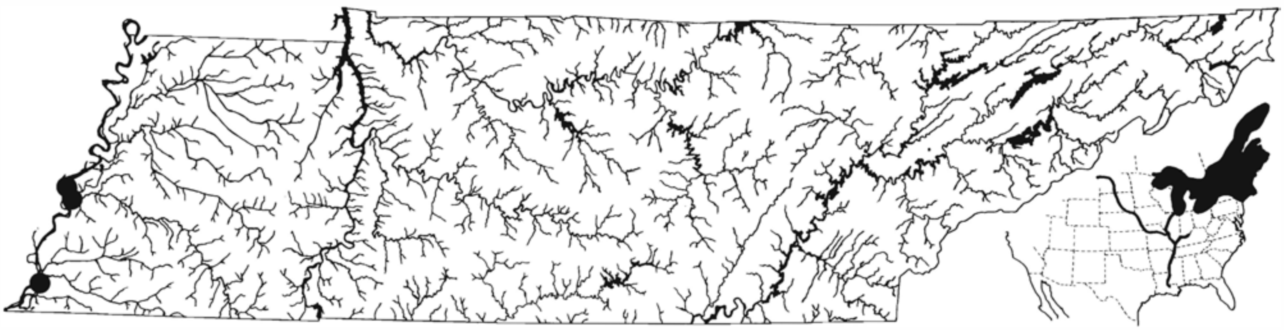


Plate 157. *Osmerus mordax*, rainbow smelt, preserved tuberculate male specimen, 110 mm SL, L. Michigan, IL.

Characters: Lateral line incomplete with about 20 pored scales and 60–74 scales in lateral series. Dorsal fin with 8–11 rays. Anal fin rays 12–17. Pectoral fin rays 11–14. Pelvic fin rays usually 8. Principal caudal fin rays 19. Branchiostegal rays usually 7. Gill rakers 26–35. Vertebrae 58–70. Mouth with teeth well developed on upper and lower jaws, vomer, palatines, pterygoids, tongue, and basibranchial. Color bright silver on sides and belly, back dark gray and often with blue or green tints. Nuptial males develop very fine tubercles over their head, body, and fins.

Biology: Biological information for Great Lakes populations has been summarized from Gordon (1961), M. Bailey (1964), Scott and Crossman (1973), and Becker (1983). Smelt were successfully introduced into Lake Michigan in about 1912, and have subsequently spread throughout the Great Lakes. The spring spawning run into Great Lakes tributaries occurs in early spring at water temperatures of about 9 C (48 F) or less, and is eagerly anticipated by local residents, many of whom suffer severe symptoms of cabin fever about that time of the year. Smelt are caught in large numbers near mouths of spawning streams with small seines and dip nets. Adults average about 200 mm (7–8 in) and spawn at night. Congregations of smelters, often fortified with libations to ward off the chill of April nights, frequently



Range Map 153. *Osmerus mordax*, rainbow smelt (Great Lakes and Mississippi Basin populations represent introductions).

attain a unique party mood, and spend the night sharing fires, spirits, fishing tales, and seining spots. Smelt are scaled, decapitated, and gutted before deep-frying, and are an excellent food fish. Significant commercial fisheries are also established. Many are frozen whole for later use as lake trout or walleye bait. Two or more males accompany each female during actual spawning, which lasts for about 1 week. About 10,000–30,000 adhesive eggs are produced per female. The eggs adhere to the substrate, and the egg covering is sloughed off except for the attachment, leaving a "stalk." Young hatch in about 2 or 3 weeks and reach total lengths of up to 75 mm (3 in) during their first year, attain about 150–175 mm the second year, 180–200 the third, and 210–225 the fourth with females being both larger and more numerous in older age classes. Sexual maturity is reached in 2 or 3 years, and life span is for 5 or 6 years. Young smelt feed on zooplankton, particularly copepods and cladocerans. Adults feed heavily on mysid shrimp, mayfly larvae, and small fishes. Maximum total length 356 mm (14 in).

Distribution and Status: Anadromous, with occasional landlocked populations, in Alaska area and western North Atlantic south to Delaware River, and a recent invader of the western Great Lakes. This very recent addition to the Tennessee fish fauna appeared explosively in the Mississippi River from Illinois to Louisiana during 1978–1980 (Burr and Mayden, 1980; Suttkus and Conner, 1980; Buchanan, 1982; Mayden et al., 1987). All Mississippi River smelt have been taken during cooler months (December through April), and all have been in their first year (68 mm or less in standard length). Burr and Mayden (1980) suggested the source of these juveniles was Lake Michigan via the Illinois River. However, Mayden et al. (1987) documented introductions in the upper Missouri River drainage in North Dakota in 1971, which they feel are responsible for the invasion of that system and the Mississippi. The absence of any adult specimens coupled with their usual avoidance of water temperatures over 16 C (60 F) makes it unlikely that a breeding population occurs in the Mississippi River or its tributaries. Efforts to establish rainbow smelt in our cooler reservoirs (Watauga, South Holston) have not been successful.

Similar Sympatric Species: The only other Mississippi River fishes in our area with adipose fins are the very dissimilar catfishes.

Etymology: *Osmerus* = smell or scent, probably referring to the "sliced cucumber" odor especially noticeable in breeding adults; *mordax* = biting.

FAMILY SALMONIDAE

Trout, Salmon, and Char

The popular trout and salmon provide the stem name for the order Salmoniformes, whose constituency is discussed under Esocidae. The family Salmonidae is a northern-hemisphere group of freshwater and anadromous fishes, dating perhaps to the Cretaceous (Cavender, 1986). Intrafamilial systematics have been studied to varied degrees by Norden (1961), Rounsefell (1962), Vladykov (1963), Behnke (1968, 1979), Utter et al. (1973), Kendall and Behnke (1984), Gyllensten and Wilson (1987), Sanford (1987), Smith and Stearley (1989), Thomas and Beckenbach (1989), and others. The family includes chars, trout and salmon (subfamily

Salmoninae), whitefishes (subfamily Coregoninae), and grayling (subfamily Thymallinae). Within Salmoninae, in addition to genera occurring in North America discussed below, three genera are restricted to Eurasia: *Brachymystax*, *Salmothymus*, and *Hucho*. Salmonids are characterized by the presence of an adipose fin, pelvic axillary process, and numerous pyloric caecae, and small cycloid scales embedded in slimy mucous. They are among our most notable food and game fishes. The five anadromous species of Pacific salmon (genus *Oncorhynchus*) are among our most valuable food fishes. The Atlantic salmon (*Salmo salar*), anadromous along our East Coast and along the European coast, is the legendary sport fish responsible for much of the lore associated with dry fly fishing. Unfortunately, Atlantic salmon populations have decreased drastically, presumably due to commercial overfishing on the high seas and to impoundment and pollution of spawning streams. Recently, there is reason for some optimism concerning at least the partial recovery of these stocks. The lake trout (*Salvelinus namaycush*) and several species of whitefish (genera *Coregonus* and *Prosopium*) were the mainstay of the commercial catch in the Great Lakes prior to their elimination as commercially fishable stocks by the introduced sea lamprey. Lake trout populations are recovering in the upper Great Lakes, but populations of several species of whitefishes are still extremely low, and possibly already extinct. The character of the Great Lakes fishery has undergone a rapid change in recent years with introductions of Pacific salmon, alewife, smelt, and rainbow and brown trout. It is likely that this change is permanent, and that the future of the fishery will continue to rely heavily on introduced species.

Because of their popularity as food and game fishes, salmonids have been widely introduced throughout the world, often with considerable success, but sometimes to the detriment of native species. The coho salmon (*O. kisutch*) and the chinook salmon (*O. tshawytscha*) appear to be well established in the upper Great Lakes as a result of yearly stocking, and are providing spectacular sport fishing. A small population of pink salmon (*O. gorbuscha*) has become established in Lake Superior. In Tennessee, many attempts have been made to establish exotic species of salmonids (see Introduced Species and Table 2), but at this writing only the brown and rainbow trout are established. Recent attempts to establish the ohrid trout (*Salmo letnica*), a lake-spawning species similar to the brown trout, into Watauga Reservoir are being followed with some optimism by Tennessee Wildlife Resources Agency personnel. Although doing well, there is no evidence of natural reproduction at this writing (Doug Peterson, TWRA, pers. comm.). Lake trout (*Salvelinus namaycush*) stocked in Dale Hollow Reservoir are showing some potential for producing an additional fishery. An attempt to establish one Great Lakes cisco species (*Coregonus artedi*) in Calderwood Reservoir in 1960 failed.

Trout and salmon spawn over gravel shoal areas, typically in small streams. Mature males differ conspicuously from females in having an elongate, hooked lower jaw. The female excavates a shallow depression in the gravel by lying on her side in contact with the substrate and then violently swimming forward. One or several males may be in attendance during excavation of the nest or redd. After spawning, the female covers the redd with gravel. The large (3.5–5 mm) eggs are dependent on water percolating through this cover of gravel for an oxygen supply, and hatching success is greatly reduced by silt which clogs the pores or interstices between gravel particles. Eggs hatch in 4–10 weeks, depending on temperature, and the juveniles remain under the gravel until the yolk sac has been absorbed. Juveniles have characteristic large, round or oval dark spots (parr marks) along the sides. Young of most species stay in the nursery stream until reaching 10–30 cm (4–12 in) in anadromous populations before moving downstream to the lake or ocean where they will mature. Trout and salmon have considerable tolerance for salt water, and sea run strains are known for all of our species. The incredible homing instinct of the Pacific salmon has received considerable attention and has been shown (Hasler, 1960, 1966) to depend on imprinting of the young on unique olfactory (smell) stimuli from the nursery stream. Thus, returning adult salmon accurately choose the proper tributary stream when they encounter forks in the river. Their ability to home to the mouth of the parent river from several hundred miles at sea is still poorly understood. Most adult Pacific salmon (*Oncorhynchus*) die shortly after spawning, but steelhead trout (*Oncorhynchus mykiss*) and anadromous strains of *Salmo* and *Salvelinus* may return to spawn again. Stream trout feed primarily on adult and immature aquatic insects, but become increasingly piscivorous with larger size. More detailed biological accounts for all of our trout appear in Scott and Crossman (1973) and Becker (1983).

KEY TO THE TENNESSEE GENERA AND SPECIES

1. Dorsum with pale spots on dark background; scales in lateral series 200 or more; teeth absent from shaft of vomer (Fig. 125a) . . . . *Salvelinus fontinalis* p.350
   Dorsum with dark spots on lighter background; scales in lateral series 160 or fewer; teeth present on shaft of vomer (Fig. 125b) 2

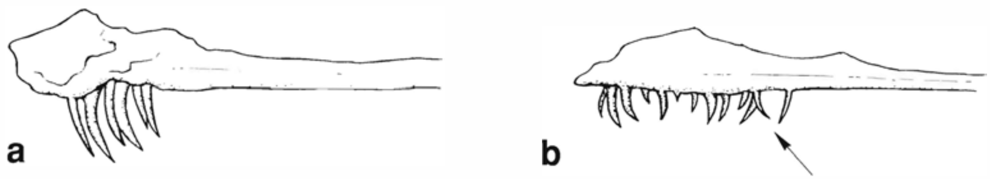


Figure 125. Vomerine teeth of trouts: a) *Salvelinus fontinalis*; b) *Oncorhynchus mykiss.*

2. Caudal fin profusely covered with black spots; sides with broad pink lateral stripe in life; dorsal fin rays 10–12 . . . . *Oncorhynchus mykiss* p.346
   Caudal fin lacking black spots, or with only a few along dorsal margin; sides with scattered red spots in life; dorsal fin rays 12–14 . . . . *Salmo trutta* p.348

Genus *Oncorhynchus* Suckley
The Pacific Salmons and Trouts

The genus *Oncorhynchus* contains the anadromous Pacific salmons (six species) and the "Pacific trouts" (five or more species) of western North America and northeastern Asia. Most of the Pacific salmons are well known commercial species, including the pink (*O. gorbuscha*), sockeye, red, or kokanee (*O. nerka*), coho or silver (*O. kisutch*), chinook or king (*O. tshawytscha*) and chum or dog (*O. keta*) salmons; these species and a sixth species, *O. masuo*, also occur in Asian waters. The western trouts include the familiar rainbow or steelhead trout (*O. mykiss*), cutthroat trout (*O. clarkii*), golden trout (*O. aguabonita*), and three geographically restricted species, the Gila (*O. gilae*), Apache (*O. apache*) and Mexican (*O. chrysogaster*) trouts. The taxonomies of the widespread species *O. clarkii* and *O mykiss* are complex and controversial, and several forms or subspecies have been recognized in each.

Until very recently, the western trouts were included in the genus *Salmo* along with the Atlantic salmon and European trouts (e.g., *S. trutta*). However, several students of salmonid systematics (e.g., Vladykov, 1963; Behnke, 1968, 1979; Berg and Ferris, 1984; Kendall and Behnke, 1984; Smith and Stearley, 1989) have hypothesized on strong evidence that the western trouts are more recently diverged evolutionarily from the anadromous Pacific salmons (*Oncorhynchus*) than from members of *Salmo*. To more accurately reflect these relationships, it was necessary to revise salmonid classification by either including all of these fishes in *Salmo*, including the western trouts with the Pacific salmons in *Oncorhynchus*, or recognizing one of the potentially available separate genus names (e.g., *Parasalmo* Vladykov or the older fossil genus name, *Rhabdofario* Cope) for the western trouts. The second of these alternatives was chosen as the least disruptive to current nomenclature of these extremely publicized fishes (Smith and Stearley, 1989), although the use of the name *Rhabdofario* for the distinctive and presumably monophyletic grouping of Pacific trouts questionably would have been no more disruptive and would have preserved the current, deeply engrained concept of the distinctive Pacific salmons alone constituting the genus *Oncorhynchus*. A good general discussion of the nomenclatural problems of these salmonids was recently presented by Behnke (1990).

In addition to the rainbow trout accounted below, the cutthroat trout, *Oncorhynchus clarkii,* was introduced to Tennessee waters in the 1950s, and Kokanee (*O. nerka*) and coho salmon (*O. kisutch*) were introduced to various localities in the 1950s and 1960s (Table 2). However, none of these introductions has resulted in persistent populations.

Etymology: *Onco* = hook, *rhynchus* = snout, in reference to the hooked jaw of breeding males.

Oncorhynchus mykiss (Walbaum)

Rainbow trout

Characters: Lateral-line scales 100–150. Dorsal fin rays 10–12. Anal fin rays 8–12. Pectoral fin rays 11–17. Pelvic fin rays 9–10. Branchiostegal rays 9–13. Gill rakers 16–22. Vertebrae 60–66. Color green dorsally, white or yellowish ventrally, with a pink to red lateral stripe. Black spots dorsally on head, back, and upper sides, and on dorsal, adipose, and caudal fins.

Biology: The popular rainbow trout was originally native to western North America, primarily in coastal streams of the Northwest. It has been introduced into suitable and unsuitable habitats throughout the world. In some areas it has had negative impacts on native trouts (see *Salvelinus fontinalis* account). It ranks with the goldfish as one of the most intensively cultured fish species. Original rainbow trout populations were extremely variable, and forms of the rainbow trout have been described under a dozen or more scientific names. This genetic diversity has been utilized by fish culturists to produce strains that adapt very well to hatchery conditions, are tolerant of warm water, grow rapidly, are disease resistant, spawn at various times of the year, or have various migratory patterns. Albino strains, which lack dark pigment and are brilliant yellow-gold with a red lateral stripe, have been developed and stocked in some states (e.g., West Virginia).

Rainbows are typically spring spawners, with lake- or sea-run (steelhead) populations entering tributary streams in response to high, turbid waters produced by heavy spring rains. Fecundity of females averages 2,500 to 4,500 (Carlander, 1969). Rainbows are stocked by the state Wildlife Resources Agency in suitable creeks, reservoirs, and rivers throughout middle and east Tennessee, but unlike the brown trout, stream rainbows seldom reach sizes even close to maximum for the species. Specimens larger than 30–35 cm TL (12–14 in) are unusual in small and medium streams. Reasons for small maximum size in streams are not definitely known, but may be related to strong migratory tendencies of mature fish and physical size of the environment. There is apparently considerable winter mortality among older fishes in these streams, as noted by Whitworth and Strange (1983). These authors reported growth in small Blue Ridge streams in Tennessee as follows: age 1, 80–120 mm TL; age 2, 160–200; age 3, 200–240. Rainbows reach larger sizes in some of our reservoirs and tailwaters. Strains that inhabit cold lakes or the ocean and spawn in tributary streams are referred to as "steelhead." One such form has had some success in Watauga Reservoir, and fish weighing 1.8–2.7 kg (4–6 lbs) are taken by anglers during spring spawning runs. Young rainbows feed on immature and emergent aquatic insects and continue to feed on insects into adulthood as well as eating small fishes. They are thus susceptible to a variety of offerings from anglers. Fly fishing with both dry and wet flies, as well as streamers, which emulate small fishes, can be effective. Anglers using spinning or bait casting gear have success with small spinners, spoons, and small lures, or bait such as worms, hellgramites, and kernels of canned corn. The Tennessee record is 6.6 kg (14.5 lb) from the tailwater of Dale Hollow Reservoir, caught by Jack Rigney in 1971. World angling record is 19.1 kg (42 lb, 2 oz) from Alaska. A Jewel Lake, British Columbia specimen of 24 kg (52 lb) is the largest reported (Scott and Crossman, 1973).

Plate 158a. *Oncorhynchus mykiss*, rainbow trout, 218 mm SL, Little R., Great Smoky Mountains National Park, TN.

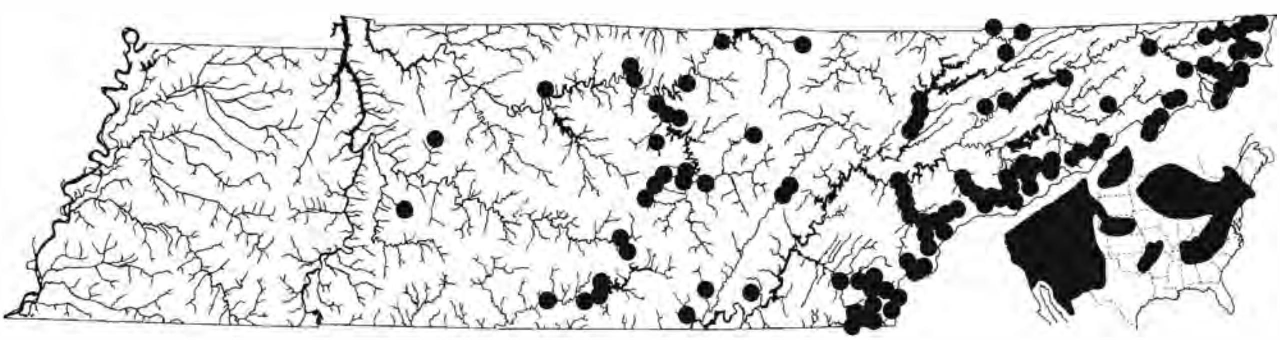
Plate 158b. *Oncorhynchus mykiss*, rainbow trout, juvenile, 105 mm SL, Little R., Great Smoky Mountains National Park, TN.

Distribution and Status: Native to Pacific drainages, with coastal populations considered "typical" while those east of the Sierras and Cascades (now largely genetically swamped by introductions) are believed to have represented another form or species, the "redband trout," from a genetic stock that may also have produced the golden and Kamloops trouts (Gold, 1977; Behnke, 1979). Coastal rainbows were the chief source for introductions, worldwide (MacCrimmon, 1971). In Tennessee they are stocked extensively in many streams and reservoirs along the Blue Ridge and in a few cooler creeks, tailwaters, and reservoirs of the Highland Rim and Cumberland Plateau regions by state and federal agencies. Fisheries are maintained in several tailwaters below deeper reservoirs such as Norris, Dale Hollow, and Center Hill, where cold water releases from the bottom layer (hypolimnion) depress temperatures to suitable levels. Elsewhere, private individuals have introduced them into many localized habitats such as spring outflows and spring-fed ponds, and rainbows may be expected occasionally in just about any cool water stream in the state. Many Tennessee populations, especially those in the Blue ridge, in the absence of heavy fishing pressure, would be capable of maintaining themselves through natural reproduction. Before its impoundment by the Tellico Dam in 1979, the Little Tennessee River below Chilhowee Dam supported a tremendous trout fishery and was reputed to be the most productive such stream in the eastern United States.

Similar Sympatric Species: Adults of our three trout species are relatively easy to separate using characters in the Key. Juvenile rainbows lack the dark caudal spotting of adults, but differ from brown and brook trout in having parr marks that are not as wide as their interspaces, and in having a distinct dark border on the adipose fin. They further differ from juvenile brown trout in lacking dark spots below the lateral line. The cutthroat trout (*O. clarkii*) was introduced into Tennessee waters in years past, but it is unlikely that they persist in our fauna. It differs from the rainbow in having only 8–11 versus 10–12 dorsal fin rays, in having teeth present at the base of the tongue (basibranchial bone), and in having a more intense streak of red pigment along the inner border of the lower jaw, giving it the typical "cutthroat" appearance.

Systematics: Until very recently, the extremely well known rainbow trout was known as "*Salmo gairdneri* Richardson," a name combination which appeared hundreds of thousands of times in the ichthyological and fishery literature. See previous comments about the former placement of this species in the genus *Salmo*. In addition to its generic reallocation, it is now apparent that the rainbow trout is probably identical with *Salmo mykiss* of eastern Siberia (Behnke, 1966, 1979, 1990; Okasaki, 1983). *Salmo mykiss* Walbaum, 1792, is an older name than *S. gairdneri* Richardson, 1836, and the species epithet for the rainbow trout must, by priority, be *mykiss*.

Etymology: *mykiss* is presumably derived from the Kamchatkan name "mikizha" or "mykyz".



Range Map 154. *Oncorhynchus mykiss*, rainbow trout (native range extends off inset through southern Alaska to Siberia; all populations east of Pacific slope represent introductions).

Genus *Salmo* Linnaeus
The Atlantic Salmons and Trouts

The genus *Salmo* contains the Atlantic salmon, *S. salar* Linnaeus, an anadromous species along the northeastern coast of North America and western Europe, the brown trout accounted herein, and several western Eurasian forms similar to the brown trout. See previous comments under *Oncorhynchus* concerning additional species formerly included in *Salmo*.

Salmo trutta Linnaeus

Brown trout

Characters: Lateral-line scales 120–130. Dorsal fin rays 12–14. Anal fin rays 10–12. Pectoral fin rays 13–14. Pelvic fin rays 9–10. Branchiostegal rays 10. Gill rakers 14–17. Vertebrae 56–61. Color brownish to tan dorsally, silvery on lower sides and belly. Black spots on top and sides of head and body and on dorsal and adipose fins often ringed by pale area; caudal fin with very few spots. Brick red spots scattered on sides. Leading edge of anal fin white.

Biology: Brown trout are native to Europe, and like the rainbow, have been widely introduced. Sea run strains are termed "sea trout" (not to be confused with members of drum family, Sciaenidae, with same name, i.e., *Cynoscion*). Of our three trout, the brown grows largest in streams, is most tolerant of higher temperatures, and is best able to maintain fishable populations under heavy angling pressure. This last attribute is certainly related to their reputation for being the trout most difficult to take by angling. Brown trout also present disease and hyperactivity problems to the fish culturist that have been largely overcome with rainbows and brookies. Strikingly colored hybrids with brook trout called "tiger trout" have been experimentally stocked in some regions with limited success. Brown trout spawn in fall, typically later than brook trout from the same area. Fecundity of larger females is 4,000–12,000 ova (Carlander, 1969). Adults are inclined to be rather sedentary, frequently spending much of their time in the same pool. Although probably more wary than other trout, their tendency toward nocturnal feeding certainly contributes to their difficulty of capture. Brown trout are reputed to be more piscivorous than other trouts with specimens over 250 mm TL feeding heavily on minnows, sculpins, darters, and young trout as well as crayfish. Large adults are known to occasionally eat turtles and small mammals (Becker, 1983). Young are thus often caught by anglers using dry flies or small bait, such as worms or hellgrammites, but larger specimens more often fall to larger baits, or fishlike lures and streamer flies. In northeastern streams (summarized in Carlander, 1969), brown trout averaged about 175 mm TL at age 1, 230 at 2, 290 at 3, 365 at 4, 400 at 5, and 440 at 6; life span is 15–20 years. Southern populations probably grow faster and are shorter lived on the average. Prior to impoundment of Tellico Reservoir, brown trout weighing over 2.5 kg (5.5 lb) were frequently taken in the lower Little Tennessee River, and specimens over 4.5 kg (10 lb) were not uncommon. The Tennessee record is 13.1 kg (28 lb, 12 oz), taken by Greg Ensor in the Norris Reservoir tailwater in 1988.

Plate 159a. *Salmo trutta*, brown trout, 180 mm SL, Little R., Great Smoky Mountains National Park, TN.

Plate 159b. *Salmo trutta,* brown trout, 110 mm SL, juvenile, Little R., Great Smoky Mountains National Park, TN.

The largest recorded specimen and world angling record of 18.3 kg (40 lb 4 oz) is from a tributary to the White River in Arkansas, May, 1992.

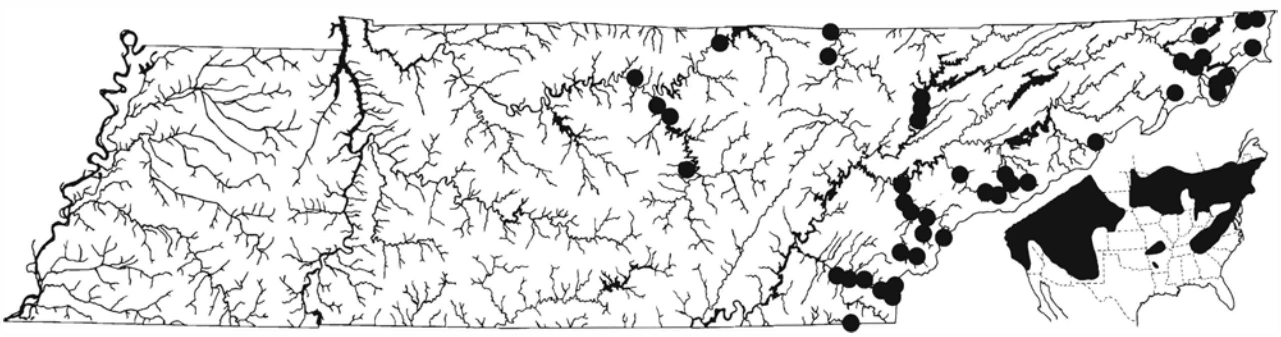
Distribution and Status: Native to Europe and western Asia. Widely introduced throughout the world; first introduced to North America in 1883. Introductions were derived from both continental and Scottish or "Loch Levin" strains or subspecies of brown trout. In Tennessee most introductions have been in and near the Blue Ridge, especially in larger creeks and tailwaters, with some tailwater stocking in the Cumberland River drainage.

Similar Sympatric Species: For distinctions between brown, brook, and rainbow trout, refer to Key and account for rainbow trout. Recently state officials have been stocking Watauga and South Holston reservoirs with a very similar European species, the ohrid trout, *Salmo letnica* (Karaman). The ohrid trout is hoped to adapt well to our cooler reservoirs and to combine its preference for pelagic habitats with the hardiness and rapid growth characteristics of brown trout. Five specimens provided us by L. Price Wilkins, TWRA, had 19–21 total gill rakers on the first arch, lacked spots on the adipose fin and dorsal lobe of the caudal fin, and lacked a leading white edge on the anal fin. The five browns of similar size with which they were compared had 13–16 gill rakers, spots on the adipose and upper caudal fins, and a distinct white leading edge on the anal fin. The Tennessee record ohrid trout of 6.5 kg (14 lb, 5 oz) is from Watauga Reservoir, and was caught by Richard Carter in 1986.

Etymology: *Salmo* is a Latin name for Atlantic salmon, *trutta* is a Latin name for trout.

Genus *Salvelinus* Richardson
The Chars

In addition to our only southeastern native trout, this genus contains the arctic char (*S. alpinus*), the western Dolly Varden and bull trouts (*S. malma*, *S. confluentus*), and the well-known lake trout (*S. namaycush*). Some authors consider the "fat lake trout" or siscowet of the Great Lakes (*S. siscowet* Agassiz), the arctic char–like Sunapee, Angayukaksurak, and blueback char or trout of New England and northern Alaska (*S. aureolus*, *S. anaktuvukensis*, and *S. oquassa*, respectively), and the extinct, brook trout-like silver trout (*S. agassizi*) of New Hampshire, as distinct species in the genus *Salvelinus*. Additional species occur in Eurasia. An extensive collection of works on the genus has been edited by Balon (1980). Systematics are discussed by Cavender (1980). Three subgenera are recognized (Vladykov, 1963; Nelson, 1984), with the brook trout in the monotypic subgenus *Baione* DeKay, the lake trout and similar siscowet placed in *Cristivomer* Gill and Jordan (sometimes treated as genus), and remaining species in the subgenus *Salvelinus*. Chars are distinguished by the usual presence of basibranchial (tongue) teeth



Range Map 155. *Salmo trutta*, brown trout (introduced; populations occur in northeastern Canada and in the Northwest off the inset).

(often absent in brook trout), and the presence of pale spots (often with red centers except in lake trout) and vermiculate markings dorsally.

In addition to the brook trout accounted below, the lake trout, *Salvelinus namaycush* (Walbaum) has been introduced at various times in Tennessee waters. Currently, there is potential for a fishery in Dale Hollow Reservoir.

Salvelinus fontinalis (Mitchill)

Brook trout

Characters: Lateral-line scales 210–230. Dorsal fin rays 10–14. Anal fin rays 9–13. Pectoral fin rays 11–14. Pelvic fin rays 8–10. Branchiostegal rays 9–13. Gill rakers 14–22. Vertebrae 58–62. Color slate gray to dark green dorsally, with pale spots and vermiculations silvery to bright yellow or reddish orange on sides and belly. Body with pale spots and a few red spots ringed by pale areas. Dorsal, adipose, and caudal fins with dark spots, blotches, and vermiculations. Leading edges of pelvic and anal fins bright silvery white accentuated by adjacent black stripe. Large adults with more numerous pale spots on body and pale vermiculations dorsally and ventrally. Breeding males golden on sides, bright orange to scarlet on belly, paired fins, and anal fin.

Biology: Brook trout, sometimes called native trout, speckled trout, brook char, or squaretail, are typically associated with small, clear streams, but the largest specimens consistently come from lakes and beaver dam ponds. Anadromous individuals from East Coast populations are termed "coasters." A large bibliography on this species was compended by Estes (1983). Brook trout are considered by many to be the most desirable of our stream trout. Unfortunately, they are less tolerant of changing conditions than either the brown or rainbow trout and are more temperature sensitive, not tolerating maximum water temperatures of much over 16 C (61 F). Disappearance of "brookies" from much of their former range may be further accelerated because of their inability to withstand heavy fishing pressure and encroachment by the introduced rainbow trout.

Brook trout spawn in fall in Tennessee, and in our smaller streams sexual maturity may be reached by specimens 100–120 mm (4–5 in) long. Fecundity of females this size typically is only a few hundred ova (Carlander, 1969). In a Tennessee Blue Ridge stream, Whitworth and Strange (1983) reported growth approximately as follows: age 1, 75–100 mm TL; age 2, 125–140; age 3, 140–160. Konopacky and Estes (1986) found varied growth in southern Appalachian streams from West Virginia to Georgia with age 1 fish averaging 87–129 mm TL among the streams sampled; age 2 fish were 118–192; age 3, 137–198. Few fish were found older than 3 years, but one individual was estimated to be 10 years old. Life span is thus thought to be short in these streams and growth restricted. Some fishes never reach the legal size limit for angling (6 in). In more northerly populations, in glacial lakes and stream systems, brook trout live much longer and attain much greater size. Likewise, brook trout reared in hatcheries for release in Tennessee's trout waters are generally much larger than native brookies of the high mountain streams.

The brookie is a voracious feeder on a variety of aquatic insects and other invertebrates and larger individuals feed on fishes (Ricker, 1932). Of our stream trout, it is by far the easiest to catch and is easily caught

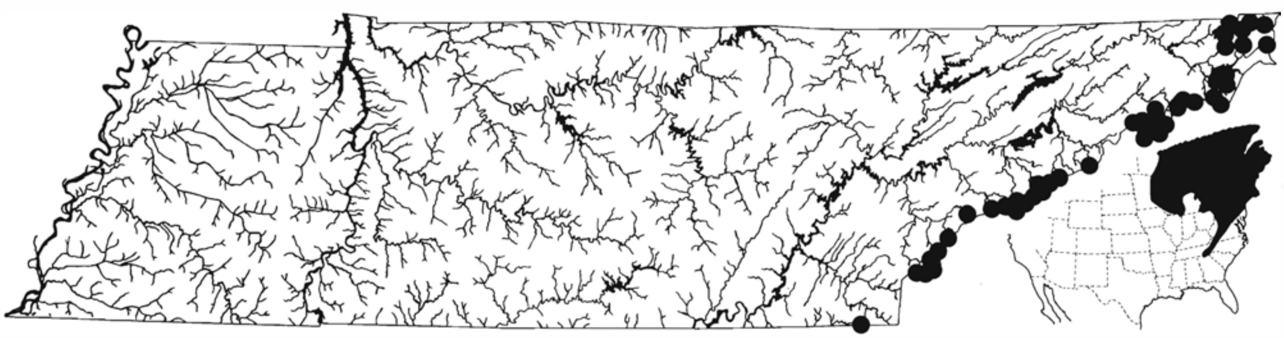
Plate 160a. *Salvelinus fontinalis*, brook trout, 135 mm SL, Little Pigeon R. system, Great Smoky Mountains National Park, TN.

Plate 160b. *Salvelinus fontinalis*, brook trout, breeding male, 160 mm SL, Little Pigeon R. system, Great Smoky Mountains National Park, TN.

on small dry flies, small spinners, and a variety of baits. Its salvation may be the relative inaccessibility of most habitat streams high in the Blue Ridge, farther than many anglers care to hike. Those who do are usually rewarded with plenty of action (but few keepers) and beautiful scenery. The state record of 1.76 kg (3 lb, 14 oz) from the Hiwassee River, caught by Jerry Wills in 1973, may represent recapture of a released brood fish. Native brookies in the Great Smoky Mountains National Park and Cherokee National Forest rarely exceed 30 cm (12 in). The world angling record of 6.6 kg (14.5 lb) from Nipigon River, Ontario, 1916, may never be topped, but fish half this size and slightly larger continue to occur in cool lakes in eastern Canada.

Distribution and Status: The brook trout is the only salmonid native to Tennessee. Its original range extended from Canada south and east of Hudson Bay southward through the northern states from eastern Minnesota and northeastern Iowa eastward to Pennsylvania. The brook trout extends south to northern Georgia along the Appalachian uplands, particularly in the Blue Ridge. It is unlikely that it was native to Cumberland Plateau streams within historical times.

A continued decrease in stream miles occupied by brook trout in the Great Smokies National Park has been apparent since around 1900 (Strange, 1979; Kelly et al., 1980). Since 1975, the park has been closed to brook trout fishing, and efforts are being made to determine the actual causes of this decline. Brook trout originally occurred in southern Appalachian streams down to elevations of about 600 m (2,000 ft), and down to 490 m (1,600 ft) in some cooler north-facing streams (King, 1937), but were restricted to streams above 925 m (3,000 ft) by about 1950 (Lennon, 1967; Bivens, 1985). Jones (1975) indicated that, since about 1960, there has been an additional loss of brook trout habitat in the park equal to nearly half the stream miles oc-



Range Map 156. *Salvelinus fontinalis*, brook trout (native range extends north off inset to latitude of middle of Hudson Bay on both east and west sides; widely introduced in West).

cupied prior to that year. Since watersheds in the park are very stable, these results seem surprising. Factors suggested as contributing to decreasing brook trout populations include loss of range due to rainbow trout competition, excessive fishing pressure, results of past logging causing siltation and rising temperatures (Moore et al., 1981), and other habitat changes such as increasing acidity due to acid rain or exposure of sulfide-rich rock strata called Anakeesta shales. On a broader scale, brook trout are currently known to occupy about 275 km (170 mi) in 135 streams in east Tennessee, representing a 20–30% loss in overall range in the state (Bivens, 1985). Rainbows appear to outcompete brookies in all but the most remote and pristine of habitats. Though waters inhabited by brook trout are naturally slightly acidic (ph 6.2–6.9) (King, 1937), Bivens (1985) found that they are now mostly restricted to the more acidic and marginally productive higher-altitude habitats. Even in streams where brookies have the competitive advantage, if accessible, fishermen will selectively remove relatively more brook trout and may tip the competitive balance toward the rainbow. Rose (1986) discovered that growth of young-of-year brook trout virtually ceased during a one- to two-month period while young-of-year rainbows were occupying the same habitats in a Lake Superior tributary. During this period, rainbow trout growth was normal, and brook trout stomachs contained only a few, very large prey items while rainbows ingested a wide range of sizes of prey similar to that utilized by brookies before young rainbows appeared in the nursery area. Brook trout growth improved after rainbows moved to swifter habitats, but Rose felt that their competition-induced growth retardation might significantly increase winter mortality. Although other ramifications of interspecific competition between brookies and rainbows may be discovered with future work, suppression of first year's growth may be sufficient to account for the disturbing loss of brook trout where sympatric with rainbows in our area. Experimental efforts to eradicate rainbow trout from some Smoky Mountain streams have resulted in some recovery of brook trout populations (Moore et al., 1983). Habera (1987) noted a significant increase in brook trout densities after removal of rainbows but no other detectable changes in brookies, such as diet composition. Ironically, brook trout introduced into streams in western North America appear to frequently have a competitive advantage over trout native to that region, especially golden trout or inland cutthroat subspecies.

Maintenance of native brook trout populations in our higher-quality streams is considered to be a top-priority management objective by personnel of the National Park Service, U.S. Fish and Wildlife Service, U.S. Forest Service, Tennessee Wildlife Resources Agency, and private organizations such as Trout Unlimited. The brook trout of the southern Appalachians is also being considered for protection under the Endangered Species Act, based on the premise that these southern populations differ sufficiently from northern populations to warrant subspecies recognition. The unsurpassed beauty of the brook trout and its habitats, plus its being our only native trout, make these efforts toward maintaining and increasing present native stocks very important.

Similar Sympatric Species: See comments under rainbow trout.

Systematics: Stoneking et al. (1981) found biochemical differences suggesting subspeciation between northern and southern brook trout populations. An earlier study by White (1978) did not reveal significant meristic or morphological differences between these populations. The extent of contamination of southern gene pools with hatchery trout derived from northern populations is an unknown factor. Efforts to arrive at answers to these difficult questions are continuing.

Etymology: *Salvelinus* is a derivation of an old vernacular name for the char; *fontinalis* = of springs.

ORDER APHREDODERIFORMES

FAMILY APHREDODERIDAE
The Pirate Perches

The pirate perches, containing one living species, are now restricted to eastern North America. Fossil forms indicate that the family once enjoyed a much wider North American distribution in Oligocene and Miocene times (Uyeno and Miller, 1963). According to Rosen (1962), Patterson (1981), and Patterson and Rosen (1989), aphredoderids are closely related to the cavefishes (Amblyopsidae). Rosen (1962) had also hypothesized a close relationship to trout perches (Percopsidae), and subsequently all these groups were included in the order Percopsiformes by Greenwood et al. (1966) and Nelson (1984). However, Patterson and Rosen (1989) have conversely presented evidence that this order is not a natural group and thus that pirate perches and cavefishes should be excluded from it and placed together in a separate group, for which they used the subordinal name Aphredoderoidei, of unresolved affinities among paracanthopterygian (see Gadiformes) fishes. Because the higher relationships of this grouping were not established with any extant order, we fail to see the reasoning for subordinal ranking and have listed it at the ordinal level for the sake of maintaining levels of organization within this book.

The trout perch, *Percopsis omiscomaycus* (Walbaum), which somewhat resembles the pirate perch in appearance (see Key to the Families), is a northerly distributed species which eventually may be recorded from Tennessee waters, perhaps as strays in the Mississippi River, as have several other northern fish species.

Genus *Aphredoderus* Lesueur

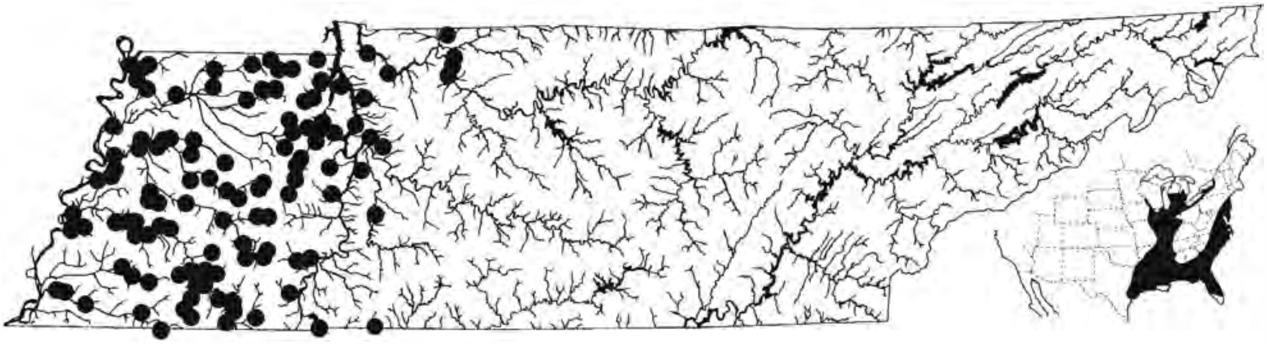
Aphredoderus sayanus (Gilliams)

Pirate perch

Characters: Lateral line absent or incomplete, scales in lateral series 47–60. Dorsal fin with 2–3 spines and 11–12 rays. Anal fin with 2–3 spines and 6–7 rays. Pectoral fin rays 12–13. Pelvic fin rays 6–7. Principal caudal fin rays 18 (17–19). Branchiostegal rays 6. About 10–12 very blunt gill rakers. Head covered with sensory papillae. Breast, opercles, and cheeks covered with ctenoid scales. The urogenital opening and anus are jugular in position, located just behind the gill juncture. The openings migrate to this position from a "normal" position just anterior to the anal fin during the early stages of growth. Color may range from purplish to dusky. Specimens from Atlantic Coastal populations may have strong white bands on the caudal fin lobes which are not much in evidence in more western populations.

Biology: The pirate perch is most common in small, sluggish streams, oxbows, swamps, and natural lakes where it is associated with dense cover such as debris or undercut banks. It is occasionally taken along the margins of larger creeks and rivers but maintains its association with heavy cover and a lack of appreciable current. Shepard and Huish (1978) reported reproductive activity from January through March in North Carolina. Murdy and Wortham (1980), who detailed gonadal morphology, documented April spawning in Virginia; spawning occurs in May in Illinois (Forbes and Richardson, 1920). Probably as a result of secretive habits and predominately murky habitats, some mystery surrounds breeding behavior. Martin and Hubbs (1973) suggested that eggs were brooded in the gill cavity based on the close relationship of pirate perch with the cavefishes, which are known gill chamber brooders and have a similarly positioned urogenital pore. However, Boltz and Stauffer (1986) found negligible support for such a hypothesis and, much earlier, Abbott (1861) had reported that nests were constructed and guarded by both parents. Total lengths at the end of the first through fourth years (Hall and Jenkins, 1954; Shepard and Huish, 1978) were 55–65 mm, 72–85 mm, 82–100 mm, and 115 mm. Four years is the indicated maximum life span. Pirate perch are apparently nocturnal feeders (Parker and Simco, 1975). Their diet consists of aquatic insects, small crustacea, and occasional small fish including their own young (Forbes and Richardson, 1920; Parker and Simco, 1975; Shepard and Huish, 1978). Maximum length 144 mm (5.6 in).

Plate 161. *Aphredoderus sayanus*, pirate perch, 70 mm SL, Hatchie R. system, TN.



Range Map 157. *Aphredoderus sayanus*, pirate perch.

Distribution and Status: Widespread and common, primarily in coastal plain habitats, from New York to the Brazos River in Texas, and extending above the Fall Line in the central portion of the Mississippi River basin and southern tributaries to the Great Lakes. Common on Coastal Plain in Tennessee, also occurring in adjacent areas of the western Highland Rim.

Similar Sympatric Species: Because of the dusky coloration, large mouth, and perch-like body, young pirate perch somewhat resemble juvenile green sunfish (*Lepomis cyanellus*) but are easily distinguished by the small number of dorsal spines, the position of the anus, the serrate preoperculum, and the proliferation of sensory papillae on the head.

Systematics: Populations of the Mississippi Valley have been treated as a subspecies, *A. s. gibbosus* (Lesueur), with Gulf Coastal drainage populations considered intergrades between *gibbosus* and *A. s. sayanus* of Atlantic coastal drainages (Boltz and Stauffer, 1988).

Etymology: *Aphod* = excrement, *dere* = throat, in reference to the position of the anal opening; *sayanus* is a patronym for the naturalist Thomas Say.

FAMILY AMBLYOPSIDAE
The Cavefishes

The amblyopsids are a small family of highly specialized fishes confined to the eastern United States. They were formerly thought to be allied to the mudminnows (Umbridae), pikes (Esocidae), and killifishes (Cyprinodontiformes) (Cox, 1905; Regan, 1911). See comments under Aphredoderidae concerning current classification of amblyopsids. Systematics of cavefishes were treated by Cox (1905), Eigenmann (1909), Woods and Inger (1957), and Swofford (1982). Outstanding features of amblyopsids are the great reduction in pigment in all genera except two, jugular position of the anus and urogenital openings, absence or reduction of eyes, and lack of pelvic fins in all but one species. The cycloid scales are minute, resulting in a naked appearance, and the sensory systems are elaborately developed, especially in hypogean (subterranean) forms. It is possible that all members of the family brood eggs in the gill cavity as has been demonstrated in the genus *Amblyopsis* (Poulson, 1963). There are five genera of amblyopsids; two, the monotypic *Forbesichthys* and *Typhlichthys*, occur in Tennessee. *Speoplatyrhinus* is a monotypic genus containing only the bizarre *S. poulsoni*, recently described from a single cave in northern Alabama (Cooper and Kuehne, 1974). Though there is a remote chance that this genus occurs elsewhere, conceivably in Tennessee, its describers feel rather certain that *Speoplatyrhinus* is an endemic relict restricted to the type locality. The fourth genus, *Amblyopsis* DeKay, contains two species, *A. spelaea* of the limestone regions of Indiana and Kentucky, and *A. rosae* in the Ozarks. The fifth genus, *Chologaster* Agassiz, contains only the epigean (non-subterranean) swampfish, *C. cornuta*, of the southern Atlantic Coastal Plain, though most workers have included the spring cavefish, in that genus as well (e.g., Robins et al., 1991). However, based on the work of D. L. Swofford (1982), which convincingly demonstrated that this species is more closely related to the subterranean genera than the swampfish, some recent workers (e.g., Page and Burr, 1991) recognize the genus *Forbesichthys* Jordan and Evermann (replacement name for the preoccupied *Forbesella* Jordan and Evermann) as we do here.

Persistent rumors concerning the presence of blind, white fishes in caves of east Tennessee have not been verified, but it is remotely possible that *Typhlichthys subterraneus* or completely unknown species of cavefishes occur in the limestone areas of that part of the state. Some of these stories may be based on cave-inhabiting sculpins, in which albinism has been reported (Williams and Howell, 1979).

All fin rays having separate bases are included in the counts.

KEY TO THE TENNESSEE GENERA AND SPECIES

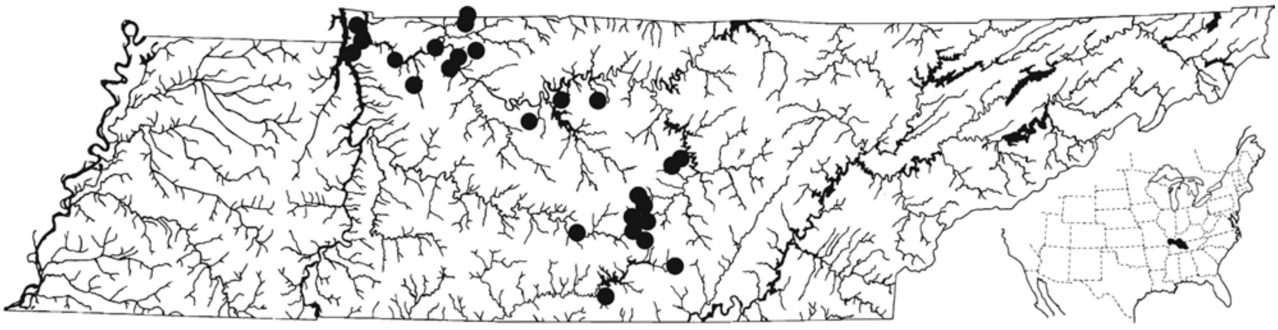
1. Body with dusky pigment; eyes poorly developed but visible .... *Forbesichthys agassizii*
   Body pallid, pigment not apparent; eyes degenerate and concealed beneath skin .... *Typhlichthys subterraneus* p.356

Forbesichthys agassizii (Putnam)
Spring cavefish

Plate 162. *Forbesichthys agassizii,* spring cavefish, 53 mm SL, Caney Fork R. system, TN.

Characters: Scales minute and embedded. Dorsal fin rays 9–11. Anal fin rays 9–11. Pectoral fin rays 9–11. Pelvic fins absent. Branched caudal fin rays 11–17. Branchiostegal rays 6. Gill rakers absent. Vertebrae 33–35. The sensory system of *F. agassizii,* though not as well developed as in its troglodytic (strictly cave dwelling) relatives, is somewhat elaborated. Triads of sensory papillae occur midlaterally and scattered clusters of neuromasts are present on the head. Coloration uniform dark gray to black with paler venter.

Biology: The spring cavefish, with a salamander-like appearance, is locally common in middle Tennessee,



Range Map 158. *Forbesichthys agassizii,* spring cavefish.

where it typically occurs in very shallow water in dense vegetation associated with springs and spring-fed streams. It is a troglophilic species (occurring in, but not restricted to caves), and adults apparently retreat to subterranean sites to spawn in late winter (Smith and Welch, 1978). We have juvenile Tennessee specimens from 23 March that are only 8 mm SL. Though spawning has never been observed, the jugular position of the urogenital opening offers some circumstantial evidence that eggs are brooded in the gill chamber, as Poulson (1963) has reported in the related *Amblyopsis spelaea*. Fecundity averages about 100 ova per female, and sexual maturity is reached at age 1 (Poulson, 1963). Maximum life span is estimated as 3 years (Smith and Welch, 1978). Activity is primarily after dark, and those populations in close proximity to caves apparently move beneath ground each day and emerge to feed at night; oxygen gradients may play some role in these daily migrations (Hill, 1968). Populations studied in Illinois fed primarily on the amphipod *Gammarus* (Gunning and Lewis, 1955), whereas Kentucky populations fed heavily on midge larvae, tiny worms, and microcrustaceans (Hill, 1969). The Kentucky populations were very cannibalistic when residing in subterranean habitats. Based on morphology, it has been suggested that the eyes of *F. agassizii* do not form images and serve only as light-detection organs to facilitate negative phototaxis (Poulson, 1963). The presence of prey items is apparently detected through the sound detection senses of neuromasts located on the head (Hill, 1969). Maximum total length about 90 mm (3.5 in).

Distribution and Status: Caves and springs from Highland Rim area of Tennessee River drainage, middle and lower Cumberland River drainage, upper Barren-Green system of Kentucky, and Ohio and Mississippi river tributaries near their junction, including one population west of the Mississippi in Missouri (McDonald and Pflieger, 1979). Locally abundant in ideal habitats.

Similar Sympatric Species: The non-pigmented *Typhlichthys subterraneus* occurs with *F. agassizii* in caves of Kentucky, and they may eventually be taken together in Tennessee.

Etymology: *Forbesichthys* = a fish named for Stephen A. Forbes, a noted former ichthyologist at the Illinois Natural History survey; *agassizii* is a patronym for the great naturalist Louis Agassiz.

Typhlichthys subterraneus Girard

Southern cavefish

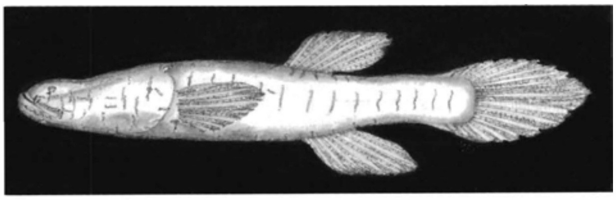
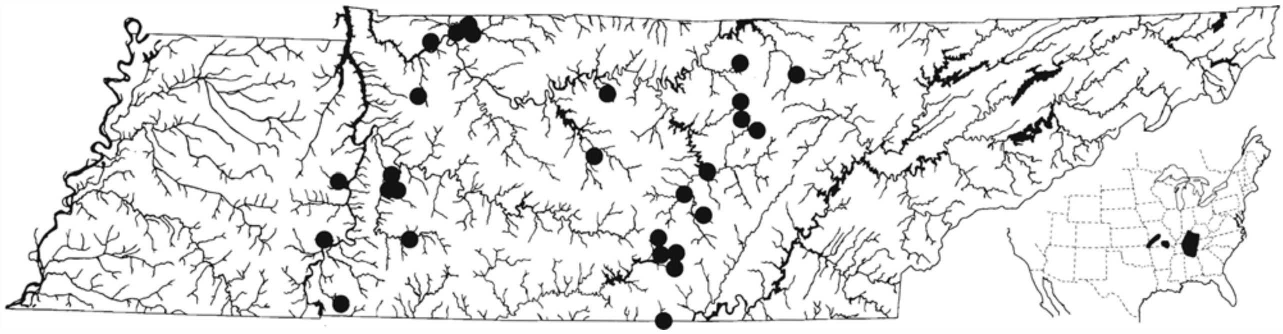


Plate 163. *Typhlichthys subterraneus*, southern cavefish, illustration based on 35 mm SL specimen out of U.S. National Museum 232538, Blind Fish Cave, Putnam Co., TN (by W. Starnes).

Characters: Scales minute and embedded. Dorsal fin rays 8–9 (7–10). Anal fin rays 7–9. Pectoral fin rays 9–12. Pelvic fins absent. Branched caudal fin rays 10–15. Branchiostegal rays 6. About 10 very short, blunt gill rakers. Vertebrae 28–29. Body dorsally flattened. Sensory system elaborately developed on head and along sides of body where vertical rows of sensory papillae occur along the midline. Caudal fin with two horizontal rows of papillae and a vertical basal row. Wild specimens appear to be without pigment, but microscopic examination reveals constricted pigment that reportedly becomes quite visible if a live specimen is exposed to light for a time (Woods and Inger, 1957).



Range Map 159. *Typhlichthys subterraneus*, southern cavefish.

Biology: As the name implies, *T. subterraneus* exists totally in hypogean (subterranean) environments and is termed a troglodytic species. The following life history information is inferable from Poulson (1963). Breeding probably occurs during spring when caves are flooded. Fecundity is reported to be very low, perhaps fewer than 50 ova per female. This factor, along with low percentages of breeding females, presumably limits recruitment to populations that must survive in a poorly nourished environment. Young emerge during midsummer, possibly after brooding in the female parent's gill chamber. Sexual maturity is reached after 2 years, and life span is about 4 years. Cavefishes have evolved a depressed metabolic rate to cope with seasonal food shortages. Principal food items are copepods, amphipods, and isopods (Poulson, 1963; Cooper and Beiter, 1972). These small crustaceans are located by the highly evolved sensory system, enabling cavefishes to survive in their world of darkness. Maximum total length about 90 mm (3.5 in).

Distribution and Status: The southern cavefish has a seemingly discontinous distribution with populations west of the Mississippi River in Mississippian limestone formations of the Ozark uplands, and in similar formations in the karst region extending from southern Indiana southward to northern Alabama and Georgia, where it occurs in both the Tennessee and Coosa river drainages (Cooper and Iles, 1971). Dispersal has apparently been achieved through subterranean channels which pervade these formations. It is conceivable that the eastern and western *Typhlichthys* populations are still in contact via limestone formations lying 30 m or more below the bed of the Mississippi River (Woods and Inger, 1957). However, populations in some regions may be disjunct from others as, for instance, in the eastern Mississippian Plateau of Kentucky (Cooper and Beiter, 1972). In Tennessee, *Typhlichthys* is restricted to that portion of the state encompassed by the eastern and western Highland Rim, including the Nashville Basin. The presence of populations in several of the caves of this region was noted by Barr (1961). *Typhlichthys* has only recently been discovered west of the lower Tennessee River (Cooper, 1974). This cavefish has been placed on the protected species list of Tennessee fishes (Starnes and Etnier, 1980). It is thought to be in no immediate danger so long as ground water quality is not threatened by percolation of agricultural chemicals or other contaminants.

Similar Sympatric Species: See comments under *Forbesichthys agassizii.*

Etymology: *Typhlichthys* = blind fish; *subterraneus* = beneath the earth.

ORDER GADIFORMES

FAMILY GADIDAE
The Codfishes

Codfishes, hakes, and other members of the order Gadiformes (about 10 families) are virtually restricted to marine environments, where they are most abundant at high latitudes or in deep water habitats. Gadiform fishes, families herein treated in Aphredoderiformes, troutperches (Percopsidae), the bizarre angler fishes (Lophiiformes), toadfishes and allies (Batrachoidiformes), clingfishes (Gobiesociformes), and several additional groups have been collectively referred to in classificatory literature (e.g., Greenwood et al., 1966) as the superorder Paracanthopterygii, meaning "near the acanthopterygians" (the spiny-rayed fishes). The naturalness of such a grouping, at least in part, is in question (Nelson, 1984; Patterson and Rosen, 1989) but the group continues to be used as a working basis for studying relationships among these fishes. Some recent workers (e.g., Howes, 1989; Markle, 1989) have recognized burbots and their marine relatives, the hakes, as a family separate from gadids, the Lotidae, while others (e.g., Dunn and Matarese, 1984; Nolf and Steurbaut, 1989) continue to regard these fishes as a subfamily or tribe within Gadidae. Several additional works on gadiform systematics appear in Cohen (1989).

Gadiforms include many important food fishes, variously marketed as cod, scrod (young cod), haddock, hake, and pollock. Their commercial value rivals that of any other fish family, and current popularity of "fish and chips" and fish sandwiches (mostly from *Gadus morhua*, the Atlantic cod) is likely to increase both demand and value. Cod fillets are often available in fish markets at prices well below those of more glamorized food fishes, but the delicate flavor and firm, white, flaky flesh of the cods is surpassed by few if any commercial fishes. Cod, served in an imaginative array of forms from chowders to fried stomachs and heads (including brains and eyeballs), has been the mainstay of commercial fishermen who spend months offshore, and is the primary ingredient for the Scandinavian specialty, lutefisk. Although several marine species occasionally enter freshwater, the genus *Lota* Linnaeus contains the only strictly freshwater species.

Lota lota (Linnaeus)

Burbot

Characters: Lateral line complete, cycloid scales small, giving a naked appearance. Dorsal fin divided into two soft-rayed portions, the anterior portion with 8–16 rays and the posterior portion with 60–79 rays. Anal fin rays 59–76. Pectoral fin rays 17–21. Pelvic fins anterior to pectorals (jugular), with 5–8 rays. Fleshy caudal fin base symmetrical and tapering to a point, with posterior vertebrae progressively decreasing in size (no upturned urostylar vertebra as in the vast majority of teleost fishes). Branchiostegal rays 7–8. Gill rakers 7–12 with length of longest rakers 3–4 times their basal width. Vertebrae 50–66. Median barbel conspicuous at anterior tip of lower jaw, and anterior nostril with a barbel-like projection. Life colors uniformly dark brown to mottled dark brown and yellowish.

Biology: Most of the following (and the above morphological data) is summarized from Robins and Deubler (1955) and Scott and Crossman (1973). Burbot, commonly called "eelpout" or "lawyer," are prevalent in cool to cold lakes in northern North America where they are benthic, avoid water temperatures over about 20 C (68 F), and may occur at depths of 200 m or more. Juveniles are occasionally encountered along rocky shorelines and near the mouths of small creeks, and both juveniles and adults may occur in large rivers. A few populations are confined to creeks and migrate to downstream areas to spawn. In riverine habitats they spend daylight hours associated with cover such as boulders, rip rap, and log jams. Feeding is primarily nocturnal. Food of juveniles is primarily crayfishes and other macrocrustacea, and insect larvae. Adults feed heavily on fishes, particularly young yellow perch, walleye, and white bass (Clemens, 1950), but seasonally may feed almost exclusively on the above-mentioned invertebrates. Spawning occurs at night during midwinter, typically under ice cover, over sand and gravel areas in depths of 1–5 m, where 10–12 adults form a compact, writhing cluster as they move along the bottom. Larger females produce over a million eggs yearly. Young hatch in spring, and reach lengths of 76–

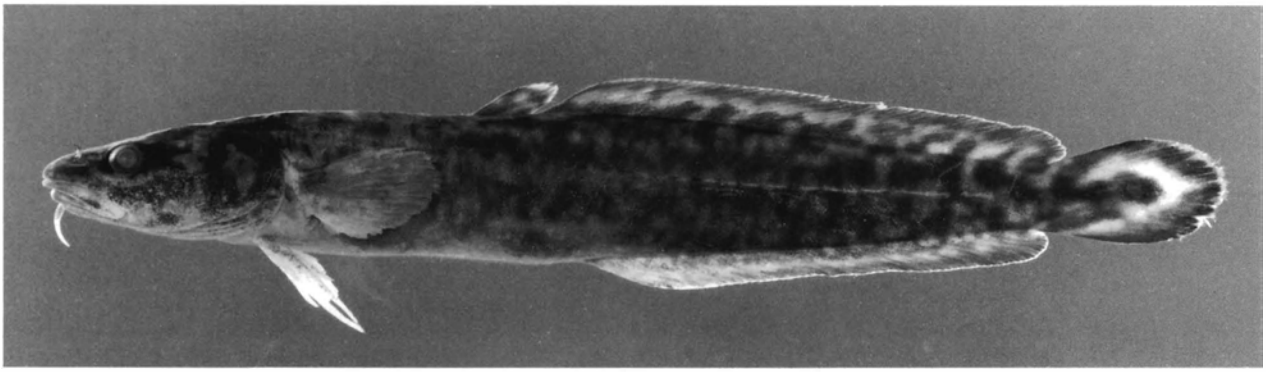


Plate 164. *Lota lota*, burbot, preserved specimen, 115 mm SL, L. Saganaga, MN.

210 mm at age 1. Sexual maturity is reached after 3–4 years at total lengths of 280–480 mm, but mature males may be considerably smaller. Life span is estimated to be about 10–15 years. Burbot are often taken by anglers fishing through the ice for walleye and lake trout. They are generally reported to be fair to good food fishes. Their lack of popularity among anglers is primarily, we suspect, due to their drastic departure in appearance from familiar sport and food fishes of these areas. Burbot livers, as rich in vitamin D as cod livers, have a number of commercial uses, but currently there is little exploitation in North America. The annual winter burbot fishing contest held in Walker, Minnesota, may be a start toward increasing the popularity of this fish that "doesn't get no respect." Maximum size in North America is apparently considerably smaller than that reported for Eurasian populations—up to 1.2 m TL and 34 kg (75 lb). Largest North American record is a Great Slave Lake specimen of 8.2 kg (18.5 lb).

Distribution and Status: The holarctic burbot occurs only sporadically south of the Great Lakes area, where most records are from large rivers and likely represent winter transients rather than established populations. A number of records are available from the lower Ohio and Missouri river systems (Lee and Gilbert, 1980). No specimens or verified records are available from Tennessee, but we are inclined to accept the report of a specimen taken by a commercial fisherman from the Hatchie River during the winter of 1982–1983. Mr. John David, TWRA officer for Tipton County, saw the specimen and identified it as a burbot. His considerable familiarity with bowfin, American eels, and the various catfishes of the area virtually precludes a mistaken identification. Assuming the validity of the Hatchie River record, burbot would be expected to occur sporadically as winter migrants in the Mississippi River as well. We would be most grateful for additional information concerning Tennessee specimens, and would be particularly happy to see one, in any condition. Even a head, decomposed carcass, or significant skeletal elements would allow positive identification.

Similar Sympatric Species: The burbot is our only Tennessee fish with a single, median chin barbel. Bowfins have coarse scales and an anal fin that is much shorter than the single dorsal fin. American eels lack pelvic fins and have the dorsal and anal fins continuous around the tail (no distinct caudal fin).

Etymology: *Lota* is derived from the French "la Lotte" = codfish.

ORDER CYPRINODONTIFORMES

FAMILY FUNDULIDAE
The Topminnows

The fundulids are a North American family representative of the large order Cyprinodontiformes, which contains many varieties of mostly small fishes inhabiting fresh and brackish waters of much of the world except the Australian region (Parenti, 1981). Previous classifications (Rosen, 1964; Greenwood et al., 1966) considered several groups herein referred to as cyprinodontiform fishes to constitute a single family, the Cyprinodontidae, which, in turn, was included among a broadly inclusive order of related fishes, the Atheriniformes; included were the silversides (Atherinidae), halfbeaks (Hemiramphidae), needle fishes (Belonidae), flying fishes (Exocoetidae), and several other families. However, Parenti (1981) and Rosen and Parenti (1981) regarded the grouping of oviparous (egg-laying) fishes previously regarded as Cyprinodontidae to be an unnatural one unless several livebearing families, such as the Poeciliidae, were included, and thus recognized these families collectively as the order Cyprinodontiformes within the series Atherinimorpha (see further under Atherinidae). Commensurate with this action, several subgroups of the former Cyprinodontidae were elevated to familial status, including Fundulidae. This family dates to the mid Miocene in the fossil record (Cavender, 1986).

Additional cyprinodontiform fishes in North America include, in the family Cyprinodontidae, the abundant sheepshead minnow of eastern coastal marshes and the desert pupfishes (genus *Cyprinodon*), and two Florida genera (*Floridichthys*, *Jordanella*); two other southwestern desert genera, the springfishes (*Crenichthys*) and desert killifishes (*Empetrichthys*) (family Goodeidae); the rivulines (*Rivulus*, Aplocheilidae) (rare in Florida mangrove areas); and the livebearer family, Poeciliidae. The order also includes the colorful African and South American aplocheilid killifishes fancied by aquarists (*Aplocheilus*, *Cynolebias*, and others), the genus *Orestias*, noted for its great diversity of species in the Lake Titicaca region of the Andes Mountains in South America, and many other Central–South American and Old World groups, including the curious "foureye fishes" (Anablepidae) of the neotropics, which are adapted to see both above and below the water surface. Cyprinodontiform fishes are characterized by having rounded caudal fins, upturned jaws with large teeth, modified pharyngeal arches for grinding of food, large cycloid scales, dorsally flattened head and nape regions, and posteriorly positioned dorsal fins (in most forms). Several groups lack pelvic fins. Most are found in slack-water habitats.

All Tennessee species of Fundulidae are members of the genus *Fundulus*. In addition to this large genus, the family, as construed by Parenti (1981), contains three genera of small fishes, *Adinia*, *Lucania*, and *Leptolucania*, confined to vegetated freshwater habitats of the Coastal Plain or brackish estuaries. However, placement of all of these genera within Fundulidae was found to be problematical by Wiley (1986).

Genus *Fundulus* Lacepede

The genus *Fundulus* contains about 40 species of fishes that occur in both brackish and fresh waters of North America south to southern Mexico and in brackish waters of the islands of Bermuda and Cuba. Students of *Fundulus* systematics have recognized as many as five subgenera of which only two, *Xenisma* Jordan and *Zygonectes* Agassiz occur in Tennessee (see *F. catenatus* and *F. chrysotus* accounts). Others are *Fundulus* s.s., containing several brackish water species including the large mummichog (*F. heteroclitus*) and gulf killifish (*F. grandis*) of the Atlantic and Gulf coasts, both popular bait fishes; *Plancterus* Garman (elevated to genus by Parenti, 1981), containing only the widespread plains killifish (*F. zebrinus*); and *Fontinus* Jordan and Evermann, containing the widespread banded killifish (*F. diaphanus*) of the upper Midwest and East Coastal regions, the marine species *F. majalis*, *F. similis*, and *F. persimilis*, and two more restricted freshwater forms, *F. waccamensis* and *F. seminolis*, of North Carolina and Florida, respectively. Systematics of *Fundulus* has been treated variously by Miller (1955), Brown (1957), Farris (1968), Chen (1971), Wiley and Hall (1975), Parenti (1981), Williams and Etnier (1982), and Wiley (1986).

Topminnows, as the name implies, spend much of their time cruising just beneath the water surface in calm backwater areas. With their upturned mouths and flattened dorsums, they are well adapted to this lifestyle, and several species feed at the surface on fallen organisms and emergent aquatic insects. Topminnows may often be seen lying motionless near the surface, with only the pectoral fins rotating for stability, and the caudal fin characteristically bent to one side. They are thus hard to detect in vegetated areas. All Tennessee topminnows, particularly mature males, are beautifully marked species. The males of most species develop breeding tubercles, and all species exhibit some degree of sexual dimorphism, particularly in the shape of the anal fin, which is longer and more pointed in males. Females have a scaly sheath that extends over the anterior base of the anal fin. Topminnows are similar in form to the unrelated mudminnows (Umbridae), which differ in having the anal fin more posteriorly placed, and in many other characters.

In addition to the species of *Fundulus* accounted herein, another species, *F. albolineatus* Gilbert, occurred in the Alabama portion of the Tennessee River drainage adjacent to Tennessee but is now presumed to be extinct (Williams and Etnier, 1982). It is possible that this spring-dwelling form was formerly a member of the Tennessee state fauna occurring in spring habitats in extreme southern portions of the state (i.e., Hardin County) that now have been inundated by impoundments of the Tennessee River.

Etymology: *Fundus* = bottom (possibly in reference to shallow habitat?).

KEY TO THE TENNESSEE SPECIES

In this key and the *Fundulus* species accounts, all dorsal and anal fin rays with separate bases are included in counts.

1. Dorsal fin rays 13–16; anal fin rays 14–18 2
   Dorsal fin rays 7–13; anal fin rays 10–13 3
2. Dark pigment on sides of body arranged in horizontal lines (Pl. 165) .... *F. catenatus*
   Dark pigment on sides of body appearing as randomly scattered spots (Pl. 171) .... *F. stellifer* p.369
3. A wide, black, horizontal, regular or irregular stripe present on midsides 4
   Sides marked with spots, discrete vertical bars, or nearly plain 5
4. Dorsolateral spots discrete and as dark as lateral stripe (Pl. 170); predorsal dark streak not broken up into series of blotches; individual dorsolateral scales usually with pigment evenly distributed throughout .... *F. olivaceus* p.368
   Dorsolateral spots paler than lateral stripe (Pl. 169) and not discrete (occasionally absent), with their borders vague; predorsal dark streak broken up into series of blotches; dorsolateral scales often with pigment concentrated near edges, leaving pale centers .... *F. notatus* p.367
5. Scales in lateral series 36–42; dorsal fin rays usually 10 or more; confined to the Barrens Plateau area of Cannon, Coffee, and Warren counties .... *F. julisia* p.365
   Scales in lateral series 30–36; dorsal fin rays usually 9 or fewer; Coastal Plain areas of west Tennessee 6
6. A wide, black suborbital bar present (Pl. 167); dorsal fin rays 6–8 .... *F. dispar* p.364
   Suborbital bar absent (Pl. 166); dorsal fin rays 8–10 .... *F. chrysotus* p.363

Fundulus catenatus (Storer)

Northern studfish

Characters: Scales in lateral series 39–52, caudal peduncle scale rows 17–21. Dorsal fin rays 13–16. Anal fin rays 14–18. Pectoral fin rays 15–18 (14–19). Principal caudal fin rays 15–18. Branchiostegal rays 6. Gill rakers 6–7. Pharyngeal arches broad with numerous pointed teeth. Vertebrae 36–38. Nuptial males, with their electric-blue sides accentuated by horizontal red lines, orange-spotted head and anal fin, and orange and black terminal bands on the caudal fin, are among our most beautiful fishes. Females, juveniles, and non-nuptial males are much more somber, with silvery to brown sides punctuated with scattered, short, horizontal brown dashes, and with unmarked fins. Breeding tuber-

Plate 165a. *Fundulus catenatus*, northern studfish, 56 mm SL, Caney Fork R. system, TN.

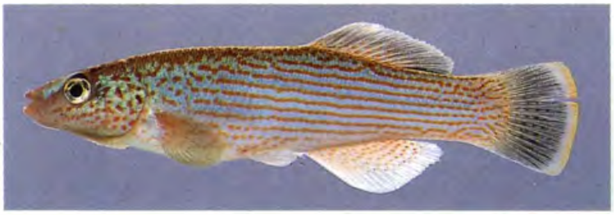


Plate 165b. *Fundulus catenatus*, northern studfish, breeding male, 108 mm SL, Caney Fork R. system, TN.

cles on males develop on the rays of all fins except the caudal, as well as on the lateral body scales (about 5 on the margin of each scale) and sides of the head.

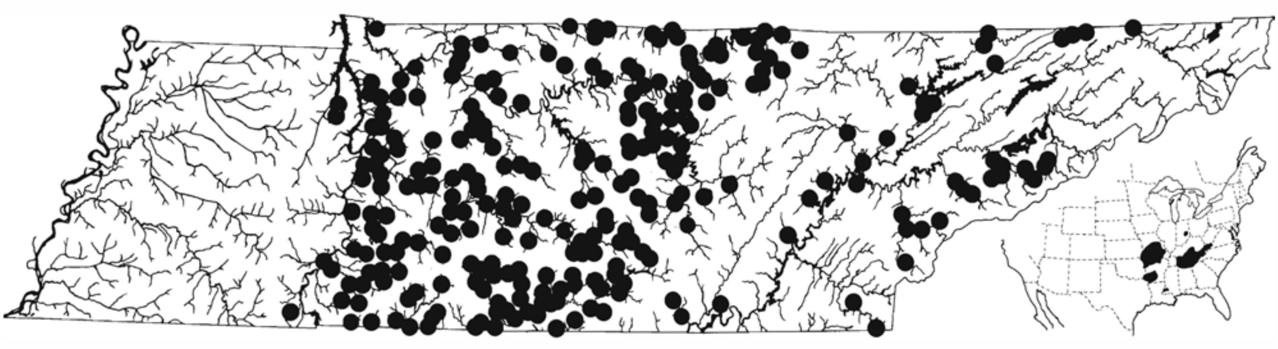
Biology: Northern studfish are usually encountered along the margins of small to medium streams in areas of sluggish to moderate current. They are adept leapers, and like most *Fundulus*, are proficient at avoiding seines. Aggressive by nature, studfish held in confinement with other fishes are often pugnacious. There is some evidence of seasonal migrations with studfishes being abundant in smaller streams only in warmer months (Fisher, 1981). Spawning occurs over shallow gravel beds in quiet water areas in which males establish territories from April through July (Pflieger, 1975). Diet is comprised largely of aquatic insect larvae and snails in adults, with juveniles taking more of their food from the surface; feeding peaks are in morning and late afternoon (McCaskill et al.; 1972; Fisher, 1981). Life span is at least 5 years (Thomerson, 1969; Fisher, 1981); average growth estimates were 40 mm TL at age 1, 60 at age 2, 77 at 3, and 98 at 4 with males slightly larger in older classes. Maximum total length (Shute, 1980) 178 mm (7 in); our largest specimen is 140 mm TL.

Distribution and Status: Tennessee and Cumberland river drainages and some southern tributaries to the Ohio River; also in small portion of Wabash River system in Indiana. Disjunct relict populations of *F. catenatus* occur in Mississippi River tributaries in southwest Mississippi (Bart and Cashner, 1980). It is widespread west of the Mississippi River in uplands from lower Missouri River tributaries south through the Red River system of southeast Oklahoma. In Tennessee, it is most abundant in the gentle gradient limestone and chert streams of the Nashville Basin and Highland Rim, and sporadic in Cumberland Plateau and Ridge and Valley habitats.

Similar Sympatric Species: Often sympatric with *F. julisia* in the Barrens Plateau area. Dorsal and anal fin ray counts show little if any overlap between these species. Juveniles and females of *julisia* are similar to *catenatus* in their somber pigmentation, but their sides are rather uniformly pigmented and lack the short, brown, horizontal lines of *catenatus*.

Systematics: Subgenus *Xenisma*. Sister species to *F. stellifer* (Thomerson, 1969; Wiley, 1986) (now presumably *stellifer* plus *bifax*). Subgenus discussed by Brown (1955) and diagnosed by Williams and Etnier (1982) and Wiley (1986). In addition to three Tennessee species, *Xenisma* includes the presumably extinct *F. albolineatus* of springs in the Tennessee River drainage in Northern Alabama, *F. bifax* of the Tallapoosa River system in Alabama and Georgia, and *F. rathbuni* of the North Carolina and southern Virginia Piedmont region.

Etymology: *catenatus* = chained.



Range Map 160. *Fundulus catenatus*, northern studfish.

Fundulus chrysotus (Guenther)

Golden topminnow

Plate 166a. *Fundulus chrysotus*, golden topminnow, male, 37 mm SL, Reelfoot L., TN.

Plate 166b. *Fundulus chrysotus*, golden topminnow, female, 39 mm SL, Reelfoot L., TN.

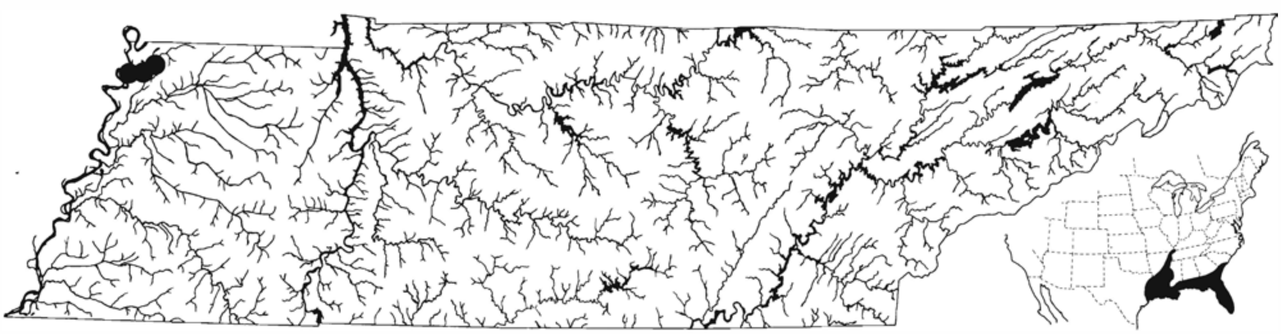
Characters: Scales in lateral series 30–34. Dorsal fin rays 9–10 (8–10). Anal fin rays 11 (10–12). Pectoral fin rays 14–15 (14–16). Pelvic fin rays 6. Principal caudal fin rays 13–18. Branchiostegal rays 5. Gill rakers 6–7. Males often but not always with about 10 vertical bars on sides; females plain. Nuptial males also have scattered red spots on their sides, while females are yellowish with a few iridescent blue or gold spots. A conspicuous gold predorsal stripe and gold nasal spots adorn both sexes. Males in our collection from May through July have tubercles on the anal fin rays, dorsal surface of the pelvic fin rays, body scales (1 tubercle per scale), breast, cheeks, and opercles.

Biology: The golden topminnow is an inhabitant of clear vegetated swamps and lakes, though it is observed to be somewhat less associated with vegetation than is the syntopic *F. dispar*. Spawning season has not been reported, but eggs are reportedly deposited on vegetation and other underwater objects (Leitholf, 1917). Food is primarily insects taken at the water surface (Hunt, 1953). Other aspects of biology not reported. Maximum total length about 80 mm (3.15 in), though Tennessee specimens tend to be much smaller.

Distribution and Status: Coastal Plain from Santee River drainage, South Carolina, to Trinity River of Texas, and extending up Mississippi River Embayment to southwest Kentucky where it reaches its northern range extremity in the Reelfoot Lake system (Sisk, 1973). *Fundulus chrysotus* is the only fish species of the Reelfoot fauna that has not been found elsewhere in Tennessee, perhaps indicating that it was not formerly present in Tennessee and gained access to Reelfoot Lake from the Missouri swamplands during the lake's formation by the gigantic New Madrid earthquake of 1812. Because of its restricted distribution in Tennessee, the golden topminnow is considered as a Species of Special Concern by the Tennessee Heritage Program (Starnes and Etnier, 1980).

Similar Sympatric Species: *Fundulus dispar*, in addition to differences noted in the Key, has dark spots covering much of the body and about 12 very narrow (about 1/2 of a scale wide) vertical bars on males, and females have parallel horizontal dark lines on their sides. In male *chrysotus* vertical bars are 1.5 to 2 scale rows wide.

Systematics: Subgenus *Zygonectes*. Closest relationships uncertain (Wiley, 1986) though earlier speculated to be sister species to *F. sciadicus* (Wiley and Hall, 1975). Other species included in *Zygonectes* are *F. cingulatus* (mostly restricted to Florida), a species very similar in appearance to, and difficult to distinguish from, *chrysotus* (see Brown, 1956a); *F. luciae* (rare in



Range Map 161. *Fundulus chrysotus*, golden topminnow.

East Coast estuaries); *F. jenkinsi* (Gulf Coast estuaries); three members of *F. notatus* group (see *F. notatus*); *F. sciadicus* (Midwest plains); and five members of *nottii* species group (see *F. dispar*).

Etymology: *chrysotus* = golden.

Fundulus dispar (Agassiz)

Northern starhead topminnow

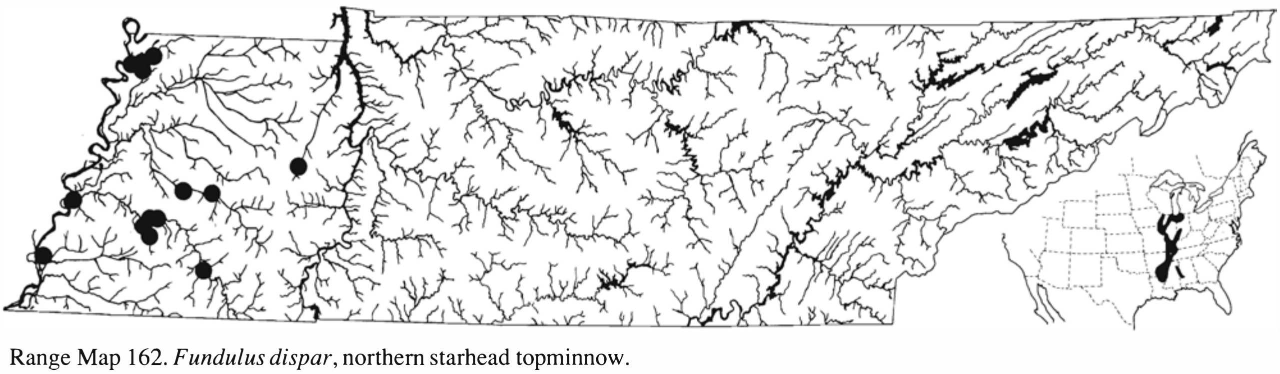
Plate 167a. *Fundulus dispar*, starhead topminnow, male, 47 mm SL, Reelfoot L., TN.

Plate 167b. *Fundulus dispar*, starhead topminnow, female, 47 mm SL, L. Isom, TN.

Characters: Scales in lateral series 30–34. Dorsal fin rays 7–8 (9 in 1 of 70 Tennessee and Arkansas specimens). Anal fin rays 10–11 (12 in 1 of 71 counted). Pectoral fin rays 12–14. Pelvic fin rays 6. Principal caudal fin rays 12–14 (11–16). Branchiostegal rays 5. Gill rakers 6–8. Males with about 12 narrow vertical bars and horizontal rows of dark spots on sides; females with a horizontal dark line associated with each scale row. Both sexes with dark patch under eye, and adult males (occasionally females) with rows of dark spots in median fins. A conspicuous gold spot present on top of the head. Other members of the *F. nottii* species group develop nuptial tubercles on dorsal and anal fin rays; we have noted tiny tubercles on these fins in an adult male *dispar* from Reelfoot Lake, 20 June, but not in April or May specimens.

Biology: An inhabitant of vegetated swamps and lakes of the Mississippi Valley, the northern starhead minnow is restricted to a few such habitats that remain in west Tennessee. It is typically encountered swimming near the surface among thick aquatic vegetation along the shallow margins of swamps and lakes. Smith (1979) indicated that breeding occurs in late spring and early summer in dense aquatic vegetation. Forbes and Richardson (1920) and Gunning and Lewis (1955) reported a diet of terrestrial insects, snails, small crustaceans, and some algae. Stomachs of Tennessee specimens examined by us contained primarily terrestrial insects. In the closely related *F. lineolatus*, Goodyear (1970) discovered that orientation in both water and when stranded on land was achieved by using the sun as a compass. These topminnows were also observed to frequently avoid predation by entering water a few millimeters deep, and even jumping onto shore for several minutes, apparently aided in returning to water by the orientation to the sun. Maximum total length 81 mm (3.2 in) (Pflieger, 1975).

Distribution and Status: Southern tributaries to Lake Michigan, Mississippi River lowlands from Illinois southward through Ouachita River system, and Tombigbee River portion of Mobile Basin. In Tennessee, *F. dispar* is fairly abundant in backwaters and ditches around Reelfoot Lake, with scattered populations in a few vegetated overflow swamps south to the Memphis area and in the Big Sandy system of the lower Tennessee drainage. Channelization of many streams in west Tennessee has eliminated most of the permanent



Range Map 162. *Fundulus dispar*, northern starhead topminnow.

swamp habitats necessary to support populations of this topminnow.

Similar Sympatric Species: *Gambusia affinis*, the western mosquitofish (Pl. 172), has a similar body shape and also has a dark patch under the eye. It lacks horizontal streaks or vertical bars on the sides, has only 8 anal fin rays, and males have the anal fin modified into a rod-like gonapodium. Also similar to *F. chrysotus* (see comments under that species).

Systematics: Subgenus *Zygonectes*. *Fundulus dispar* is one of five very closely related topminnows which constitute the *F. nottii* species complex of the Mississippi Valley and Atlantic and Gulf coastal plains: *nottii* (Lake Pontchartrain east to tributaries to lower Mobile drainage), *lineolatus* (eastern Gulf and southern Atlantic tributaries), *escambiae* (Florida Panhandle area), *blairae* (lower Escambia and southwestern Mississippi to Texas). This group has been revised by Wiley (1977) with taxa formerly treated as subspecies (Brown, 1958) being elevated to species status; Grady et al. (1988) generally supported this revision based on biochemical studies. Although Wiley's treatment has not received universal acceptance (Robins et al., 1980), we are of the opinion that his work should not be discredited in the absence of a rigorous published analysis that is contradictory. Wiley (1977, 1986) hypothesized that *dispar* is closest related to *F. blairae.* Recent publications dealing with this species in and near Tennessee have listed it as *F. notti* or *F. notti dispar*. Agassiz's original spelling (as *nottii*) is retained under current rules of zoological nomenclature.

Etymology: *dispar* = dissimilar.

Fundulus julisia Williams and Etnier

Barrens topminnow

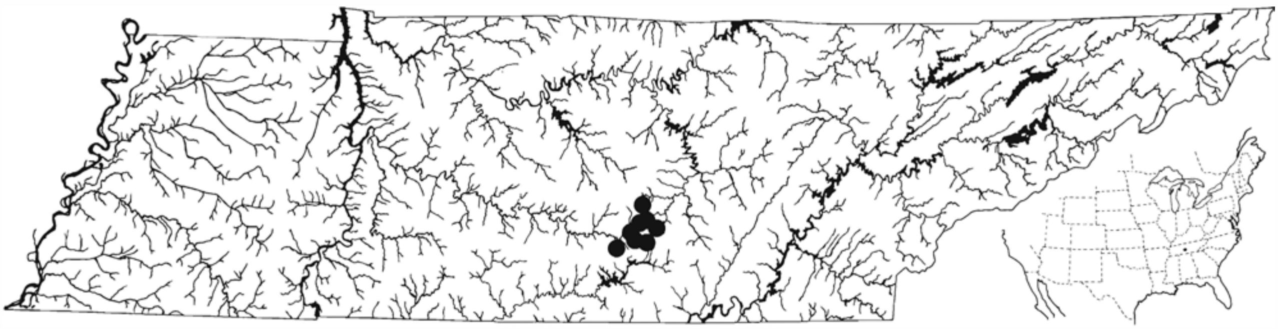
Characters: Scales in lateral series 36–42 (35–43). Dorsal fin rays 10–13. Anal fin rays 11–13. Pectoral fin rays 14–16 (14–17). Pelvic fin rays 6. Principal caudal fin rays 15–19. Branchiostegal rays 6. Gill rakers 5–6. Vertebrae 34–36. Nuptial males with red spots on blue body, and yellow on fins. Females, juveniles, and non-nuptial males pale brown with scattered dark spots on sides or lacking distinctive pigmentation. Nuptial males have conspicuous tubercles on anal fin rays; tubercles also occur on dorsal fin rays, cheeks, opercles, and body scales (about 5 per scale).

Plate 168a. *Fundulus julisia*, Barrens topminnow, male, 60 mm SL, Caney Fork R. system, TN.

Plate 168b. *Fundulus julisia*, Barrens topminnow, female, 55 mm SL, Caney Fork R. system, TN.

Biology: The Barrens topminnow reaches maximum abundance in heavily vegetated spring pools, especially in association with watercress and filamentous algae. It also occurs in vegetated pool areas of sluggish streams. Life history information was provided by Rakes (1989). Spawning occurs primarily over clumps of filamentous algae (*Cladophora*, *Pithophora*), with peak spawning from late May through early June at water temperatures of 15–20 C (59–68 F). Spawning may continue into August and September at water temperature as high as 30 C (86 F). Larger males defend breeding sites against conspecific males and other fishes. Males court females by approaching them with fins depressed and swim in loops around her if she does not flee. Receptive females nip at the spawning substrate, and this apparently triggers the spawning embrace. The female assumes an S-shaped position with her anal sheath directed toward

Banks Spring north of TN Hy. 55, Coffee Co., TN, a refugium for the Barrens topminnow.



Range Map 163. *Fundulus julisia*, Barrens topminnow.

the spawning substrate, with the male parallel to her, head to head, and with his dorsal and anal fins folded over hers. In aquaria, 1–6 (up to 17 in one case) eggs were laid per spawning act. Fertilized eggs average 2.2 mm diameter and have several tendrils up to 100 mm long that anchor them to the substrate. Fertilized eggs are virtually identical in shape and color to the numerous gas bubbles typically present in the algal clumps. The algae may protect developing eggs from fungi, as eggs cultured in the absence of algae quickly developed fungal growths unless a fungicide was used. Females probably produce about 300 eggs per year, but in aquaria a maximum of about 60 eggs was produced before the female's condition deteriorated, presumably due to constant harassment by the male. Sexual maturity and standard lengths of 40–45 mm occur at age 1; age 2, 3, and 4 fish are 55–60, 65–70, and 75–80 mm SL, respectively. Only about one-third of the population survives to a second breeding season, with age 3 and 4 fish rare in natural populations. Juveniles feed primarily on microcrustacea and midges; adults continue to utilize these foods plus amphipods and isopods, small mayflies, terrestrial insects, and snails. Maximum total length 98 mm (3.9 in).

Distribution and Status: Restricted to the Barrens Plateau area of Cannon, Coffee, and Warren counties, Tennessee, occurring in headwaters of the Duck and Elk rivers (Tennessee drainage) and the Caney Fork River system of the Cumberland drainage. Discovery of additional populations subsequent to the description of *F. julisia* (Etnier, 1983) has resulted in a suggested status change from Endangered to Threatened. While the description was being written, it was feared that the Barrens topminnow was largely restricted to the type locality, which would have dried completely during 1980 and 1981 had it not been for occasional pumping of well water into the spring by owners Mr. and Mrs. Joe Banks, who are very fond of their topminnows and have entered into a cooperative agreement with state agencies to protect the species at the type locality. In spite of exhaustive recent efforts, Barrens topminnows were last collected in the Duck River system in 1964, and they are believed to be extirpated from that system (Etnier, 1983). During 1982 and 1983, additional population centers were found in the Caney Fork system in Duke and McMahan creeks of Cannon County and Little Hickory Creek of eastern Coffee County. An additional find of a large population in the upper Elk River system (Pond Spring, Mrs. Florence Fultz farm, Hillsboro, Coffee County) increased its known range considerably. Recent droughts were a serious threat to all populations except that of Pond Spring, and may have eliminated the species from Little Hickory Creek; the species has to be considered in jeopardy. Introductions being considered by state agencies, if successful, will hopefully result in eventual removal of this interesting topminnow from our list of jeopardized fish species.

Similar Sympatric Species: Often taken with *F. catenatus*, which has higher scale and fin ray counts and broken or continuous dark horizontal lines along the sides. Sides of *julisia* are plain or with scattered dark spots.

Systematics: Subgenus *Xenisma*, and believed closely related to the presumably extinct *F. albolineatus* (see Williams and Etnier, 1982). Wiley (1986) did not resolve its relationships within *Xenisma*.

Etymology: *julisia* is derived from the Cherokee *amjulisi atsat*, or watercress fish.

Fundulus notatus (Rafinesque)

Blackstripe topminnow

Plate 169. *Fundulus notatus*, blackstripe topminnow, male, 46 mm SL, Hatchie R., TN.

Characters: Scales in lateral series 32–37. Dorsal fin rays 9–10 (8–12). Anal fin rays 12–13 (11–14). Pectoral fin rays 14–15. Pelvic fin rays 6. Principal caudal fin rays 12–15 (11–17). Branchiostegal rays 6. Gill rakers 6–7. Color pale brownish yellow to green dorsally with a prominent dark lateral stripe on sides. Many males develop vertical projections from the lateral stripe, which is more regular in females. Breeding males may have a bluish sheen (Carranza and Winn, 1954). Nuptial tubercles of males are apparently weak and ephemeral. We have seen several specimens from late May and June in which a few weak tubercles were present on the middle anal fin rays, and midlateral body scales had a marginal row of about 5 setiform tubercles. These conditions may not represent maximum tuberculation.

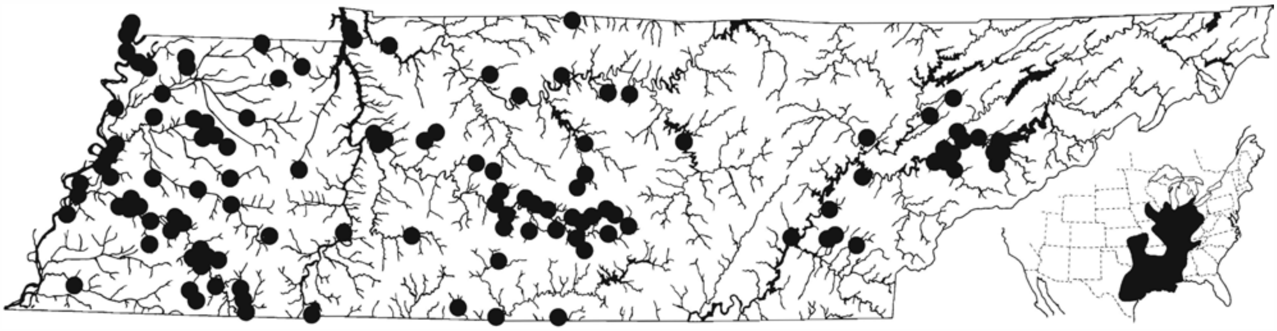
Biology: Interest in the uncommon but occasional syntopic occurrence of *F. notatus* and the very similar *F. olivaceus* has led to several attempts to quantify habitat as of potential significance in the typically allopatric distributions of the two species (Braasch and Smith, 1965; Thomerson, 1966). Thomerson (1966) summarized previous attempts at characterizing habitats, and concluded that *F. notatus* may occur from headwater streams to large rivers, from small ponds to large lakes, and is only excluded from blackwater habitats. The blackstripe topminnow occurs in a variety of habitats in Tennessee, but is continuously abundant only in lower-gradient tributaries to the Mississippi River in west Tennessee, and, to a lesser extent, in the Duck River system of middle Tennessee. Most of our collections from east Tennessee are from the Little Pigeon and Little river systems, where *notatus* occurs both in the main channels and in small tributaries. We have commonly noted small schools in Fort Loudon Reservoir. In all habitats, slack-water areas are preferred. Breeding apparently occurs in submerged vegetation in late spring and early summer, and has been described by Carranza and Winn (1954). There is some evidence of migration to spawning areas. Males defend loose territories near vegetation and court females to a limited extent by following beneath and beside them and engaging in a head-dipping behavior. Receptive females press against the spawning substrate, eggs are laid singly in the vegetative mass, and fertilized by the males. Natural hybridization with the uncommonly sympatric *F. olivaceus,* producing fertile offspring, was reported by Thomerson (1967) and Setzer (1970). Braasch and Smith (1965) suggested that only two age groups were present in their June-through-August collections from the southern Illinois area, indicating a life span of about 3 years. A similar life span was reported by Nieman and Wallace (1974). Food is similar to that described for *F. olivaceus*, principally terrestrial arthropods, emergent stages of aquatic insects, benthic larvae, and midwater insects, except there is considerable intake of filamentous algae, apparently in order to obtain associated invertebrate prey (Thomerson and Wooldridge, 1970; Atmar and Stewart, 1972). Thomerson and Wooldridge inferred that *notatus* may have a competitive advantage in feeding over the similar *F. olivaceus* in areas of sympatry because of more aggressive feeding behavior. Maximum total length (Braasch and Smith, 1965) 74 mm (2.9 in). Pflieger's (1975) report of specimens up to 96 mm may be valid.

Distribution and Status: Widespread in southern Great Lakes tributaries, Mississippi River basin, and other Gulf Coastal drainages from Tombigbee River portion of Mobile Basin west to San Antonio Bay, Texas. Common in streams of Mississippi Alluvial Plain portion of Coastal Plain of west Tennessee (Starnes, 1973), but distribution very spotty elsewhere in state.

Similar Sympatric Species: See *F. olivaceus*.

Systematics: Subgenus *Zygonectes*, closely related to *F. olivaceus* and *F. euryzonus* (Howell and Black, 1981; Suttkus and Cashner, 1981; Tatum et al., 1981; Wiley, 1986). Black and Howell (1978) found Tombigbee River populations to differ in chromosome counts from other populations studied (44 vs. 40, respectively). Geographic variation treated by Brown (1956b).

Etymology: *notatus* = spotted.



Range Map 164. *Fundulus notatus*, blackstripe topminnow.

Fundulus olivaceus (Storer)

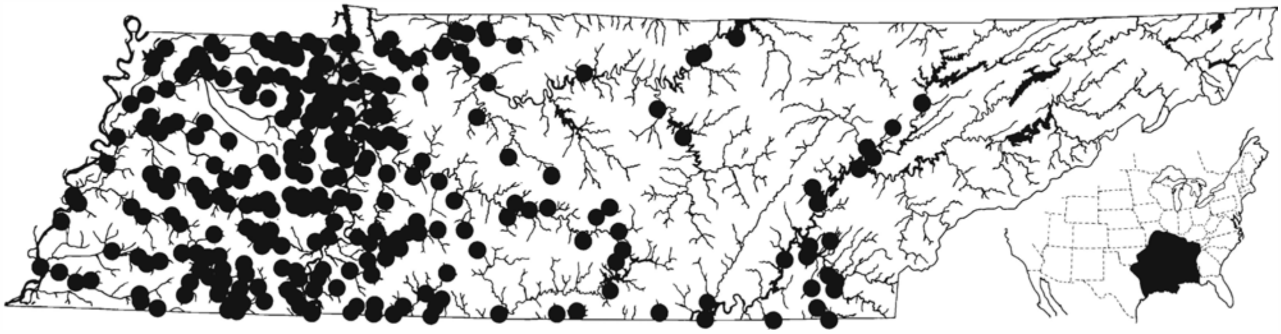
Blackspotted topminnow

Characters: Scales in lateral series 32–37. Dorsal fin rays 9–10 (8–12). Anal fin rays 11–13 (10–14). Pectoral fin rays 13–15. Pelvic fin rays 6. Principal caudal fin rays 13–15. Branchiostegal rays 6. Gill rakers 6–7. Color pale brownish yellow to olive green dorsally with a prominent black stripe on sides and black spots in dorsolateral area. Breeding males develop dorsal and ventral projections from the black lateral band, and yellowish fins. Tubercles of nuptial males are not prominent, and occur on the anal and dorsal fin rays, and as a marginal row of about 5 setiform tubercles on body scales.

Biology: In Tennessee *F. olivaceus* typically occurs in small to medium streams with moderate current. Like its congeners, it is a very visible species, and small schools can usually be located near the stream margin swimming just under the surface, individuals often resting with their caudal fin flexed at nearly a right angle to the body. In cooler months, blackspotted topminnows concentrate in small clumps of vegetation along stream banks and are typically much easier to collect at this time. *Fundulus olivaceus* seems to have a decided preference for slightly faster-flowing streams than the very similar *F. notatus* and, in unchannelized streams in west Tennessee, seems to avoid the naturally sluggish downstream areas often occupied by *F. notatus* (Starnes, 1973); such an ecological separation was also noted by Braasch and Smith (1965). This distributional pattern breaks down where channelization has altered current regimes. Breeding season apparently extends from May through August, based on occurrence of tuberculate males in our collection. Reproductive behavior may approximate that of *F. notatus*, and natural hybrids are known to occur (see *notatus*). Food consists of terrestrial arthropods, aquatic insects, small crustaceans, and diatoms (Rice, 1942; Thomerson and Wooldridge, 1970). Like *notatus*, life span is probably about 3 years. Further details of its biology have not been reported. Maximum total length (Braasch and Smith, 1965) 97 mm (3.8 in).

Distribution and Status: Widespread and abundant in central and lower Mississippi River basin, and Gulf Coastal drainages from Choctawhatchee River, Florida, through San Jacinto River, Texas. In Tennessee *F. olivaceus* is more common than the similar *F. notatus* in Coastal Plain tributaries to the Mississippi River, particularly above the Mississippi Alluvial Plain (Starnes,

Plate 170. *Fundulus olivaceus*, blackspotted topminnow, male, 50 mm SL, Hatchie R. system, TN.



Range Map 165. *Fundulus olivaceus*, blackspotted topminnow.

1973), and in the lower Tennessee drainage; fairly common in western Highland Rim, and of sporadic occurrence elsewhere in state.

Similar Sympatric Species: The blackspotted topminnow and the very similar blackstripe topminnow are two of the most difficult species of Tennessee fishes to distinguish with certainty. While many specimens are readily identifiable using characters given in the key, other specimens may prove difficult even for a trained ichthyologist to distinguish, as most characters overlap greatly (Brown, 1956b). Since both natural and aquarium-reared hybrids are known (Thomerson, 1966, 1967), apparently intermediate specimens from areas of sympatry may be due to mixed parentage. In spite of their great similarity, there is little question that they represent separate species (Braasch and Smith, 1965; Thomerson, 1966; Tatum et al., 1981). Setzer (1970) reported that diploid chromosome number was 40 in *F. notatus* and 48 in *F. olivaceus*, even though both species had the same number of chromosome arms. Black and Howell (1978) discovered a race of *F. notatus* from the Tombigbee River system with an intermediate count of 44 chromosomes.

Systematics: Subgenus *Zygonectes*, and closely related to *F. euryzonus* of Lake Pontchartrain tributaries (Suttkus and Cashner, 1981; Wiley, 1986) in addition to *F. notatus*. Tatum et al. (1981) hypothesized that *euryzonus* and *olivaceus* are sister species. Geographic variation treated by Brown (1956b).

Etymology: *olivaceus* = olive colored.

Fundulus stellifer (Jordan)

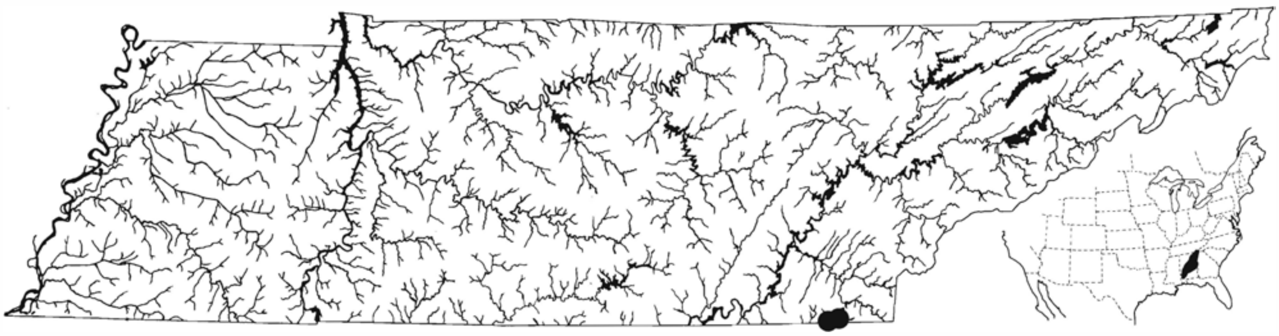
Southern studfish

Plate 171a. *Fundulus stellifer*, southern studfish, male, 92 mm SL, Conasauga R. system, TN.

Plate 171b. *Fundulus stellifer*, southern studfish, female, 76 mm SL, Coosa R. system, AL.

Characters: Scales in lateral series 38–52, caudal peduncle scale rows 20–24. Dorsal fin rays 13–15 (12–16). Anal fin rays 13–16. Pectoral fin rays 15–18. Pelvic fin rays 6. Branchiostegal rays 6. Gill rakers 5–6. Pharyngeal arches broad with large molariform teeth. Vertebrae 35–38. Sides of females and non-nuptial males plain silvery brown or with a few small, brown spots, especially on the caudal peduncle. Nuptial males pale bluish with yellow fins, with bright red spots on body and fins, and with black posterior margin on caudal fin. Nuptial tubercles are as described for *F. catenatus*, but tend to be slightly more prominent.

Biology: This Mobile Basin endemic species occurs in the Conasauga River in pools or flowing pool areas adjacent to riffles. Nuptial males of *F. stellifer* in our collection are from late April and May, presumably the



Range Map 166. *Fundulus stellifer*, southern studfish.

peak of breeding activity. Thomerson (1969) noted that *F. stellifer* has much heavier molariform pharyngeal dentition than does *F. catenatus*, presumably an adaptation for feeding on snails, which are important in the diet. A detailed biological study has not been published. Maximum total length 140 mm (5.5 in).

Distribution and Status: Restricted to Alabama River portion of Mobile Basin (except as noted below), occurring both above and below the Fall Line. Tennessee distribution of *F. stellifer* is restricted to the Conasauga River system, where it is moderately common.

Similar Sympatric Species: Thomerson (1969) reported a single specimen from the Tennessee River drainage of north Georgia, apparently the result of an introduction. If this specimen represents a successful population, sympatry with *F. catenatus* would be established. The two studfish differ markedly in coloration of nuptial males, lateral pigmentation of females and nonnuptial males, and in number of caudal peduncle scale rows. The very different *F. olivaceus*, with its black lateral band, is the only other *Fundulus* occurring in the Conasauga River system.

Systematics: Subgenus *Xenisma*, closely related to *F. catenatus* (see comments thereunder). Cashner et al. (1988) have discovered that Tallapoosa River, Alabama, populations represent an electrophoretically distinct species, *Fundulus bifax* Cashner and Rogers, that is inseparable from *stellifer* in counts and measurements, but differs conspicuously in pigmentation.

Etymology: *stellifer* = star bearer.

FAMILY POECILIIDAE
The Livebearers

The Poeciliidae is a large family of small fresh- and brackish-water fishes that occurs in North and South America, Africa, and Madagascar; the family is included in the order Cyprinodontiformes along with the closely related killifishes (Cyprinodontidae), topminnows (Fundulidae), and several other families, most of which are primarily tropical in distribution (Parenti, 1981; Parenti and Rauchenberger, 1989). Previous classifications (Rosen, 1964; Greenwood et al., 1966) placed these families in a more inclusive ordinal grouping, the Atheriniformes, along with the distantly related silversides (Atherinidae), flying fishes (Exocoetidae), and others (see further under Fundulidae and Atherinidae), combining all of the above families plus others in the series Atherinomorpha. Many lineages of this group have tendencies toward internal fertilization, reaching greatest development in the livebearing poecilliids. Under Parenti's classification, the common name "livebearers" is partially a misnomer; only the New World members of the family, subfamily Poeciliinae (about 200 species), which constituted the entire family under earlier classifications (e.g., Greenwood et al., 1966), lend themselves to this term; Old World genera now included in the family are egg layers. Although poeciliines bear close morphological similarity to several closely related oviparous (egg-laying) cyprinodontiform groups, they differ trenchantly in their mode of reproduction. Poeciliines are ovoviviparous or viviparous fishes; that is, eggs are fertilized internally and develop within the ovary or oviduct. The young are born as free-swimming juveniles, thus leading to the common name. Several broods a year are usually born, and some species have the capability of carrying broods of varied stages of development simultaneously (superfetation) (Constantz, 1989). Internal fertilization is achieved by means of a male intromittent organ, the gonopodium, which consists of modified anterior anal fin rays suspended such that it can be freely pivoted to the side. Many of these structures are equipped with elaborate arrangements of hook-like bones. It has been suggested that these function both to hold fast during copulation and to slightly injure the female to prevent subsequent copulations with other males (Constantz, 1989). The comparative morphology of gonopodia is taxonomically definitive for the various species. Excellent detailed discussions of the reproductive morphology of poeciliids are found in Rosen and Gordon (1953), Rosen and Bailey (1963), and Constantz (1989). Ovoviviparity may have evolved independently in a few other cyprinodontiform groups (e.g., Goodeidae, Anablepidae, etc.) (Parenti, 1981). A systematic overview of poeciliines was presented by Parenti and Rauchenberger (1989).

Several gynogenetic or hybridogenetic (see Reproduction and Early Development) all-female "species" of supposed hybrid origin have evolved within poeciliids (Schultz, 1989), including the "amazon" molly, *Poecilia formosa* (see Schultz and Kallman, 1968; Turner et al., 1980). This phenomenon is also found among desert topminnow species (*Poeciliopsis*) (Moore et al., 1970; Vrijenhoek and Schultz, 1974). The livebearer family contains many popular aquarium fishes such as the guppies and mollies (*Poecilia*) and swordtails and platyfishes (*Xiphophorus*). Four poeciliid genera occur naturally in the United States (*Gambusia*, *Heterandria*, *Poecilia*, and *Poeciliopsis*). *Heterandria* and *Poecilia* are lowland- or brackish-water forms occurring near the Atlantic and Gulf coasts; *Poeciliopsis*, now nearly extirpated from the United States, inhabits the desert Southwest.

The biology of poeciliids has been well studied; several works on the ecology and evolution of livebearers were presented in Meffe and Snelson (1989).

Genus *Gambusia* Poey

Gambusia is a relatively large genus of about 45 species occurring in the southeastern United States and southward through Texas and eastern Mexico to Central America (Rosen and Bailey, 1963; Rauchenberger, 1989). It was hypothesized to be closest related to the Central American genera *Brachyrhaphis* and *Belonesox* with which it was placed in the tribe Gambusiini by Parenti (1981) and Parenti and Rauchenberger (1989). Members of *Gambusia* are distinguished from other poeciliids primarily by several characters uniquely possessed by males, including the presence of knobby structures on the segments of pectoral fin rays 3–6 and gonopodial characters. Within the United States, the majority of species are endemic to spring-fed habitats of southern Texas. In the southeastern states, only three species are known at present, the brackish water *G. rhizophorae* of southern Florida, *G. holbrooki* native to the Atlantic and eastern Gulf Coastal Plain, and *G. affinis*, native to the western Gulf Coastal Plain and lower Mississippi Valley region. *Gambusia holbrooki*, and possibly *G. affinis* have been widely introduced around the world for mosquito control. It is therefore possible that *holbrooki* has been locally introduced to Tennessee, occurring in the state in addition to the native *affinis*.

KEY TO THE POSSIBLE TENNESSEE SPECIES

1. Distal segments of ventral-most major element of gonopodium (anal ray 3) essentially smooth dorsally (Fig. 126a); dorsal fin rays usually 7, anal fin rays 9 . . . . *G. affinis*
   Distal segments of ventral-most element of gonopodium finely serrate dorsally (Fig. 126b); dorsal fin rays usually 8, anal fin rays 10 . . . . *G. holbrooki*

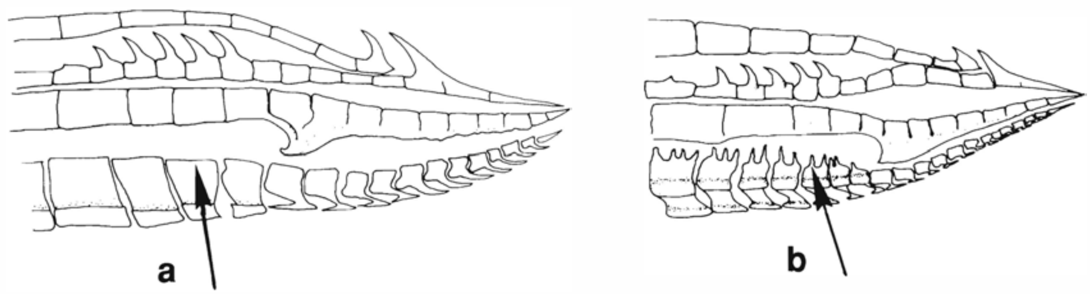


Figure 126. Gonopodia of *Gambusia*: a) *G. affinis*; b) *G. holbrooki* (modified from Rauchenberger, 1989).

Gambusia affinis (Baird and Girard)

Western mosquitofish

Plate 172a. *Gambusia affinis*, western mosquitofish, male, 25 mm SL, Conasauga R. system, TN.

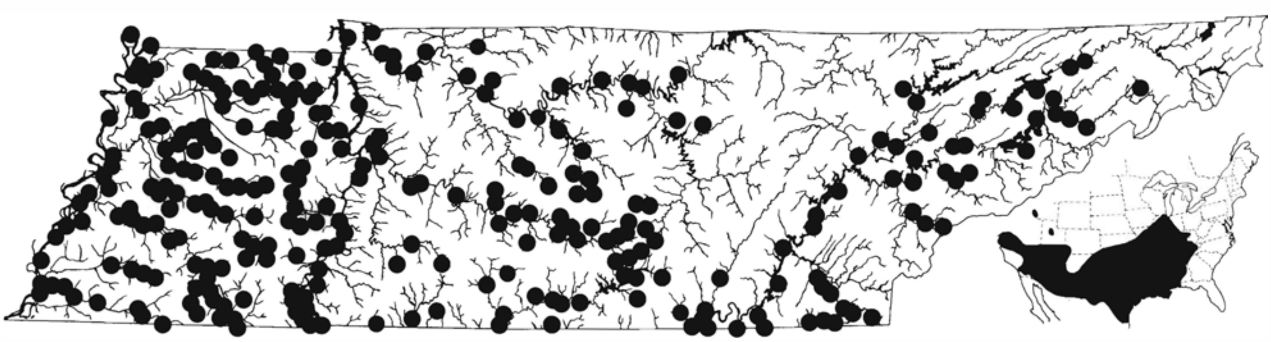
Plate 172b. *Gambusia affinis*, western mosquitofish, female, 45 mm SL, Conasauga R. system, TN.

Characters: Large cycloid scales, lateral series about 30. Dorsal fin rays 7. Anal fin rays 9 and highly modified in males. Pectoral fin rays 12–14. Pelvic fin rays 6. Principal caudal fin rays 13–16. Gill rakers 12–14. Head and body dorsally flattened anterior to dorsal fin. Bellies of females often greatly distended by brooding young. Dorsolateral area gray to straw-yellow with scales well outlined by dark pigment; belly silvery. A black subocular bar is usually present, and the body and caudal fin are often speckled with black. In females, the dark lining of the posterior body cavity often shows through the skin as two large spots on either side above the anus. Melanism, including completely black specimens, is common in males (and rarely females, Snelson et al., 1986) in southern (primarily Floridian) *G. holbrooki* populations, but this trait is apparently lacking in *G. affinis*.

Biology: *Gambusia affinis*, with its dorsally flattened body, upturned mouth, and strong anterior teeth, is well adapted to surface feeding. Mosquitofish spend much of the time patrolling about the surface in quiet, shallow backwaters where they feed opportunistically on fallen insects and other organisms. In a study conducted in Reelfoot Lake, Tennessee, mosquitofish were shown to feed on, in addition to fallen insects, aquatic insect larvae, microcrustaceans, small snails, and larval fishes, including their own young (Barnikol, 1941); similar results are reported for the closely related *G. holbrooki* (Hildebrand, 1917). When abundant, mosquito larvae become a preferred prey item for these fishes (Hildebrand, 1925; Hess and Tarzwell, 1942), and these fishes (particularly *G. holbrooki*) have been introduced throughout the world as a biological control measure for malaria (Jordan, 1927). Unfortunately, introductions outside the natural range of *G. affinis* have often been to the detriment of native fishes, particularly in the southwestern United States, where highly restricted desert species are outcompeted and their young are preyed upon by the aggressive mosquitofish. Reproduction occurs throughout the warmer months. In confinement, breeding males are aggressive toward each other and spend considerable time displaying, tail-beating, and chasing, with larger males dominant (Itzkowitz, 1971); but such behavior may be infrequent in the wild (Martin, 1975). Several males may court a female, all orienting head-toward her, but one is usually dominant. A successful male then follows slowly behind and left of the much larger female, who may repeatedly wheel to repulse him. To succeed in copulation, the male must avoid these rebuffs, quickly dart forward alongside the female, and curl the gonopodium to the right, inserting it for an instant into the female's urogenital pore (Seal, 1911; Peden, 1972). Internal fertilization is achieved by the passage of sperm along a groove in the male gonopodium. Sperm are stored within the female's reproductive system and used to fertilize repeated broods of a few to a hundred or more young which are eventually born as well-developed juveniles (Krumholz, 1948). A single female may have three or four broods a year. Due to the high degree of parental care afforded by this mode of reproduction, as well as the species's high tolerance of elevated temperatures, low oxygen, and poor water quality, the reproductive potential and success of mosquitofishes is unusually high, especially in environments unfit for habitation by other species. Growth is rapid, and individuals born early in a season reach maturity and may reproduce that season; these may not survive to the following season, whereas individuals born late in the season mature the following year. Thus, life span is probably never much over one year. Females grow much more rapidly and to larger size. Males experience high mortality in early summer and are outnumbered considerably by females later in the year (Hildebrand, 1927). As is true of *Fundulus*, the dorsally positioned mouth of mosquitofishes allows them to take respiratory water from the typically oxygen-rich surface film. Because of its hardiness and adaptability to the laboratory, a tremendous amount of experimental research, including numerous toxicity studies, has been conducted on this species. Maximum total length of females about 65 mm (2.5 in), though most specimens are smaller; males are always much smaller, rarely exceeding 35 mm (1.3 in).

Distribution and Status: Native range probably was the Coastal Plain from western Alabama northward to southern Illinois, and westward into eastern Mexico where the extent of its range is uncertain (Wooten et al., 1988; Rauchenberger, 1989). Mosquitofish are abundant in shallow waters of swamps and lakes and sluggish backwaters of creeks and rivers throughout Tennessee. It is difficult to ascertain the former natural range of *G. affinis* in the state prior to introductions, and we have no historical information concerning introductions, if any, in Tennessee. Range information given in Jordan and Evermann (1896) indicates that *G. affinis* was probably originally more or less restricted to the Coastal Plain, i.e., west Tennessee; but, it was present in east Tennessee at least as early as the 1920s, based on preimpoundment records. However, the extensive surveys of the Duck River system by A. R. Cahn, circa 1940, did not yield *Gambusia*. It is common there now, and Cahn's collecting methodology would certainly have revealed it had it been there in any numbers. It is very possible that the mosquitofish has expanded its range considerably in the state within recent decades, perhaps assisted by human-induced habitat alterations that favor it.

Similar Sympatric Species: *Fundulus dispar* (Pl. 167) occurs syntopically at a few localities in west Tennessee, shares a black suborbital bar, and appears superficially similar; it is easily separable by the presence of horizontal streaks along the sides and vertical bars in males, the position of the dorsal fin almost directly above rather than well behind the anal fin origin, and the lack of a gonopodium in males. It is conceivable that the very similar eastern mosquitofish, *Gambusia*



Range Map 167. *Gambusia affinis*, western mosquitofish (inset shows native and introduced populations; Mobile Basin populations may be introgressed with *G. holbrooki*).

holbrooki, could have been introduced to locales in Tennessee, as it is the primary species that has been introduced over the world for mosquito control (see Key). None of the few representative samples examined by us are *holbrooki*, but its occurrence in the state is a possibility that should continue to be considered.

Systematics: Unlike earlier workers (e.g., Geiser, 1923; Hildebrand, 1925) who accorded species status to *holbrooki*, Rosen and Bailey (1963) regarded *G. affinis* and *G. holbrooki* Girard as subspecies with supposed intergrades occurring in western Florida and Alabama. Black and Howell (1979) referred to these forms as "semispecies" rather than subspecies because of the interesting finding that only male *G. affinis* x female *G. holbrooki* matings were successful (and not the reverse) due to chromosomal differences, thus resulting in partial reproductive isolation. Rauchenberger (1989) regarded *holbrooki* as a separate species which, along with *affinis* and about 15 other species ranging from Texas to southern Mexico (one in Columbia), constitute the subgenus *Arthrophallus* Hubbs. Based on biochemical evidence, Wooten et al. (1988) and Lydeard et al. (1988) also recommended species-level recognition for *holbrooki* and, in a recently discovered area of sympatry of the two forms in the upper Savannah and Chattahoochee drainages, Georgia, species identity appeared to be maintained (Lydeard et al., 1991).

Etymology: *Gambusinos* = provincial Cuban word for "nothing," possibly in reference to the small size; *affinis* = related.

ORDER ATHERINIFORMES

FAMILY ATHERINIDAE

The Silversides

The Atherinidae is a large family of principally marine and euryhaline (living in varied salinities) fishes that is circumglobal in distribution. A few species are strictly confined to fresh water. The atherinids are placed in the order bearing their name, Atheriniformes, along with four families of similar fishes which occur in the Indo-Pacific region (Rosen and Parenti, 1981; Nelson, 1984). One such family is the Melanotaeniidae, the rainbow fishes of Australia and New Guinea, which are familiar to aquarists. Under older classifications (Greenwood et al., 1966; Nelson, 1976), Atheriniformes included a wider variety of 16 families including the flyingfishes (Exocoetidae), needlefishes (Belonidae), killifishes (Cyprinodontidae), and livebearers (Poeciliidae). However, elevating cyprinodontids and their near relatives to ordinal rank (Rosen and Parenti, 1981, and comments under Fundulidae) necessitated restriction of Atheriniformes to five families. Needlefishes, flyingfishes, and their close relatives were allocated to an additional order, Beloniformes. Collectively, all families comprising the former, more inclusive Atheriniformes are now termed a "series," the Atherinomorpha, which may constitute the sister group to percomorph (see Perciformes) fishes (e.g., Stiassny, 1990). Atherinomorph, particularly cyprinodontiform and some atheriniform, fishes have tendencies toward internal fertilization and possess gonadal modifications (e.g., Grier et al., 1980) to facilitate such tendencies; while many such fishes are known egg-layers, more and more species are discovered as being ovoviviparous.

Atherinids characteristically have flattened dorsums, pectoral fins inserted high on the sides and near the top of the gill opening, widely separated dorsal fins, cycloid scales, and, in life, a conspicuous metallic silvery streak along the side, lending to their common name. Most are small fishes, under 125 mm TL, but a few species, such as the jack smelt (*Atherinopsis*) and topsmelt (*Atherinops*) of the eastern Pacific, and the freshwater *Basilichthys* of temperate South America, may attain 500 mm or more and are of importance in fisheries. All silversides, which typically school by the thousands, are important forage for other fishes. The fabled grunion (*Leuresthes*), which "runs" (spawns) by the millions on California beaches during high lunar tides, is a member of this family. Both genera occurring in the fresh waters of North America occur in Tennessee, the strictly freshwater monotypic genus *Labidesthes* Cope, and the euryhaline *Menidia*.

KEY TO THE TENNESSEE GENERA AND SPECIES

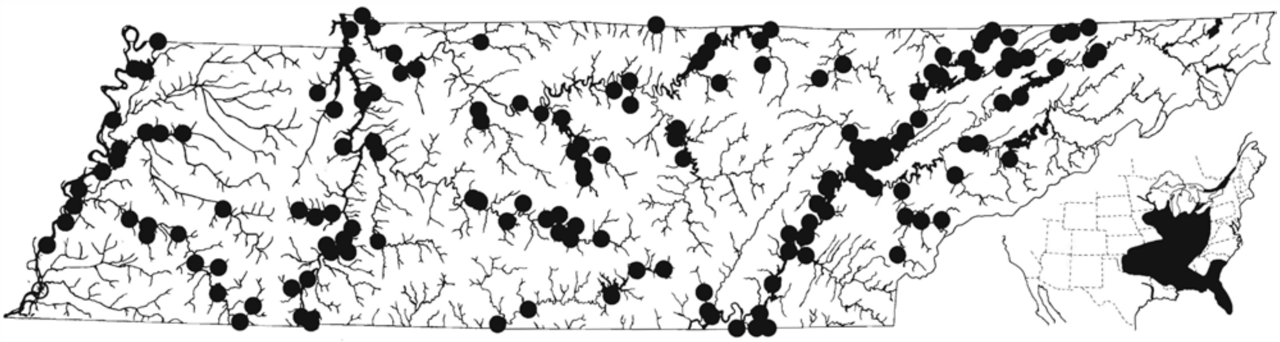
1. Scales small, predorsal scales (counted on the dorsal midline) about 40; anal fin rays 21 or more; snout and jaws produced into a beak . . . . *Labidesthes sicculus*
   Scales larger, predorsal scales about 20; anal fin rays 20 or fewer; snout not greatly produced . . . . *Menidia beryllina* p.377

Labidesthes sicculus (Cope)

Brook silverside

Plate 173. *Labidesthes sicculus*, brook silverside, 77 mm SL, Sulphur Fork R., TN.

Characters: Scales in lateral series 74–94, lateral line absent or with a few pores on caudal peduncle. Two widely separated dorsal fins; first with 4 spines, second with 1 spine and 10–11 soft rays. Anal fin with 1 spine and 21–27 rays. Pectoral fin rays 12–15. Pelvic fin with 1 spine and 5 rays. Principal caudal fin rays 17. Branchiostegal rays 6. Gill rakers 22–24 in our area. Vertebrae 40–43. An extremely slim species with a characteristic beak-shaped snout, long anal fin, and narrow silvery lateral streak. Dorsolateral coloration of



Range Map 168. *Labidesthes sicculus*, brook silverside.

specimens from clear to turbid waters ranges from translucent green to pallid; specimens from acid-stained swamp waters are much darker and have yellowish fins.

Biology: The brook silverside is an open-water fish and most often schools near the surface of lakes, reservoirs, rivers, and large creeks. Its common name is rather inappropriate, as it is definitely not a characteristic species of brooks. Spawning occurs from June through August. Eggs were thought to be extruded and fertilized in midwater and then drift until attaching to underwater objects by means of adhesive anchoring filaments that trail from the ova (J. Nelson, 1968). Grier et al. (1990) have shown that fertilization, at least in the Florida population they studied, is internal, with the tubular urogenital papilla of the male serving as the intromittent organ; females may deposit fertilized eggs at selected sites. Larvae hatch at about 5.5 mm TL, take nourishment from the yolk sac to about 7 mm, and then presumably feed on microorganisms and transform to juveniles at about 15 mm (Rasmussen, 1980). Young brook silversides reach total lengths of about 60 mm (2.3 in) by their first fall. Sexual maturity is reached and spawning occurs the following spring and summer. Growth continues until lengths of about 80 mm (3 in) are reached, but few if any survive into a second winter (Hubbs, 1921). The diet is composed chiefly of zooplankton, including copepods, cladocerans, and midge larvae (Forbes and Richardson, 1920; Hubbs, 1921; Mullan et al., 1968). Brook silversides are doubtless an important forage species for many predatory fishes. They have been observed to often skip along the surface, perhaps as a predator avoidance behavior (Hubbs, 1921). Maximum length (Lee, 1980) 112 mm SL, or about 5.2 in TL.

Distribution and Status: St. Lawrence drainage and southern Great Lakes tributaries, Mississippi River basin, and Atlantic and Gulf drainages from Santee River, South Carolina, to Sabine River, Texas. The brook silverside is common in suitable habitats throughout Tennessee west of the Blue Ridge.

Similar Sympatric Species: The brook silverside occurs in the Mississippi River and adjacent areas with the inland silverside, *Menidia beryllina*. Scale counts and snout shape differ markedly between these two species. In *Labidesthes* the dorsolateral scales are nearly microscopic in all but the largest specimens; in *Menidia* these scales are easily visible.

Etymology: *Labidos* = a pair of forceps, *esthio* = to eat, in reference to the beak-like jaws; *siccus* = dried, perhaps in reference to being found in drying pools.

Genus *Menidia* Jordan and Gilbert

This is a small genus containing mostly euryhaline or strictly marine species including *Menidia beryllina*, *M. menidia* of the Atlantic Coast, *M. peninsulae* of the Gulf Coast, *M. conchorum* of the Florida Keys, and *M. extensa*, endemic to Lake Waccamaw, North Carolina; *M. clarkhubbsi* is a novel all-female species of the Texas coastal region believed to have a hybrid origin involving *M. beryllina* and *M. peninsulae* (Echelle and Mosier, 1981, 1982). Such a "species" is probably gynogenetic (see Reproduction and Early Development), depending on sperm of one of the parental species to trigger development.

Menidia beryllina (Cope)

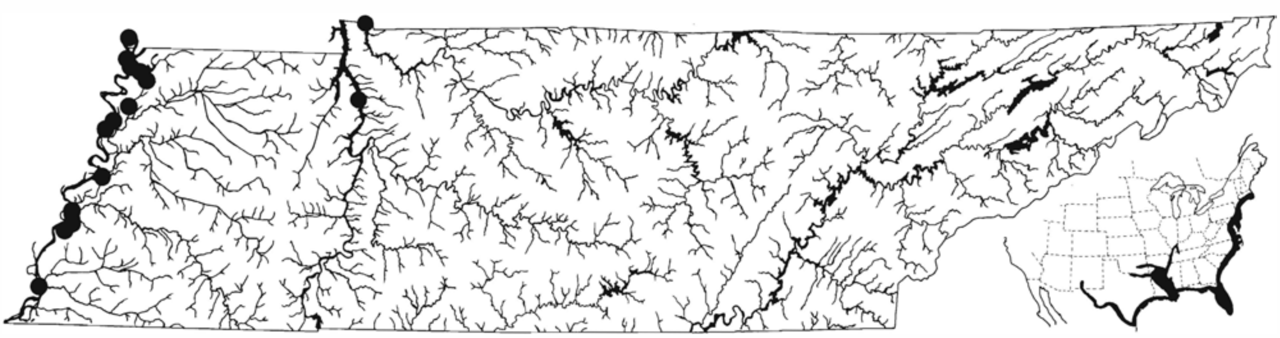
Inland silverside

Characters: Scales in lateral series (counted just above the lateral band) 38–45 in our area (34–41 in Gulf Coast populations). Lateral-line canal in two segments with about 8 pored scales above lateral stripe behind head, continuing below lateral stripe from near tip of pectoral fin to caudal base. Two widely separated dorsal fins; first with 4–5 spines, second with 1 spine and 8–9 rays. Anal fin with 1 spine and 15–20 (14–21) rays. Pectoral fin rays 13–15. Pelvic fin with 1 spine and 5 rays. Principal caudal fin rays 17. Branchiostegal rays 6. Gill rakers 18–20 in Tennessee specimens. Vertebrae 36–42. Dorsolateral coloration above the silver lateral stripe ranges from pale yellowish to translucent green.

Biology: The inland silverside is a euryhaline species occurring in both brackish coastal waters and freshwater rivers and lakes. In typical silverside fashion, it is a schooling surface fish, usually of larger waters. The following life history information is inferable from Hildebrand (1922), Mense (1967), and Hubbs and Dean (1979). At the latitude of Tennessee, frequent multiple spawning probably occurs from late spring through summer, resulting in protracted recruitment of young. Fecundity averages about 1,000 ova per female. As in *Labidesthes*, eggs of *M. beryllina* have anchor filaments. Hatching requires about 3 weeks. Young grow to about 60 mm (2.3 in) TL by their first winter and reach about 100 mm (4 in) by the end of their second summer. Studies in Florida (Middaugh and Hemmer, 1992) indicated lower fecundity (up to 420 ova per female), rapid maturity, and fewer multiple spawnings, resulting in two broods per year. Life is short, and death typically occurs after the second summer. Saunders (1959) reported a diet composed of zooplankton. However, stomachs of adults from the Mississippi River in west Tennessee contained many midge larvae, mayfly larvae (*Hexagenia*), and fallen terrestrial insects (Homoptera, Hymenoptera, etc.). This silverside is a significant forage species for such predators as the white and yellow basses and the largemouth bass. Maximum length (Gilbert and Lee, 1980) 125 mm SL (about 5.5 in TL).

Distribution and Status: Coastal Plain from New England to Mexico, and extending up Mississippi River to southern Illinois. The inland silverside is often common where it occurs, but populations in the upper Mississippi River Embayment are restricted to areas in close proximity to the Mississippi River. Habitats in west

Plate 174. *Menidia beryllina*, inland silverside, 78 mm SL, Mississippi R., TN.



Range Map 169. *Menidia beryllina*, inland silverside.

Tennessee are primarily the Mississippi River and Reelfoot Lake, but populations occur in Open Lake, Lauderdale County, and Running Reelfoot Bayou. Occasionally it enters lower reaches of tributaries to the Mississippi River. Recently taken in Kentucky and Barkley reservoirs near Kentucky/Tennessee border (lower Tennessee and Cumberland rivers) by TVA.

Similar Sympatric Species: See *Labidesthes sicculus*.

Systematics: In previous literature, *Menidia* populations from the Mississippi River drainage have been referred to as *Menidia audens* Hay, the Mississippi silverside. Chernoff et al. (1981) considered this form to represent the northern component of a meristic cline of the euryhaline *M. beryllina*.

Etymology: *Menidia* = Greek term for a small, silvery fish; *beryllina* = emerald color.

ORDER MUGILIFORMES

FAMILY MUGILIDAE

The Mullets

Mugilidae, commonly known as the mullets, is a widespread marine family currently construed as containing about 13 genera and 70 species (Schultz, 1946; Thomson, 1964), but the group is badly in need of revision. Mullets resemble atherinids (silversides, etc.) in having a short spinous dorsal fin (4 spines) that is remote from the soft dorsal fin, and in having their pectoral fins placed high on the body. They also lack the firm articulation between pelvic and pectoral girdles that is typically present in perciform fishes. They had been classified near atheriniform fishes (as the order Mugiliformes) in the past (e.g., Berg, 1940), but recent classifications (e.g., Nelson, 1984) included mugilids within the Perciformes with possible affinities with the barracudas (Sphyraenidae) and threadfins (Polynemidae), and remote from atherinomorph fishes. However, new evidence (Stiassny, 1990; B. Chernoff, in litt.) again suggests relationships with atherinomorph (silversides, topminnows, etc.) fishes, rather than higher perciform groups.

Most mullets are strictly marine in occurrence but, in addition to the striped mullet, treated here, *Agonostomus monticola* (Bancroft), the mountain mullet, also makes extensive forays into tropical and subtropical freshwaters, spending much of its life in streams, as do members of the circum-Caribbean genus *Joturus*.

Genus *Mugil* Linnaeus

All mullets are very similar in appearance, with *Mugil* characterized by prominent adipose eyelids and cycloid or very weakly ctenoid scales. The genus, which is in need of revision, is worldwide in distribution except at high latitudes, and contains an indeterminent number of species, with at least five occurring in North American waters.

Mugil cephalus Linnaeus

Striped mullet

Characters: Lateral line absent, 38–42 scales in lateral series. Dorsal fin with 4 spines in anterior portion and 1 spine and 8 (6–8) soft rays in posterior portion. Anal fin with 3 spines and 8 (7–8) soft rays, but in young the third element is a soft ray, giving a count of 2 spines and 9 rays. Pectoral fin rays 16–17 (14–18). Pelvic fins with 1 spine and 5 soft rays. Principal caudal fin rays 14. Gill rakers long and numerous, the number increasing with body size. Vertebrae 24. Branchiostegal rays 5–6. Gill membranes separate. Frenum absent. Scales are large and cycloid or weakly ctenoid and occur on all fins except the spinous dorsal and pelvics, and cover the body and head except for the jaws and branchiostegal membranes. Coloration in life is silvery with about 6 narrow dark stripes often apparent along the side. The iris is yellow, and there is a dark blue blotch at the base of the pectoral fin. A single row of tiny, bristle-like teeth borders the upper and lower jaw.

Biology: Striped mullets are familiar residents of estuaries, salt marshes, and shoreline areas along the Atlantic and Gulf coasts, where they often are seen jumping and schooling near the surface. They have remarkable ability to move between fresh water and salt water without experiencing water balance problems. Biological information has been summarized from Martin and Drewry (1978) and Collins (1985). During fall and winter, adults migrate to offshore areas to spawn. In the Gulf of Mexico the spawning area is near the edge of the continental shelf, and along the Atlantic shore it is presumably near the edge of the Gulf Stream. Young drift with prevailing currents and move into shallow nursery areas at about 16–18 mm SL, apparently swimming toward shore in response to olfactory cues. Adults and subadults are almost exclusively detritivores, but young feed on small invertebrates such as copepods and mosquito larvae. In Atlantic and Gulf coast areas, sizes are about 156–196, 228–298, and 290–351 mm TL at ages 1, 2, and 3, with females growing slightly faster than males. Sexual maturity typically occurs at age 2+, and life span is up to 13 years. Mullet probably rival herring in their importance as a forage base for pis-

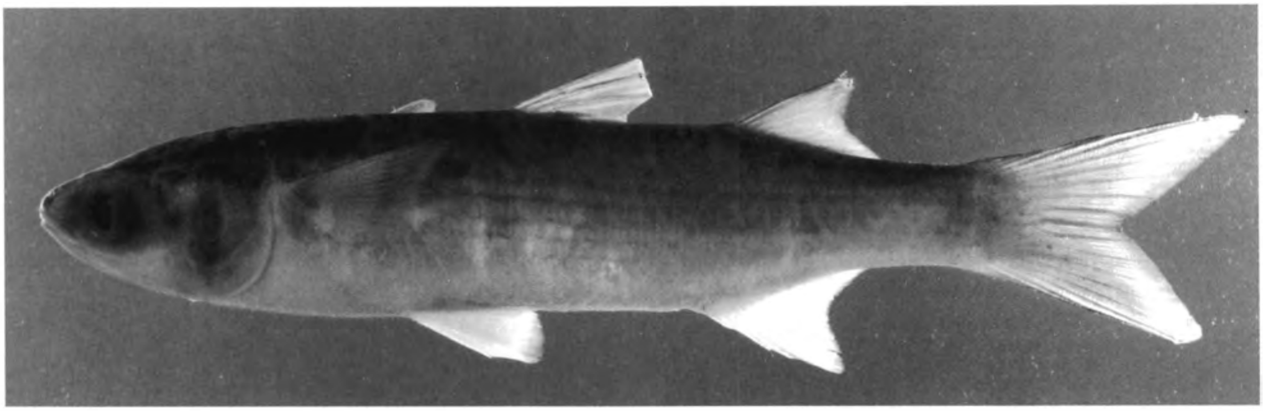
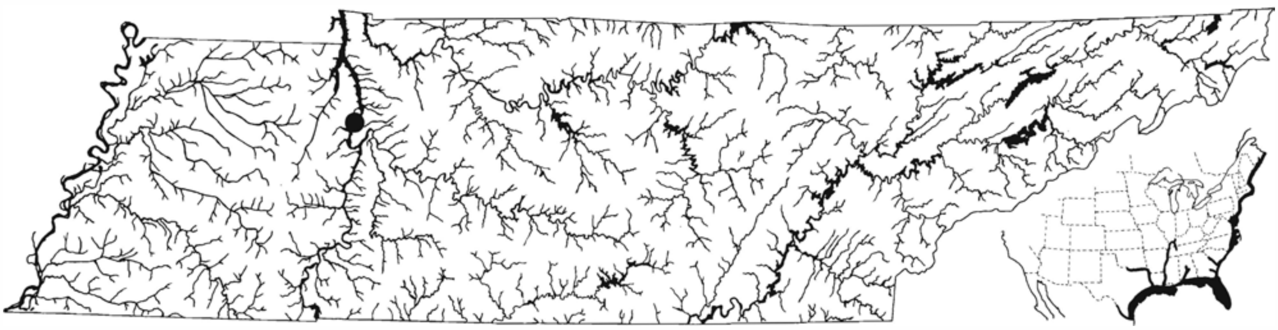


Plate 175. *Mugil cephalus*, striped mullet, preserved specimen, 210 mm SL, Edisto Beach, SC.



Range Map 170. *Mugil cephalus*, striped mullet.

civorous fish, birds, and mammals, and are favored bait for many spectacular marine gamefish such as bluefish, mackerel, tarpon, sailfish, and marlin. Adults are important food fishes that are exploited commercially for their flesh and roe. They are often available fresh and smoked in restaurants near the coast but are less popular in interior areas, apparently because the meat does not preserve well when frozen. Mullet rarely strike lures, but they can occasionally be enticed to strike natural or artificial offerings that resemble small, soft-bodied invertebrates. They are powerful swimmers that usually swim around or jump over small seines. Commercial fishermen rely on gill nets or extremely long seines for their catches, and anglers typically use cast nets for catching mullet for bait. Maximum recorded size (from India) slightly over 900 mm (3 ft) TL.

Distribution and Status: Under current taxonomic concepts, *M. cephalus* occurs in all temperate and tropical oceans but is absent from some oceanic island areas. We have not collected or seen specimens in the Mississippi River in west Tennessee, but their journeys up the Mississippi River occasionally extend as far upstream as Missouri (W. L. Pflieger, pers. comm.). Collected in Kentucky Reservoir, Tennessee, in 1993.

Etymology: Mugil is a vernacular name for the mullet; *cephalus* = head.

ORDER GASTEROSTEIFORMES

FAMILY GASTEROSTEIDAE

The Sticklebacks

Sticklebacks are small marine and freshwater fishes with a holarctic distribution. The family contains fewer than ten species and has affinities with the marine tubesnouts (Aulorhynchidae), which are included with sticklebacks in the order Gasterosteiformes (Nelson, 1984) and have been listed in the same family by some authors (e.g., Robins et al., 1980). Previous workers (Greenwood et al., 1966; Fritzsche, 1984; and others) have grouped (as Gasterosteiformes or Syngnathiformes) sticklebacks with the familiar seahorses and pipefishes (family Syngnathidae), the coral-reef inhabiting trumpetfishes (Aulostomidae), and the marine cornetfishes (Fistularidae) and seamoths (Pegasidae), as hypothesized by Pietsch (1978); however, the naturalness (monophyly) of this group has been questioned (Nelson, 1984).

Sticklebacks are characterized by their very slender caudal peduncles, free dorsal spines, and the tendency to have plates of dermal bones rather than typical scales on their sides. Males of all species construct a hollow, globose nest of fragments of vegetation, and defend eggs and young until they are able to leave the nest. Their small size, hardiness, and aggressive nature make them interesting aquarium fishes, and they have been intensely studied by students of animal behavior. Accounts of their elaborate courtship and territorial behavior are included in many journal articles (see Coad, 1981) and many biology textbooks.

The brook stickleback, *Culaea inconstans*, has apparently been introduced to Tennessee on several occasions, and populations of varied persistence have resulted. In addition to that species, Gasterosteidae includes *Pungitius pungitius*, the ninespine stickleback, common in fresh and slightly brackish waters of northern North America and Eurasia, and a congener, *P. platygaster*, occurring in south central Eurasia. The fourspine stickleback, *Apeltes quadracus*, occurs mostly in brackish and saltwater habitats in northeastern North America, as does *Gasterosteus wheatlandi*, the blackspotted stickleback. The most intensely studied species, *G. aculeatus*, the threespine stickleback, occurs in both fresh and saltwater habitats, usually in coastal areas, in both North America and Eurasia. *Spinachia spinachia*, the fifteenspine stickleback, is an elongate, strictly marine species of the eastern North Atlantic. The two genera of marine tubesnouts, *Aulorhynchus* and *Aulichthys*, of the eastern and western North Pacific, respectively, are very similar in appearance to *Spinachia*. Relationships among these fishes were studied on the basis of behavior by McClennan et al. (1988) and protein analysis by Hudon and Guderly (1984), with incongruent results.

Genus *Culaea* Whitley

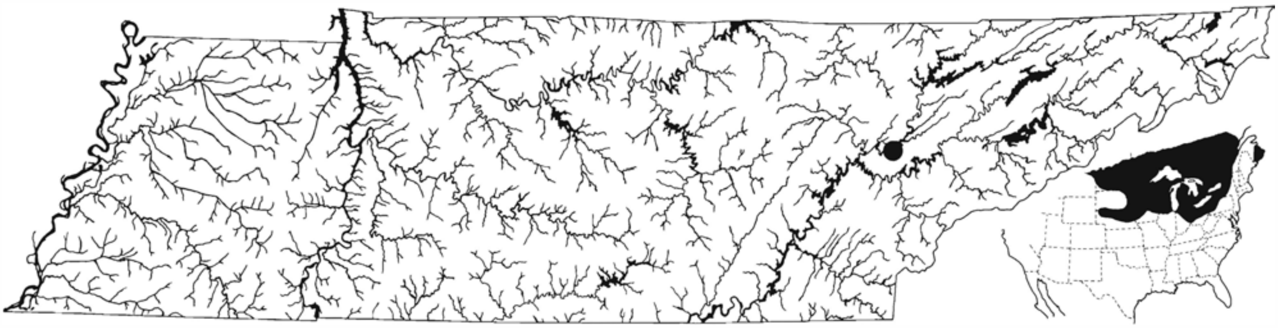
This genus contains a single species, the brook stickleback, long known as *Eucalia inconstans* (Kirtland). A change in the generic name was necessitated when it was discovered that *Eucalia* was also in use for a genus of nymphalid butterflies, and that usage had priority (Whitley, 1950; Bailey and Allum, 1962).

Culaea inconstans (Kirtland)

Brook stickleback

Plate 176. *Culaea inconstans*, brook stickleback, 32 mm SL, pond, Oak Ridge National Laboratory, TN.

Characters: Lateral line complete. Body appearing naked, but with weakly developed bony plates along sides. Dorsal fin with modally 5 (2–7) spines and 10 (8–13) soft rays. Anal fin with a single spine and modally 10 (7–12) rays. Pectoral fin rays 9–11. Pelvic fin with 1 spine and 1 ray. Principal caudal fin rays 12 (11–13). Branchiostegal rays 3. Gill rakers 11–13. Vertebrae 29–35. Coloration dark olive with dark reticulations around paler areas posteriad. Breeding males dark with copper or orange tinges.



Range Map 171. *Culaea inconstans*, brook stickleback (native range, shown in inset, extends north to Hudson Bay and northwest through Alberta and the Mackenzie River drainage of Northwest Territories).

Biology: Brook sticklebacks occur in streams, swamps, bogs, and the vegetated bays of larger lakes throughout much of north central North America. Along with central mudminnows (*Umbra limi*) and fathead minnows (*Pimephales promelas*), they are capable of occupying many of the shallow, organic lakes of this region whose dissolved oxygen concentrations are seasonally too low to support other fishes. Biological information, and much of the above morphological information, is summarized from Scott and Crossman (1973) and Wooten (1976). Spawning occurs from April to July, depending on latitude, at water temperatures of 8–19 C (46–66 F). Males are territorial and construct spherical nests, about 2 cm in diameter, composed of strands of plant material which are attached to the vertical stems of rooted aquatic plants by means of the male's kidney secretions. Males, which darken during the breeding season, nudge, prod, and chase females until they enter the single opening into the nest. After eggs are deposited and fertilized, the female forces her exit through the opposite side of the nest from her entrance. This second opening is often repaired by the male, and subsequent spawning with additional females may occur. Males may also construct an additional nest after responsibilities to the first nest are completed. Fecundity is 40–250 or more eggs, which hatch in 8–9 days at 18 C (65 F). The male defends the nest, eggs, and developing young until they are ready to leave the nest. Sexual maturity is reached by near the end of the first year, and life span is about 3 years. In Wisconsin, total lengths of 35–58 mm are reached the first year and 56–63 the second (Becker, 1983). Food consists of small crustacea, insect larvae, snails, small annelids, water mites, and fish eggs. Maximum total length 87 mm (3.5 in).

Distribution and Status: Freshwater habitats of northern North America east of Rocky Mountains. The southern extent of the brook stickleback's range ends well to the north of Tennessee in southern Indiana and Ohio, but this species commonly occurs in small numbers in shipments of bait minnows (*Pimephales promelas*, the fathead minnow, or "tuffy," locally) from the Midwest. Specimens presumably released from bait buckets or escapees from holding ponds are encountered occasionally in waters in and adjacent to Tennessee (e.g., Smith-Vaniz, 1968), but established populations are few. We know of past occurrences in the Obey River near Celina (D. Albaugh, pers. comm.), and an "accidental" population is currently established in ponds and creeks of the White Oak Creek system near Oak Ridge in Roane County (Ryon and Loar, 1988). In the past, a TWRA ruling prohibited import of brook sticklebacks into Tennessee, based on the potential hazard their sharp spines pose to game fishes such as largemouth bass. This ruling is no longer in effect, and any ill effects on game fishes preying on them are surely minimal, since they serve as forage for many midwestern piscivores.

Similar Sympatric Species: Their unique combination of characters makes it unlikely that sticklebacks would be confused with any other Tennessee fishes.

Etymology: *Culaea* is apparently a meaningless anagram formed from letters contained in the earlier generic name, *Eucalia*; *inconstans* = variable.

FAMILY COTTIDAE

The Sculpins

The sculpins (Cottidae) are a large family of primarily northern-hemisphere marine fishes occurring in cooler waters around the world. Cottoid fishes are provisionally considered a suborder of the scorpaeniform fishes which includes many families of rather large-headed fishes generally having spiny fins and spiny armature about the head (Nelson, 1984). Some workers (e.g., Berg, 1940) have included scorpaeniform fishes with perciform fishes, but recent classifications (e.g., Nelson, 1984) place them in a broader grouping, the series Percomorpha, along with perciform, beryciform, gasterosteiform, and some other acanthomorph (spiny-rayed) fish orders. Sculpins attain maximum diversity in the northern Pacific Ocean. They are characterized by large heads, which often bear spiny armature, large mouths, and large dorsally placed eyes. With a few exceptions, the body is usually somewhat dorsally depressed and tapers rapidly from the head. Spinous and soft dorsal fins are present as well as a spineless anal fin. Pectoral fins are large; the pelvic fins bear a single spine and 2–5 soft rays. Most species are scaleless or nearly so, and their mucous covering results in a slippery texture. A lateral line is present. The circumpolar genus *Cottus* is strictly confined to fresh waters of North America and Eurasia. Freshwater fossils similar to *Cottus* date at least to the Miocene (Cavender, 1986). Members of other genera occasionally enter fresh waters in North America but are mostly confined to marine habitats. One exception is the genus *Myoxocephalus*, which inhabits deep northern lakes.

Genus *Cottus* Linnaeus

Most nominal species of *Cottus* occur in the northwestern United States. In the East, in addition to the species (or species complexes) occurring in Tennessee, *C. hypselurus* is distributed in Ozark uplands, *C. girardi* is restricted to the Potomac drainage, the tiny *C. pygmaeus* to a single spring in the Coosa system of Alabama, and the widely distributed boreal species *C. ricei* and *C. cognatus* extend to the northeastern states with the latter occurring southward to Virginia. *Cottus* is characterized by relatively reduced armature of the head (usually 3 preopercular spines of which only the upper is prominent). Villiform teeth are present on the jaws, head of the vomer, and may or may not be present on the palatine bones (Fig. 127a,b). The flaring gill covers are separated by a wide isthmus. There are 6 branchiostegal rays. Gill rakers are vestigial. Many members of the genus inhabit swift waters. Their flattened bodies and large oblique pectoral fins serve as excellent hydrodynamic adaptations to this environment, as the sculpin's body tends to be pressed to the bottom by the flow of water overhead, thus aiding in maintenance of position. Nonbuoyancy is also facilitated by the lack of a swimbladder. Sculpins are capable of consuming prey nearly as long as themselves. There is considerable evidence that sculpins feed heavily at night (Starnes and

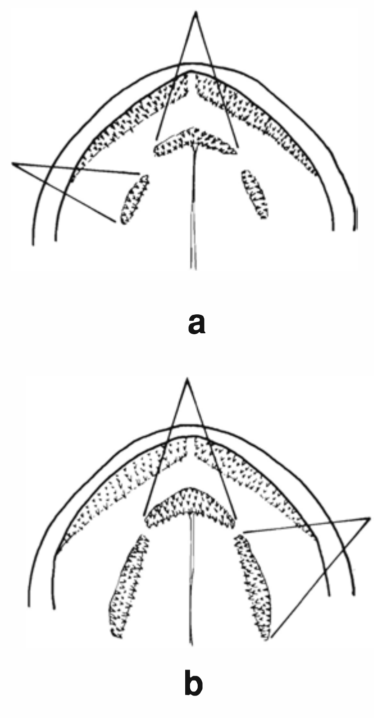


Figure 127. Palatine and vomerine teeth in Cottus: a) *C. bairdii;* b) *C. carolinae.*

Starnes, 1985; Greenberg and Holtzman, 1987). Stream anglers using bait such as worms occasionally catch sculpins, and they are sometimes used as bait, particularly for brown trout. Sculpins have a variety of local names including "hog molly," "cod molly," and "mud molly," and were known to early ichthyologists as "blob."

The taxonomy of southeastern members of the genus *Cottus* remains a perplexing problem. According to Robins (1954), two basic species complexes occur in the region, the *C. bairdii* and *C. carloinae* groups, but this concept has been recently questioned based on biochemical data (Strauss, 1988). Variation of many characters is great between populations in both of these putative groups, creating difficulty with identification of species and supposed subspecies. Robins' two groups can be separated on two characters. In the *bairdii* group, males have a relatively wide red marginal and a black basal band in the spinous dorsal fin, and the body becomes darkened during the breeding season; these traits are less pronounced or lacking in members of the *carolinae* group. Body shape also serves to separate these groups fairly reliably but requires a trained eye. All other characters which have been employed by previous workers, including palatine dentition, preopercular armature, lateral-line development, saddle pattern, number of pectoral fin rays, and chin and body pigmentation greatly overlap in various combinations between certain populations and thus will not serve to reliably separate these forms on a range-wide basis; however, they can be useful in comparing specimens from within a given system. Some additional characters (see Key) can aid in separation but are tenuous generalizations at best. It may therefore be difficult for the beginning student of fishes to place certain specimens (especially females) in either species group with confidence, though others may be fairly "typical" and thus relatively easy to identify. Careful reading of the keys, systematic notes, and discussions of similar sympatric species which follow should facilitate accurate identification of most sculpin specimens from Tennessee to at least the species group level.

The systematics of sculpins occurring in Tennessee has been under study by several workers, including C. R. Robins, R. E. Jenkins, R. E. Strauss, and J. D. Williams. Hopefully their efforts will result in a better understanding of these perplexing fishes. Since much of our Tennessee material is currently on loan, our review of variation in this area is very incomplete and in need of refinement.

Etymology: *Cottus* = an old name for miller's thumb, the common name given to these fishes in Europe.

KEY TO THE SPECIES GROUPS OF TENNESSEE COTTUS

1. Nuptial males with dark bodies and a wide red marginal and black basal band in spinous dorsal fin (Pl. 177); dorsal dark saddles usually indistinct and not darker near edges; dark chin pigment uniformly distributed; small brown spots abundant on upper sides and back; pectoral fin rays modally 15 except in Doe River of Watauga-Holston system, French Broad system, and lower Little Tennessee and Hiawassee systems; maximum size rarely larger than 80 mm SL; palatine teeth absent or length of tooth patch less than width of prevomerine tooth patch (Fig. 127a) . . . . *Cottus bairdii* group

   Never with contrasting red marginal and black basal band in spinous dorsal fin (Pl. 178); dorsal dark saddles narrow, distinct, and typically darker at edges; dark chin pigmentation blotchy; brown spots absent or nearly so from upper sides and back; pectoral fin rays modally 16 or 17 except in Conasauga River, where *C. bairdii* does not occur; maximum size up to 140 mm SL; length of palatine tooth patch equal to or greater than width of prevomerine tooth patch (Fig. 127b) . . . . *Cottus carolinae* group p.386

Cottus bairdii Girard

Mottled sculpin (group)

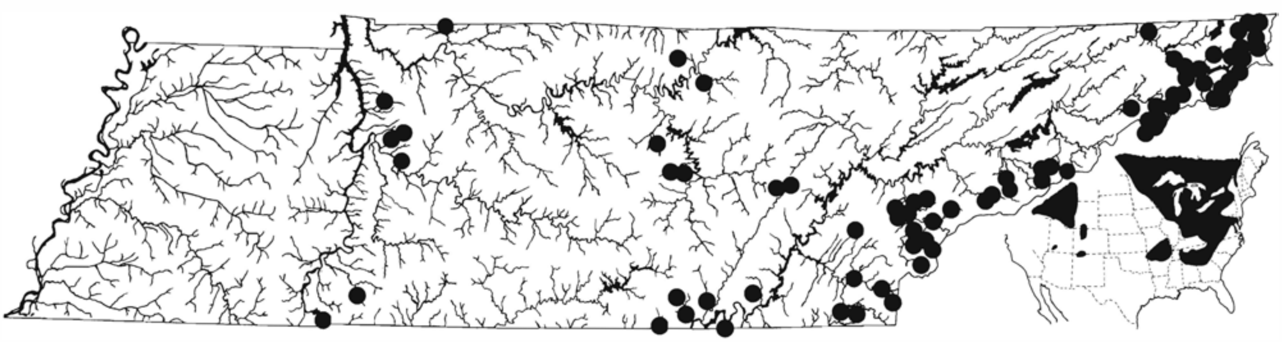
Characters: Lateral line usually incomplete except in many upper Holston, Little, Little Tennessee, and Hiwassee river main channel populations; pores 18–34. Dorsal fin with 7–8 (6–9) spines and 16–18 (15–18) soft rays. Anal fin rays 12–14 (11–14). Pectoral fin rays 14–16 (14–17), modally 15 except as noted in Key. Principal caudal fin rays 10–11 (9–12). Palatine teeth range from well developed (Fig. 127a) to absent. The preopercular spines are generally reduced and concealed beneath skin, the lower 2 curved downward and difficult to detect. Pigmentation highly variable, with

Plate 177. *Cottus bairdii,* mottled sculpin, 65 mm SL, Caney Fork R. system, TN.

dorsal saddles usually as wide as or wider than interspaces and indistinct, but occasionally narrower and more distinct, approaching those typical of *C. carolinae*. Red marginal and black basal bands in spinous dorsal fin are most apparent in nuptial males, but are somewhat evident in adult males throughout the year. Ground color of body varies with the environment and can range from coppery brown to slate grey, and approaches black in nuptial males.

Biology: The various forms of *C. bairdii* occur in several habitat types, including quiet springs and small creeks to high-gradient montane rivers. They have also adapted to some cool tailwater habitats below reservoirs. They are generally found in the faster-current areas within these habitats and are associated with rubble or boulder substrates where their cryptic coloration serves to conceal them from predator and prey alike. In rivers where they occur with the banded sculpin, mottled sculpins usually predominate in more upstream reaches with gradient having been suspected as a chief determining factor (Abrahamsen, 1978). In Tennessee, spawning occurs from mid March through mid April (Nagel, 1980; Reagan and West, 1985; R. E. Jenkins, pers. comm.) at water temperatures of 12–14 C. Both Nagel (1980) and Reagan and West (1985) reported that our populations have lower fecundity (30–110, mean about 60 ova per female), larger eggs (3–3.3 mm diameter), and larger hatchlings (9.8 mm TL) than reported for most northern and western populations. Males select nest sites beneath stones or ledges in riffles, and several females may contribute to the clutch of a single nest (Bailey, 1952; Savage, 1963). Courtship involves various quick head movements by the male, and frequently the male bites the approaching female on the cheek or pelvic fin, or engulfs her head and pulls her into the nest cavity (Savage, 1963). Males remain in the vicinity of the nest, apparently maintaining it by removal of debris and fungused eggs until hatching (Bailey, 1952). Eggs hatch in about 2–3 weeks (Hann, 1927; Rohde and Arndt, 1982). Average standard lengths of fall specimens in our collection are about 35, 52, and 58 mm at ages 0+, 1+, and 2+, respectively. Sexual maturity occurs at age 2, males are larger than females, and life span may be as much as 6 years in our area (Nagel, 1980; Reagan and West, 1985). Sculpins apparently feed mainly by ambush tactics rather than active foraging (Starnes, 1977). Facilitated by their large mouths, they feed on relatively large prey such as immature caddisflies, mayflies, stoneflies, and midges; and adults consume occasional crayfish, small fishes, and fish eggs (Koster, 1937; Dineen, 1951; Bailey, 1952; Daiber, 1956; Rohde and Arndt, 1982). *Cottus bairdii* and other species have been implicated as potentially having negative impacts on salmonid populations due to predation on eggs and larvae, but these are believed to be largely unfounded (Moyle, 1977). Maximum size about 92 mm SL (= 114 mm TL, or 4.5 in) from Nolichucky River system, but usually less than 80 mm SL. Northern specimens may be somewhat larger.

Distribution and Status: *Cottus bairdii* is widespread in the eastern half of North America from Arctic Canada south where cool streams with rocky substrates



Range Map 172. *Cottus bairdii,* mottled sculpin (range extends off inset to southern Alberta and British Columbia, and in northcentral portion of range to Hudson Bay, northern Quebec, and Labrador).

are present, including the Great Lakes area, the Ozarks, much of the Mississippi Basin, many Atlantic Slope drainages, and in the Mobile Bay drainage of the Gulf slope. Populations also occur in western North America on both sides of the Continental Divide. In Tennessee it is widespread in the Tennessee drainage from the headwaters downstream to the Pickwick Reservoir area, and much less common in the remainder of the Tennessee and in the Cumberland drainage. It is absent from the Conasauga and Barren river systems and from the area west of the lower Tennessee River.

Similar Sympatric Species: All Tennessee populations are included within the general range of the very similar *Cottus carolinae*, and the two are often sympatric. We can offer little besides characters included in the key to the species groups, but have noted a subtle difference in body shape, with *C. bairdii* tending to be more streamlined (tapering more gradually from a rounded head to a relatively less slender caudal peduncle) while *C. carolinae* have a more triangular head, an abruptly narrower body, and a more slender caudal peduncle. A thumb or forefinger gently slid forward along the side of the head typically "hooks" the more prominent upper preopercular spine of *C. carolinae*, but meets no resistance in *C. bairdii* but fixative-induced differences in position of gill cover bones causes considerable variation. Even the most experienced sculpin workers make occasional errors of identification, especially where the taxa are sympatric.

Systematics: In his dissertation, Robins (1954) provided descriptions of subspecies of *C. bairdii,* as yet unpublished, from the Tennessee River drainage and upper Coosa system; his description of *C. baileyi* of the *C. bairdii* group was subsequently published (Robins, 1961). *Cottus baileyi* has been generally recognized as a valid species by subsequent workers. Robins regarded the nominate *C. b. bairdii* as occuring in the lower bend of the Tennessee River and characterized it as having moderately developed palatine teeth (Fig. 127a) and an incomplete lateral line. Our specimens from Highland Rim tributaries to the lower Tennessee River generally fit this description, but many specimens from the Sequatchie system virtually lack palatine teeth. A second subspecies, having the palatine teeth as well developed as in *C. carolinae* and a more or less complete lateral line, was described from larger montane rivers in the Blue Ridge region from the French Broad southward through the Hiwassee system as well as from the Mobile and Savannah drainages. These are easily confused with *C. carolinae*. We have noted considerable interpopulation variation in lateral-line development in these, and main-channel Hiwassee specimens have a mode of 16 pectoral fin rays (as in *C. carolinae*), as do at least some Little Tennessee River populations. Representatives of the *Cottus bairdii* group from small streams in the Cumberland drainage have moderately to well-developed palatine teeth and very incomplete lateral lines.

An additional subspecies was described from the Holston portion of the upper Tennessee drainage of Virginia and extreme eastern Tennessee and characterized as having reduced palatine teeth ("small oval patch") and a complete lateral line. In their extensive analysis of Virginia *Cottus*, R. E. Jenkins and N. M. Burkhead (in press) consider this form to represent a valid species, with considerable reservation, and report it from the extreme upper Clinch River and from the Bluestone River of the New River system (Ohio drainage). *Cottus baileyi* (Robins, 1961) was also described from the Holston system (reported from Laurel and Little Doe creeks, Tennessee) and characterized as lacking palatine teeth and having an incomplete lateral line. However, specimens examined from the Holston system (including Robins's localities for *baileyi*) exhibit a full range of these characters within certain populations, and are not separable by us from many specimens from the Sequatchie and other Tennessee River tributaries in the Chattanooga area. *Cottus baileyi* continues to be recognized as valid by Jenkins and Burkhead for Virginia portions of the Holston, but its validity in Tennessee is certainly questionable. This inconsistency of characters is indicative of the chaotic state of sculpin systematics in the region and in general and renders it difficult to impossible at this time to regard the *bairdii* species group either as one or two polymorphic species or as a complex of cryptic species until further exhaustive research, perhaps incorporating biochemical and molecular techniques, has been accomplished on a region-by-region basis.

Etymology: *bairdii* is a patronym for Spencer F. Baird, first U.S. fish commissioner and prominent ichthyologist during the middle 1800s.

Cottus carolinae (Gill)

Banded sculpin (group)

Characters: Lateral line usually complete, but often to typically incomplete in the Conasauga River system, Tennessee River tributaries from the Little Tennessee River system downstream through the Sequatchie River,

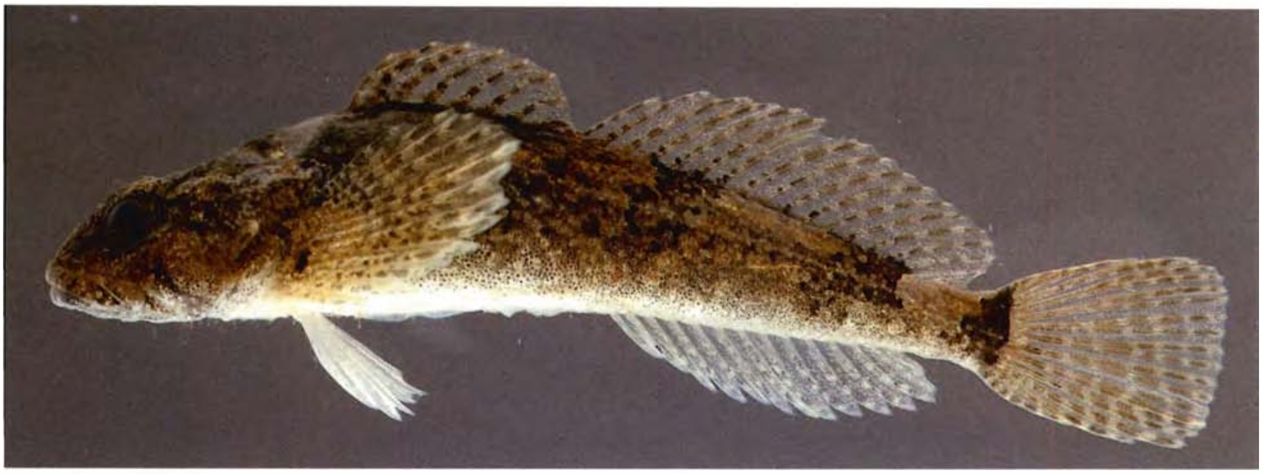
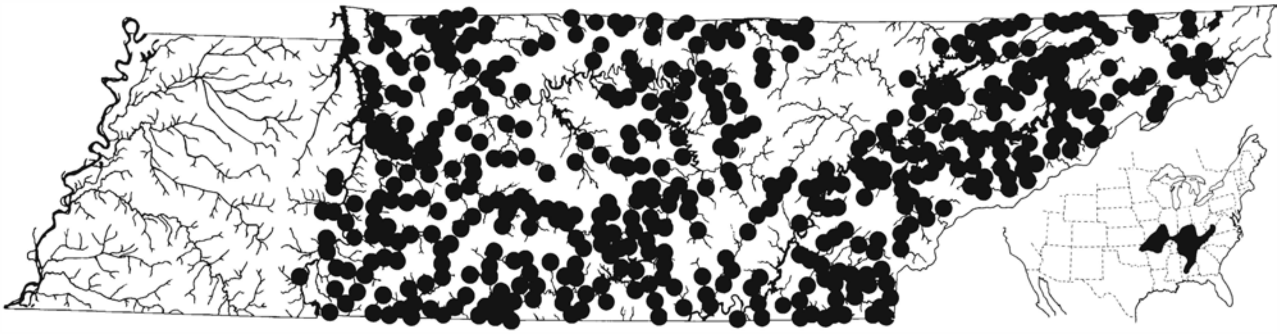


Plate 178. *Cottus carolinae*, banded sculpin, 71 mm SL, Conasauga R., TN.

and in many spring habitats from elsewhere in the Tennessee drainage; pores 24–37. Dorsal fin with 7–8 (6–9) spines and 15–18 (15–19) soft rays. Anal fin rays 12–14 (11–16). Pectoral fin rays 15–17 (14–18), 14–16 (13–16) in Conasauga River system. Principal caudal fin rays 10–12 (9–12). Palatine teeth always well developed and usually contiguous with vomerine tooth patch (Fig. 127b). Upper preopercular spine prominent but lower ones generally concealed beneath skin. Ground color most often rusty brown with four dark dorsal saddles, at least the posterior three of which are typically distinct. Color of body variable depending on substrate and water clarity (see Biology). The edge of the spinous dorsal fin is rust colored like the body but may be tinged with red in some spring habitats. Chin mottled with dark pigment.

Biology: The banded sculpin inhabits streams of all dimensions, is equally common from small springs to large upland rivers, and is frequently found in caves. It frequents riffle areas, living over gravel or rubble where its contrasting dark and pale dorsal pattern provides excellent camouflage. Small young occur in quiet shallows and detritus-strewn areas. In rivers where both species occur, banded sculpins usually predominate in more downstream, lower gradient reaches than mottled sculpins (*C. bairdii*) (Abrahamsen, 1978). Color changes to match the substrate such that specimens from chert gravel streams may be predominantly brown, chalk white, or pale green, while those from streams with other types of gravel may be a more typical rusty brown with dark saddles. The biology has not been as well studied as that of *C. bairdii.* Spawning occurs beneath stones or other objects where the eggs are deposited in winter and early spring in large clumps and the male guards the nest (J. D. Williams, pers. comm.). Most females involved in reproduction are 2 or more years old. Fecundity averages 475 ova per female (Craddock, 1965). Growth in Kentucky populations studied by Craddock was highly variable, with total lengths at ages 1–3 being 50–80 mm, 100–130 mm, and over 160 mm, respectively; maximum life span was estimated as 4 years. Large collections from Tennessee appear to have as many as six distinct length classes. Banded sculpins feed by stalking or ambushing prey, making effective use of their cryptic coloration (Starnes, 1977), and apparently feed most heavily at night (Starnes and Starnes, 1985). The diet of young banded sculpins contains aquatic insect immatures of many kinds, including caddisflies (especially hydropsychids), mayflies, and midge larvae. Adults prefer larger prey such as larger stonefly nymphs (pteronarcids, perlids, larger perlodids) and maturing stages of other insects, occasional small fish, especially other benthic riffle species such as darters (Starnes, 1977), as well as salamanders and crayfish. Small (1975) also reported isopods and water penny beetle larvae (Psephenidae) as important in the diet. Maximum total length 185 mm (7.25 in).

Distribution and Status: Banded sculpins are widespread and common throughout the Ozark region, the Tennessee and Cumberland river drainages, and the Mobile Basin both above and, less commonly, below the Fall Line. They also occupy the Ohio River drainage from its mouth to its southern headwaters (New River system), but are absent from much of the northern portion of the Ohio drainage. They occur throughout east and middle Tennessee, but are absent from direct tributaries to the Mississippi River in west Tennessee.



Range Map 173. *Cottus carolinae*, banded sculpin.

Similar Sympatric Species: See comments under *C. bairdii.*

Systematics: Robins (1954) discussed variation and subspeciation in the *Cottus carolinae* species group. The nominate subspecies, *C. c. carolinae*, characterized by a heavily mottled chin, complete lateral line, and modally 16 or 17 pectoral fin rays, occurs in upland streams of central United States including most of Tennessee. *Cottus c. zopherus* (Jordan), reportedly having overall darker coloration and more extensive belly pigmentation, fewer pectoral fin rays (modally 15), and an incomplete lateral line (mean of 28.2 vs. 32.9 pores), is a Coosa River system endemic (Williams and Robins, 1970) which occurs in the Conasauga River system in Tennessee. Our specimens from the Conasauga tend to have more complete lateral lines than is typical for *zopherus*. According to Robins (1954), *C. c. carolinae* x *C. c. zopherus* intergrades occur in the Hiwassee and adjacent systems in the Tennessee River drainage. However, banded sculpins in Tennessee River tributaries from Little Tennessee River downstream through Sequatchie River are like *zopherus* in often having incomplete lateral lines, but show no reduction in pectoral fin ray counts and have more anal fin rays (modally 13 or 14) than from elsewhere in Tennessee. It seems equally likely that these populations with incomplete lateral lines and high anal fin ray counts have evolved independently of *zopherus*. A second subspecies (unpublished) was described by Robins (1954) from spring-like habitats of the Kanawha system (Ohio drainage) in Virginia with an isolated outlying population listed from a spring tributary (Mossy Creek) to the Holston River in Jefferson County, Tennessee. It is characterized by an incomplete lateral line, reduced chin pigmentation, and a hint of a narrow red marginal band in the spinous dorsal fin. Specimens examined by us from some other spring habitats in the upper Tennessee drainage generally fit this description, suggesting that this form may be more widely distributed in such habitats than first thought. Robins (1954) felt that this form was a relict representation of the original *C. carolinae* stock which inhabited the eastern portions of the Tennessee drainage (and crossed the divide into the Kanawha) which had been supplanted or swamped by *C. c. carolinae* stock dispersing from the west. The original stock was felt to be better adapted to spring habitats and thus persisted there. An examination of spring populations of *C. carolinae* throughout its range would perhaps support this theory or alternately indicate ecophenotypic convergence between these isolated populations throughout the range. An additional subspecies, *C. c. infernatis*, occurs in the Mobile Basin below the Fall Line (Williams and Robins, 1970).

Etymology: Named in honor of Miss Caroline Henry, "estimable young friend" of the species' describer, Theodore Gill.

ORDER PERCIFORMES

In all recent classifications, all families following herein are included in the huge order Perciformes along with about 150 to 200 (depending on authority) additional families of spiny-rayed (acanthomorph) fishes which are generally characterized by having both spiny and soft dorsal fins, anteriorly positioned pelvic fins with 1 spine and 5 rays, usual presence of ctenoid scales, and several other features. However, none of these characteristics is unique to families included in the group, and it may not be a natural one, with its members possibly having evolved from within the presumably related beryciform fishes in several different lineages (polyphyletic). All of these fishes and several other spiny-rayed groups, such as Scorpaeniformes, Gasterosteiformes, and a few other groups are known collectively as "percomorph" fishes. The closest relatives to this group may lie among the atherinomorph (silversides, topminnows, etc.) fishes (e.g., Stiassny, 1990). Perciformes is therefore a strictly provisional grouping until relationships among these fishes are better understood. As such, it contains about one-third of all fish species in the world. The suborder Percoidei contains about 70 of the "lower" or more generalized perciform families, including all those herein. This suborder is an equally provisional grouping with poorly understood relationships (Johnson, 1984). This group is best represented in the near-shore marine environment in addition to the few freshwater families.

FAMILY MORONIDAE

The Temperate Basses

Moronidae is a small family containing anadromous, euryhaline, and freshwater species in North America, Europe, and Africa (genus *Morone*), the anadromous *Dicentrarchus* of European waters, and the Asian euryhaline species of the genera *Lateolabrax* and *Coreoperca* (Johnson, 1984). Most classifications (i.e., Greenwood et al., 1966; Nelson, 1984; and others) have grouped these fishes, along with such fishes as the giant sea bass (*Steriolepis*), several less well-known marine genera, and fishes belonging to south temperate freshwater genera of South America and Australia in the family Percichthyidae (sensu Katayama, 1960; Gosline, 1966). However, Johnson (1984) held that this group is not a natural one, restricted Percichthyidae to *Percichthys* and relatives in South America (see Arratia, 1982) and several Australian genera, and recognized the family Moronidae as restricted above. The family contains two of our more important freshwater game fishes, the white and yellow basses, as well as the highly esteemed anadromous striped bass which now has introduced landlocked populations. A popular food fish, the mostly brackish water white perch (*Morone americana*) of the Atlantic seaboard, is also a member of this family. It has been introduced to some inland waters, e.g., in Nebraska (Hergenrader and Bliss, 1971), and has invaded lakes Ontario and Erie via the St. Lawrence Seaway (Boileau, 1985) where it is occasionally hybridizing with white bass.

Genus *Morone* Mitchill

The Striped Basses

The genus *Morone* is a small one containing the three species accounted from Tennessee, the white perch, *M. americana*, and two Old World species, *M. labrax* and *M. punctata* occurring in Europe and northern Africa. All members of the genus have relatively deep bodies, complete lateral lines, two well-defined dorsal fins (the first with 9 spines, the second with 1 spine and 10–14 soft rays), 3 anal spines, pelvic fins with 1 spine and 5 rays, 17 principal caudal fin rays, 7 branchiostegal rays, an opercular spine, a finely serrate preopercle, jaws with rows of close-set, conical (villiform) teeth, and mostly ctenoid scales on the entire body and most of the head. All members of the genus are inhabitants of large bodies of water such as rivers and reservoirs or coastal environments. They are piscivorous schooling fishes and are among the top level carnivores in their respective habitats. From the mid 1950s to the 1960s, fishes currently assigned to the genus *Morone* Mitchill were referred to in the literature as *Roccus* Mitchill, but the priority of *Morone* was reestablished by Whitehead and Wheeler (1967).

Etymology: Unknown.

KEY TO THE TENNESSEE SPECIES

1. Second anal spine longer than anal fin base and much thickened, extending beyond base of last anal fin ray when depressed (Fig. 128a); tip of lower jaw not protruding .... *M. mississippiensis* p.392

   Second anal spine shorter than anal fin base, slightly thickened, not reaching to base of last anal fin ray when depressed (Fig. 128b); tip of lower jaw protrudes past upper jaw except in very small specimens 2

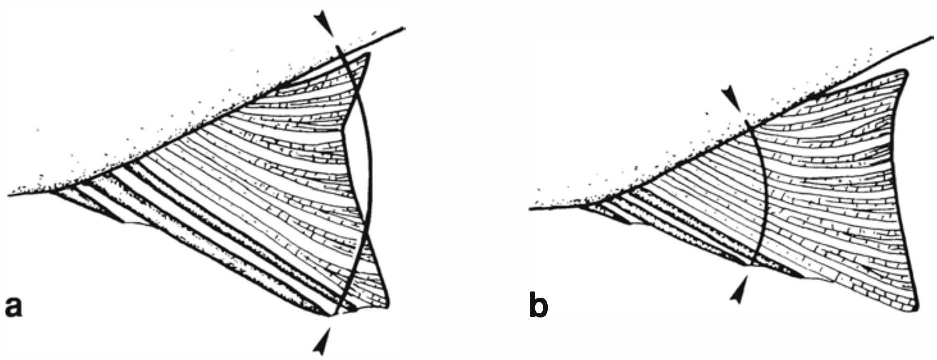


Figure 128. Anal fin spine lengths relative to anal fin lengths in *Morone* spp.: a) *M. mississippiensis*; b) *M. chrysops* and *M. saxatilis*.

2. Dorsal fin soft rays usually 12; adults more elongate (body depth less than 33% of SL), the dorsal profile little arched; tongue with two patches of teeth basally, each of which is more than half the length of the patch of lateral tongue teeth (Fig. 129a); juveniles (up to about 150 mm TL) with narrow, dark, vertical "parr marks" on sides .... *M. saxatilis* p.394

   Dorsal fin soft rays 12–14; adults deeper (body depth over 33% of SL), the dorsal profile well arched; tongue with a single patch of teeth basally or with two narrowly separated patches whose length is only half that of the patch of lateral tongue teeth (Fig. 129b); juveniles never with "parr marks" .... *M. chrysops*

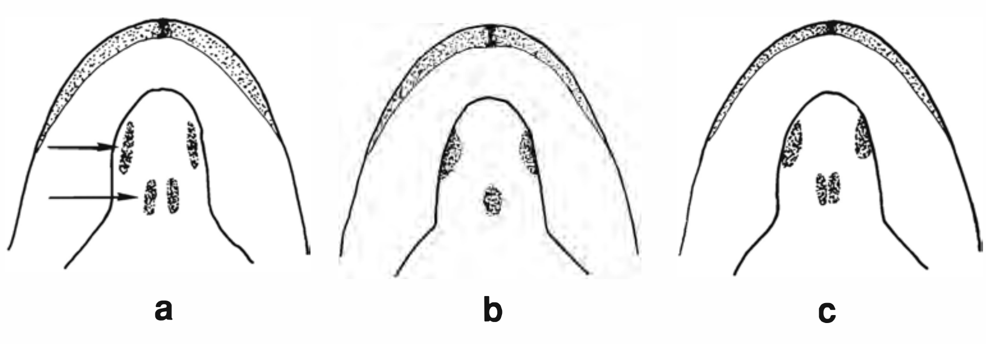


Figure 129. Tooth patches on tongues of *Morone* spp.: a) *M. saxatilis*; b) *M. chrysops*; c) *M. chrysops* x *saxatilis* hybrid.

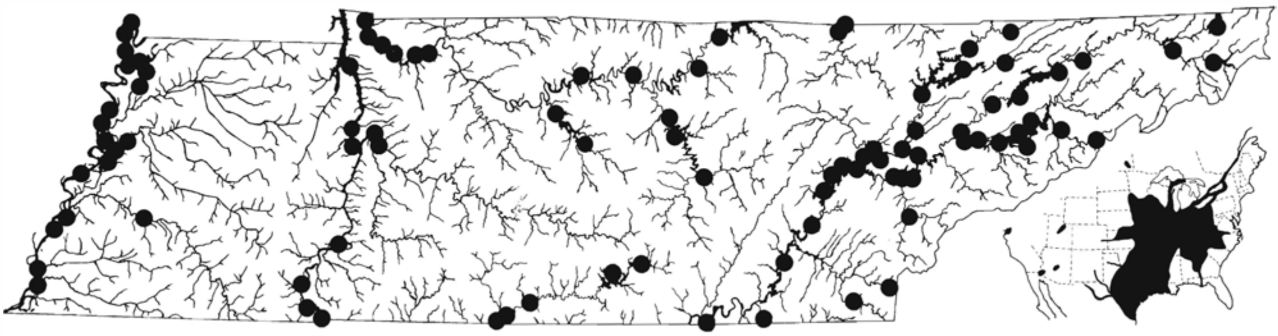
Morone chrysops (Rafinesque).

White bass

Characters: Lateral-line scales 51–60. Dorsal fin rays 12–14. Anal fin rays 11–13. Pectoral fin rays 15–17. Gill rakers 20–25. Vertebrae 24. Other counts typical for genus. Tongue with conspicuous teeth (Fig. 129b) near tip, laterally, and in one fused or two narrowly separated patches basally on basihyal bone (Waldman, 1986). Color silvery gray to steel blue dorsally and white to pale green laterally, with intense black horizontal stripes on sides that may be less distinct in specimens from turbid water; the lower stripes may be represented by scattered dots. Eye often with a yellowish tint.

Biology: The white bass, which is locally called "stripe," therefore creating some confusion with the introduced striped bass or "striper" (*M. saxatilis*), is an inhabitant of all larger rivers in Tennessee as well as natural lakes and reservoirs. Spawning runs are made into accessible rivers beginning in mid February with males migrating to the spawning grounds first (Webb and Moss, 1968). Many thousands of eggs (fecundity averages about one-half million ova/female) are strewn about as spawning occurs in midwater with several males attending a single female (Riggs, 1955; Baglin and Hill, 1977). Natural hybridization with yellow bass (*M. mississippiensis*) has been reported in Texas (Fries and Harvey, 1989), with white perch (*M. americana*) in Lake Erie (Boileau, 1985; Todd, 1986), and possibly with striped bass in Arkansas (Crawford et al., 1984). The demersal eggs are adhesive and sink to the bottom, becoming attached to objects, and hatch about 2 days later. Larvae begin to appear in Tennessee spawning rivers in March and persist into May (TVA data). These larvae drift downstream where later stages of development occur. There is evidence that larvae utilize low-velocity refugia or hug the bottom rather than being passively transported downstream at average current velocities (Starnes et al., 1983). Growth is rapid. In Center Hill Reservoir an average of 212 mm TL was reported at age 1, 364 at 2, 401 at 3, and 426 at 4 (Webb and Moss, 1968). This considerably exceeds estimates for more northerly populations in Iowa and New York, but fish in these populations are longer lived, up to 8 years (Sigler, 1949; Forney and Taylor, 1963). Most fish reaching adulthood in southern populations live only about 4 years. The diet of juveniles consists mainly of small invertebrates such as cladocerans, copepods, and midge larvae (Voigtlander and Wissing, 1974). Adults are highly piscivorous, feeding heavily on shad, silversides, and occasional young sunfish. Insects and crayfish are also important in the diet at times (Swor, 1973). Two to four daily peaks in feeding activity occur, varying seasonally (Olmsted and Kilambi, 1971). Schools of white bass occasionally attack schools of forage fish, causing a great commotion at the surface, termed "the jumps" by local anglers. Casting jigs, spinners, or plugs into these feeding frenzies when the opportunity presents itself can be very productive. The white bass is a popular sport and food fish. The flesh is of fair quality but may have a strong flavor. It is often taken in numbers in rivers above reservoirs during the spring spawning runs and is also abundant in tailwaters below dams. It strikes viciously at light-colored

Plate 179. *Morone chrysops*, white bass, 128 mm SL, Mississippi R., TN.



Range Map 174. *Morone chrysops*, white bass (both native and introduced populations are shown in inset).

jigs or spinners and is also taken on minnows. It provides a strong tussle when hooked. The white bass was formerly abundant in Reelfoot Lake where a commercial fishery existed, but it apparently succumbed to that fishery (Baker, 1937). Hybrids between the white bass and striped bass (*M. saxatilis*) have been stocked in many Tennessee reservoirs (see Comments under Striped Bass). World angling record 2.5 kg (5 lb 9 oz). Tennessee record is 2.3 kg (5 lb 2 oz) caught in Parksville Reservoir, 1989, Wade Parker.

Distribution and Status: Widespread in southern Great Lakes, Mississippi River basin, and Gulf Coastal drainages from Mississippi River west through Rio Grande. Widely introduced elsewhere. Common throughout Tennessee in reservoirs and large rivers.

Similar Sympatric Species: Occurs throughout much of its range with the yellow bass (*M. mississippiensis*) and in several reservoirs with the introduced striped bass (*M. saxatilis*), which are usually separable on characters given in the Key. In addition, the interrupted and poorly aligned lower lateral stripes of the yellow bass are distinctive. The striped bass x white bass hybrid (Pl. 182) also may have broken and poorly aligned lateral stripes but is distinguished from the yellow bass by the relatively shorter second anal spine which does not reach the base of the last anal fin ray when depressed. In juveniles 150 mm TL or less, yellow bass, striped bass, and the above hybrid have conspicuous "parr marks" on the sides that are absent in *M. chrysops*. White bass x striped bass hybrids are most similar in body configuration to white bass, being relatively deep-bodied. They can usually be distinguished from white bass by the more irregular and slightly broader lateral stripes and the presence of two well-separated basal tooth patches on the tongue (Fig. 129c) as opposed to a single patch.

Waldman (1986) has cast some doubt on the validity of tongue dentition in separation of white and striped bass and their hybrids, finding variation in this condition in white bass. However, white bass specimens examined by Williams (1978) and Kerby (1979) had single patches and, in specimens greater than 100 mm TL examined by us, the two basal patches possessed by smaller juveniles had fused into one or had a hairline separation. Potential confusion is most likely in trying to distinguish progeny of backcrosses between hybrids and white bass which are apparently occurring in some populations, e.g., in Cherokee Reservoir (Avise and Van Den Avyle, 1984). The assorted phenotypes resulting from such backcrosses will be difficult to distinguish from parental species.

Etymology: *chrysops* = golden eye.

Morone mississippiensis Jordan and Eigenmann.

Yellow bass

Characters: Lateral line scales 49–55. Dorsal fin rays 11–12. Anal fin rays 9 (10). Pectoral fin rays 15–17. Gill rakers 18–22. Tongue without median tooth patch. Color brassy yellow dorsally and pale below with intense black lateral stripes. The lower stripes are usually interrupted and offset. Juveniles with faint "parr marks" on the sides. The eye may be yellow.

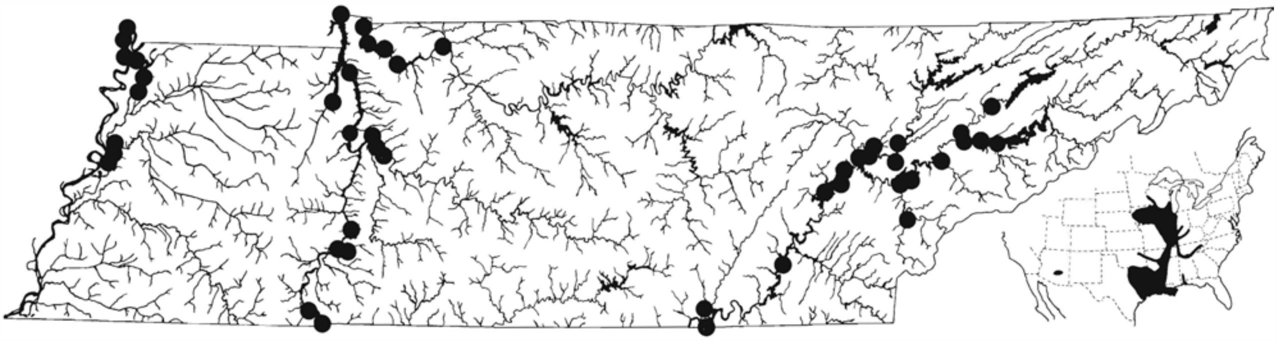
Biology: The yellow bass is an inhabitant of large sluggish rivers, overflow waters, and lakes. It is a schooling fish living in open water and seems to avoid lotic (flowing) habitats much more so than the white bass, and prefers clearer waters with vegetation. Spawning occurs in April and May with spawning runs into tributaries occurring in a manner similar to that of the white bass, and natural hybridization with the white bass has been

Plate 180. *Morone mississippiensis*, yellow bass, 200 mm SL, Reelfoot L., TN.

reported in Texas (Fries and Harvey, 1989). The eggs require a longer development period than those of the white bass, hatching in 4–6 days (Burnham, 1909). Growth of specimens from Reelfoot Lake, Tennessee (Schoffman, 1956) was as follows: "Age group 2" (third summer of life?), 195 mm TL; 3, 218; 4, 238; 5, 271; younger individuals were not sampled. This is roughly similar to growth reported in a Wisconsin population (Priegel, 1975). Both studies estimated maximum life span at 6 years. Apparent 1-year-old specimens in our collections from Reelfoot Lake average about 95 mm TL and 2-year-olds are only 125 mm. Young-of-year from Watts Bar Reservoir in eastern Tennessee were about 50 mm TL by late July. This is more comparable to growth reported in Iowa by Carlander et al. (1953). Food habits of yellow bass are similar to those of the white bass with young feeding on microcrustaceans and midge larvae and adults preying on fish such as shad and silversides (Welker, 1963). However, in some populations adults continue to feed heavily on aquatic insects (Kraus, 1963). The yellow bass is an important game species in Reelfoot Lake and other natural lakes of west Tennessee and may become increasingly important in the Tennessee River reservoir fishery as its numbers grow. It is caught by similar techniques as the white bass, and doubtless many fishermen will confuse these species. Maximum size 1.02 kg (2 lb 4 oz). Tennessee record .79 kg (1 lb 12 oz), Chris Henson, from Watts Bar Reservoir, 1990.

Distribution and Status: The yellow bass is native to Gulf Coastal drainages from Mobile Basin west to the San Jacinto River, Texas. It is less tolerant of turbid waters than is the white bass, as evidenced by its being supplanted in abundance by that species in the increasingly turbid streams of Illinois (Smith, 1979) and being more common in the Mississippi River above its confluence with the muddy Missouri River (Pflieger, 1975). In Tennessee, it is abundant in Reelfoot Lake and other clear natural lakes along the Mississippi River but is uncommon in the turbid main channel. Recently it has become common in main-channel reservoirs on the Tennessee River in eastern Tennessee, particularly Watts Bar. This is apparently a result of migration from the lower reaches of the river since impoundment, but *M. mississippiensis* may have been present in small numbers in prior years (Stroud, 1947; Starnes et al., 1982). Whatever the case, the creation of a more lentic (lake-like) habitat, coupled with increased water clarity, has apparently created a favorable habitat in which the yellow bass is beginning to flourish.

Similar Sympatric Species: Throughout its range, *M. mississippiensis* is sympatric with the white bass and also occurs in several reservoirs which have been stocked with striped bass (*M. saxatilis*). Key characters given separate the yellow bass from these species as well as the striped bass x white bass hybrid, which resembles the yellow bass because of its interrupted lateral stripes.



Range Map 175. *Morone mississippiensis*, yellow bass (both native and introduced populations are shown in inset).

Systematics: *Morone mississippiensis* Jordan and Eigenmann appeared in much literature prior to 1956 as *M. interrupta* Gill (or *Roccus interruptus*) which proved to be a junior synonym of *M. saxatilis* (see Bailey, 1956).

Etymology: *mississippiensis*, in reference to the Mississippi River.

Morone saxatilis (Walbaum).

Striped bass

Characters: Lateral line scales 57–68. Dorsal fin rays 12 (8–14). Anal fin rays 7–12. Pectoral fin rays 15–17. Gill rakers 20–29. Vertebrae 25. The two elongate parallel patches of teeth situated near the base of the tongue are each more than half as long as the patch of lateral tongue teeth, and teeth at the tip of the tongue are weak or absent. Color gray to steel blue above and white to pale green on the sides with dark lateral stripes.

Biology: The striped bass, or "rockfish" as it is most often called in Tennessee, is a large predatory species that was formerly strictly anadromous along the Atlantic and Gulf coasts, spending most of its life in bays and estuaries. It is an extremely important game and commercial species which has been intensively studied over the years. Comprehensive information on its biology and migrations is available (e.g., Merriman, 1941; Horseman and Kernehan, 1976; and many papers in Transactions of the American Fisheries Society, Vols. 110[1] and 114[1]). The impoundment of the Santee River in South Carolina during the 1940s resulted in a reproducing population adapted to a landlocked existence (Stevens, 1958). Offspring from these fish have been stocked in many inland waters of North America, where they generally inhabit reservoirs and the rivers forming them. Upstream spawning runs in landlocked populations occur in spring when water temperatures approach 15 C. Possible natural hybridization with the white bass has been reported in Arkansas (Crawford et al., 1984). Spawning occurs in midwater and, unlike the white bass, it is necessary for the eggs to remain suspended in

Plate 181. *Morone saxatilis*, striped bass, 295 mm SL, U.S. Fish & Wildlife Hatchery, Warm Springs, GA.

the current during their entire development period (1–3 days); those that sink to the bottom generally die due to siltation or other factors (Scruggs, 1955). Hogue et al. (1977) reported some possible natural reproduction in Tennessee, but the numerous dams on Tennessee's rivers preclude almost all such reproduction. However, striped bass are easily propagated in hatcheries (Stevens, 1965) and are stocked annually in reservoirs. In Tennessee reservoirs, striped bass grow to about 200 (175–217) mm TL in one year (Saul, 1981). In Percy Priest Reservoir, growth averaged as follows: age 1, 21.6 cm; 2, 40.4; 3, 52.8; 4, 62.5; 5, 70.1; 6, 73.1 (Weaver, 1975). Young *M. saxatilis* are reported to feed on midge larvae and planktonic crustacea, but begin to consume small fish by the time they have reached a length of 50–75 mm (Heubech et al., 1963; Ware, 1971; Saul, 1981; Richardson, 1982). Cheek et al. (1985) found that striped bass in Watts Bar Reservoir distributed themselves with regard to temperature and dissolved oxygen, thus being restricted to cooler arms of the reservoir in summer months. Adult striped bass live in roving schools which prey heavily on forage fishes, particularly shad (Stevens, 1958), probably serving as virtually the only predator (except where muskellunge and northern pike are introduced) on adults of these abundant fishes. Spectacular feeding displays occur at the water's surface as striped bass (and white bass) slash into schools of forage fish. Anglers in boats often pursue these "jumps" in hopes of hooking monster "rockfish" which put up a tremendous battle when hooked. This method is used principally in the cooler months. Several lunker specimens are also incidentally hooked each year by anglers using minnows. Best lures are large white jigs, spinners and spoons, and fishlike plugs. One of the largest Cumberland Lake specimens was caught on a green tennis ball! Trolling with deep-running plugs and fishing deep with live bait such as bluegills is sometimes effective in summer when fish are deeper. Significant numbers also are caught in rivers during their attempted spring spawning runs. Striped bass are not one of the more "catchable" fishes as a considerable amount of effort is usually expended for each specimen actually caught, but the allure of landing a lifetime trophy keeps many anglers keenly interested in pursuing them. Striped bass weighing over 100 lbs. have been reported in commercial catches along the Atlantic Coast. The world angling record, taken at Atlantic City, N.J., in 1982, weighed 35.6 kg (78.5 lb). The Tennessee and freshwater angling record of 27.5 kg (60.5 lb) was taken from Melton Hill Reservoir in 1988 by Gary Helms.

In addition to striped bass, striped bass x white bass hybrids (Pl. 182) were cultured and stocked in many of Tennessee's reservoirs in the belief that they were perhaps more adaptable to inland waters (Bishop, 1968). In South Carolina, these hybrids are reported to grow rapidly, attaining lengths of 46 cm after 2 years while feeding heavily on shad (Williams, 1972). These hybrids rarely reproduce naturally (Avise and Van Den Avyle, 1983) but there is evidence that they are back-crossing with white bass, and thus potentially becoming genetically introgressed with that species in some populations, particularly Cherokee Reservoir in Tennessee (Avise and Van Den Avyle, 1984). The practice of stocking hybrids in Tennessee's reservoirs has declined somewhat in recent years as the striped bass has proved successful enough to eliminate most of the need for culturing hybrids. A considerable number of hybrids in

Plate 182. *Morone saxatilis* x *M. chrysops* hybrid, 205 mm SL, Ft. Loudon Res., TN.

the 5–12 lb category have been taken in Tennessee waters. World record hybrid is 10.49 kg (23 lb 2 oz) from Warrior River, AL, 1989. The Tennessee record hybrid was taken from Chickamauga Reservoir in 1991 by Robert G. Davis and weighed 10.33 kg (22 lb 12 oz).

Distribution and Status: Originally anadromous in Atlantic and Gulf coastal rivers from St. Lawrence drainage to Lake Pontchartrain, Louisiana. Widely introduced elsewhere. Also introduced to the West Coast of the United States where it has flourished, especially in the Sacramento–San Joaquin delta region. Introduction of striped bass into Tennessee reservoirs began as early as 1958 when thousands of adults were introduced into Kentucky Reservoir in hopes that a naturally reproducing population would become established (Bishop, 1968). After this apparently failed, stocking of fry and fingerlings began in many reservoirs across the state during the mid 1960s. Both striped bass and hybrids have been stocked and now are widespread in impoundments of the Tennessee and Cumberland rivers and their larger tributaries. In some areas, indigenous East Coast populations have experienced serious declines in abundance in recent years due to undetermined environmental factors, over fishing, or possibly a natural cycle.

Similar Sympatric Species: The white bass occurs in all habitats in which the striped bass has been introduced, and the yellow bass is syntopic in Tennessee River impoundments; both are easily separable (see Key). The white bass x striped bass hybrid is separable from the striped bass by its deeper body and broken lateral stripes. Waldman (1986) pointed out that the positioning of teeth at the base of the tongue is diagnostic for separating *chrysops* and *saxatilis* (see key), but unreliable for identifying hybrids (but see comments under *M. chrysops*).

Etymology: *saxatilis* = dwelling among rocks.

FAMILY ELASSOMATIDAE

The Pygmy Sunfishes

The pygmy sunfishes, genus *Elassoma*, have been regarded by many recent authors as constituting a subfamily of the sunfishes, Centrarchidae (Greenwood et al., 1966; Nelson, 1984; and many regional reference works). However, morphological evidence presented by Branson and Moore (1962), biochemical studies (Avise and Smith, 1977), and considerable differences in reproductive behavior may indicate that the relationship between *Elassoma* and other genera placed in Centrarchidae is not particularly close, and it is possible they are not a sister group of the sunfishes. Humphries and Lauder (1985) also found no evidence to support a close relationship with centrarchids. It is also possible that some characters which differ in *Elassoma* are simply reductive ones owing to their small size, thus obscuring a close relationship to centrarchids. Johnson (1984) questioned whether the relationships of pygmy sunfishes even lie among the so-called percoid fishes. Until a definitive study clarifying the phylogenetic position of *Elassoma* has been published, we prefer to assume no relationships and therefore follow the arrangement of Branson and Moore (1962), Johnson (1984), and earlier works such as Jordan (1923), in regarding pygmy sunfishes as a separate family.

As the name indicates, pygmy sunfishes are very diminutive species, seldom exceeding 35 mm (1.4 in) in length, and most specimens encountered are even smaller. They typically inhabit Coastal Plain swamps, but one species has adapted to a more upland, swamplike spring habitat. A widespread species, *Elassoma zonatum*, inhabits both the Atlantic and Gulf coastal plains and occurs in Tennessee. A second species, undescribed, occurs in the Tennessee River drainage but is known only from springs in Limestone County, Alabama. One of its associates, the Tuscumbia darter, formerly occurred in spring systems in Hardin County, Tennessee, now beneath Pickwick Reservoir; it is conceivable that the undescribed *Elassoma* may also have occurred there. Additional species of *Elassoma* are limited to Coastal Plain swamps from North Carolina to Florida and Alabama; these include *E. evergladei*, *E. okefenokee*, and the recently described *E. boehlkei* and *E. okatie* (Rohde and Arndt, 1987).

Elassoma zonatum Jordan.

Banded pygmy sunfish

Characters: Lateral line degenerate, scales in lateral series 31–36. Dorsal fin with 4–5 spines and 9–10 soft rays. Anal fin with 3 spines and 5–6 soft rays. Pectoral fin short and rounded, with 14–17 rays. Pelvic fin with

Plate 183. *Elassoma zonatum*, banded pygmy sunfish, male, 30 mm SL, Reelfoot L., TN.

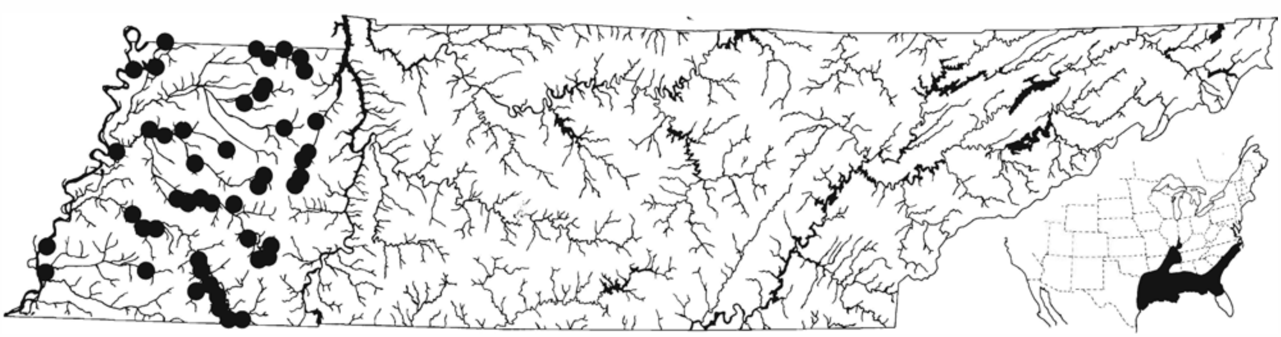
1 spine and 5 rays. Principal caudal fin rays 13–16. Branchiostegal rays 5. Gill rakers 6–8 and about as wide as long. Vertebrae 24–25. Gill membranes broadly joined and free from isthmus. Scales cycloid, lacking cteni, those on cheeks and opercles mostly embedded. Jaws armed with tiny conical teeth. Vertical dark bars and black specklings most evident on breeding males, which also have darkened fins with iridescent blue highlights. Females and juveniles brownish, often with a pink or purple sheen. One or a pair of dark spots usually present laterally below the dorsal fin origin.

Biology: The banded pygmy sunfish is an inhabitant of swamps, natural lakes, and sluggish streams of the Coastal Plain. It is secretive, remaining in or near vegetation or debris and beneath banks. The following biological information is summarized from studies on Louisiana (Barney and Anson, 1920) and Kentucky (Walsh and Burr, 1984) populations. Spawning occurred during March, April, and May in both studies, and was most intense from late March through April in Kentucky. No nest is built, but males in aquaria defended small territories during the breeding season, and displayed to females by erecting their fins, bobbing, undulating their bodies, and alternately extending each pelvic fin vertically. A single male and female are typically involved in spawning, but Walsh and Burr observed several instances in which a female was flanked on either side by a male. Females spawn repeatedly until all mature ova are deposited, but fewer eggs are laid with each successive spawning. Mean eggs laid per spawning was 38 in Kentucky, and annual fecundity estimates range from 145 in Kentucky to about 300 in Louisiana. Males may remain with and guard eggs they have fertilized for up to 48 hours. Eggs hatch in 4–5 days at 21 C (70 F). Food consists primarily of microcrustacea supplemented with midge larvae, larger crustacea (isopods and amphipods), mayfly nymphs, and small snails and clams. Both males and females are sexually mature when 1 year old, and life span is typically only about 1 year, with maximum ages reported as 25 months in the Kentucky study and 3 years in Louisiana. Maximum total length 47 mm (1.8 in).

Distribution and Status: Widespread and abundant on Atlantic and Gulf coastal plain from Albemarle Sound, North Carolina, through Brazos River, Texas, but absent from much of Peninsular Florida. Occurs throughout Mississippi River Embayment, with a few records above Fall Line in southern Illinois and the Green and Tradewater river systems in Kentucky (Warren, 1980; Burr and Warren, 1986). Locally common throughout Coastal Plain in west Tennessee, and extending into Tennessee River drainage in swampy portions of the Big Sandy River system.

Similar Sympatric Species: Most easily confused in the field with very young centrarchids (which have 6 or more dorsal spines) and young pirate perch (*Aphredoderus*) which have a similar purplish sheen, but have the anus in a jugular position (behind gills), and have only 3 dorsal spines and 2 anal spines.

Etymology: *Elassoma* = small body; *zonatum* = banded.



Range Map 176. *Elassoma zonatum*, banded pygmy sunfish.

FAMILY CENTRARCHIDAE

The Sunfishes

Sunfishes are known to nearly everyone. The family contains the familiar bluegill, redear sunfish or shellcracker, crappies, and large- and smallmouth basses, as well as several other small species which occasionally grace the frying pan and are collectively known to anglers as bream, sunfish, or sun perch. A substantial number of Tennessee's sport fishes are members of the Centrarchidae. Many species have bright yellow, orange, or red colors on the breast and belly. These bright colors, most evident in breeding males, have doubtless led to the common name "sunfishes." Of the 30 known species of centrarchids, 20 occur in Tennessee. Extralimital species are the Sacramento perch, *Archoplites interruptus*, native to the Sacramento–San Joaquin Basin of California, the mud sunfish, *Acantharcus pomotis*, of Atlantic Coastal Plain swamps, the banded, bluespotted, and black banded sunfishes (genus *Enneacanthus*) of the eastern Coastal Plain region, and some species of *Ambloplites* and *Micropterus* (see generic accounts).

The relationships of centrarchids to other perciform fish families are not known. Centrarchids first appear in the fossil record in the Eocene of North America (Cavender, 1986), and they were already quite diverse in the Miocene (Smith, 1981). That record would indicate that they were originally distributed across North America, but only the Sacramento perch naturally occurs in the West today; all others are restricted to east of the Rockies. Some members of the family have been widely introduced as sport fishes throughout the world, and some have been detrimental to native fish populations, particularly in the American Southwest. Centrarchid interrelationships have been studied by Bailey (1938), Branson and Moore (1962), Hester (1970), Avise and Smith (1977), Avise et al. (1977), Humphries and Lauder (1985), Lauder (1986), and Mabee (1987, 1989). There are disagreements among the above authors with regard to these relationships, as will be pointed out in various genus and species accounts, and thus relationships are not well clarified as yet. Many authors have included pygmy sunfishes (genus *Elassoma*) as members of Centrarchidae, but they are treated separately herein (see discussion under Elassomatidae).

As in other perciform fishes, sunfish have a spinous dorsal fin (with 6–13 spines) followed by a soft dorsal fin; the anal fin has 3 or more spines at its origin. The pelvic fins are beneath the pectorals and have 1 spine and 5 soft rays, and there are 17 principal caudal fin rays. The lateral line is complete in all except *Lepomis symmetricus*. Scales are ctenoid except in *Acantharcus* and occur all over the body, including the breast, cheeks, and opercles.

Except when very young, sunfish are territorial or occur in small aggregations, and they are often associated with a particular favorite haunt such as a submerged stump or tree, rocks, vegetation, or overhanging bank. The crappies (*Pomoxis* spp), however, may occur in large aggregations, especially just prior to spawning. Sunfish are sight feeders and procure food either by lying in wait and making a sudden lunge (surface-midwater) or, in some species, active foraging at the bottom. All species (except *Archoplites*) are nest builders, and males typically guard the nest after spawning with the female. Nests are shallow pits hollowed out by the male, who sweeps aside the substrate and sediments with his caudal fin. Spawning is quite ritualized with much circling activity about the nest punctuated by short encounters during which the female lies on her side while eggs are extruded and fertilized; two or more females may spawn within the nest of a single male (Breder, 1936; Witt and Marzolf, 1954). Because of overlaps in spawning habitat and behavior, sunfishes (primarily members of the genus *Lepomis*) hybridize quite frequently. The green sunfish, *Lepomis cyanellus*, is an especially promiscuous and indiscriminate spawner. The frequency of hybrids should be kept in mind when contemplating any specimen which is particularly difficult to identify through use of keys and illustrations herein. Keys found within this section should aid in identification of all except possibly very immature specimens of sunfish as well as the above-mentioned hybrids, whose intermediacy in characters may give some indication of the parental species involved.

KEY TO THE TENNESSEE GENERA

1. Anal fin with 5 or more spines 2
   Anal fin with 3 spines 4
2. Anal fin with 11 or fewer soft rays . . . . . *Ambloplites*
   Anal fin with 14 or more soft rays 3
3. Dorsal fin with 6–8 spines . . . . . *Pomoxis* p.436
   Dorsal fin with 12–13 spines . . . . . *Centrarchus* p.402
4. Scales in lateral series 53 or more; body elongate and robust, with depth usually not exceeding 30–35% of SL in specimens under 150 mm (6 in or so); dorsal fins nearly separate . . . . . . *Micropterus* p.427
   Scales in lateral series 52 or fewer; body deep and somewhat laterally compressed, with depth usually about 40–50% of SL (occasionally less in *L. cyanellus*); dorsal fins continuous . . . . *Lepomis* p.403

Genus *Ambloplites* Rafinesque
The Rockbasses

The genus *Ambloplites* contains four species. *A. cavifrons* is a large species restricted to Atlantic Coastal drainages in Virginia and North Carolina (see Cashner and Jenkins, 1982; Petrimoulx, 1983); *A. constellatus* is a recently described species restricted mostly to the White River system of Missouri and Arkansas (Cashner and Suttkus, 1977). The remaining two species occur in Tennessee and are popular sport and food fishes. Rockbass are commonly taken while fishing along streams with spinners or other small lures, flies, or live bait. Red pigment is often conspicuous in the iris of these fishes, lending to the colloquial name "redeye." Other local names include "goggleye" and "black perch." Bailey (1938) and Mabee (1987) concurred that closest relationships of *Ambloplites* lie with the genera *Pomoxis*, *Centrarchus*, and *Archoplites*; Branson and Moore (1962) hypothesized a closer relationship to *Lepomis* and *Enneacanthus*.

Etymology: *Amblo* = blunt, *plites* = armature.

KEY TO THE TENNESSEE SPECIES

1. Dorsal soft rays usually 12; anal soft rays 10–11; cheek scales coarse, usually 4–5 rows below eye (about 75 total scales on cheek); larger specimens (over 100 mm SL) deep, body depth about 43% of SL; eye large, averaging about 14% of SL; Conasauga R . . . . . *A. ariommus*
   Dorsal soft rays usually 10–11, rarely 12; anal soft rays 9–10; cheek scales smaller, usually 7–8 rows below eye (about 120 total scales on cheek); larger specimens more elongate, body depth 40% or less of SL; eye smaller, averaging 11–12% of SL . . . . . *A. rupestris* p.401

Ambloplites ariommus Viosca.

Shadow bass

Plate 184a. *Ambloplites ariommus*, shadow bass, 130 mm SL, Conasauga R., TN.

Plate 184b. *Ambloplites ariommus*, shadow bass, juvenile, 35 mm SL, Conasauga R., TN.

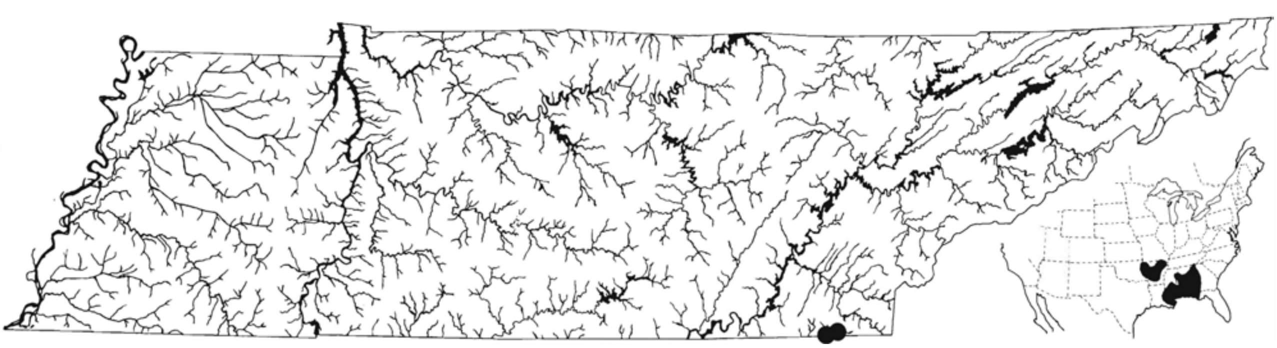
Characters: Lateral-line scales 36–42. Dorsal fin with 11 spines and 11–12 soft rays. Anal fin with 6–7 spines and 10–11 soft rays. Pectoral fin rays 13–15. Gill rakers long and slender, with 7–10 developed. Branchiostegal rays 6. Cheek scales in 4–5 rows. Color in life olive to brassy green with dark mottling which can change drastically with surroundings. Horizontal rows of dark scale spots present on sides of larger specimens. Dorsal and anal fins with contrasting blotches of dark pigment and pale areas, especially in young.

Biology: Viosca (1936), in his description of *A. ariommus*, also addressed aspects of its biology. The shadow bass occurs in moderately flowing pool areas in association with brush, logs, or other cover. Food includes small fish (darters, madtoms, minnows), crayfish, and larger insects including dragonfly, mayfly, and stonefly nymphs. Most prey items are benthic species, indicating the location of feeding. The presence of large numbers of diurnally secretive insect nymphs may indicate considerable crepuscular (dawn and dusk) feeding activity. Perhaps the large eye has evolved to facilitate these habits. Reproduction has not been studied in the shadow bass but it probably compares closely to that of *A. rupestris*. This rockbass is occasionally taken by anglers in quest of redeye bass (*Micropterus coosae*) and spotted bass (*M. punctulatus*), but it is of lesser interest to anglers due to its small maximum size of about 200 mm TL (8 in)

Distribution and Status: Above and below the Fall Line in Gulf Coastal drainages from the Apalachicola River west to Lake Pontchartrain, eastern tributaries to the Mississippi River in southern Mississippi, and west of the Mississippi River in the St. Francis, White, and Ouachita river systems. In Tennessee restricted to the Conasauga River, where it is common.

Similar Sympatric Species: The warmouth, *Lepomis gulosus*, has similar mottled coloration but has only 3 anal spines.

Systematics: In recent decades *A. ariommus* has been regarded as a subspecies of the rockbass, *A. rupestris*, but more recently was regarded as a full species (Cashner and Suttkus, 1977). Comparison of our Conasauga River material with rockbasses from the adjacent Tennessee and Cumberland drainages, and with Gulf Coastal material, corroborates this view. In addition to characters noted in the Key and accounts, there are



Range Map 177. *Ambloplites ariommus*, shadow bass.

rather consistent differences in coloration between *A. ariommus* and *A. rupestris*. Particularly noticeable are the more extensive pale areas in the posterior soft dorsal and anal fins of *ariommus*.

Etymology: *ari* = an intensifying prefix, *ommi* = eye, or "big-eyed."

Ambloplites rupestris (Rafinesque).

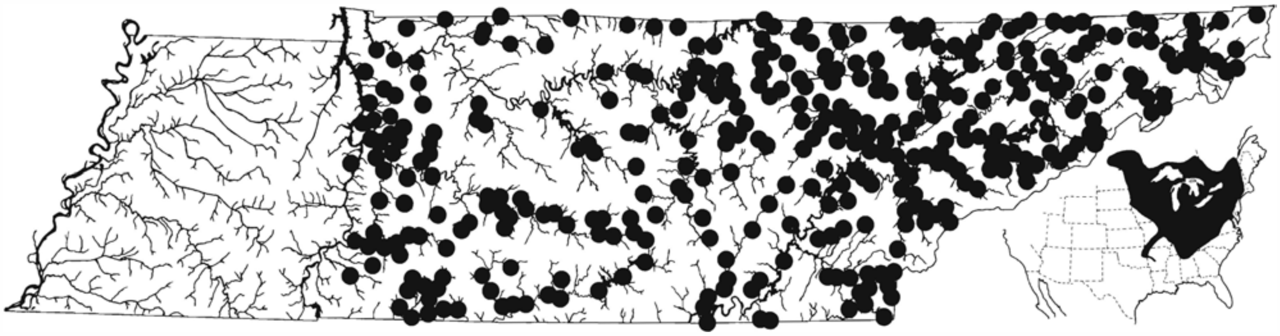
Rockbass

Characters: Lateral-line scales usually 39–46. Dorsal fin with 10–13 spines and 10–12 soft rays. Anal fin with 5–7 spines and 9–11 soft rays. Pectoral fin rays 13–15. Gill rakers long and slender, with 7–10 developed. Branchiostegal rays 6. Vertebrae 29–32. Cheek scales in 7–8 rows. Colors as in *A. ariommus*, but generally more uniformly mottled (less "blotchy") on body and fins.

Biology: In our area, rock bass are associated with sheltered pool areas in creeks and rivers, occurring from warmwater streams to trout streams, and are occasionally encountered in reservoirs near rocky shores. They are most often associated with cover such as root complexes, brush, or water willow (*Justicia*) beds. In the upper Midwest they are common inhabitants of cool glacial lakes. According to Pflieger (1975), spawning occurs from April to June. The male fans out a nest in an area of sand and gravel substrate at the bottom of a moderately flowing pool. Females produce 3,000 to 11,000 eggs per year (Scott and Crossman, 1973). After spawning, the male remains with the nest until fry have dispersed. Several life history studies have been conducted on rockbass in Tennessee (Speir, 1969; Cathey, 1973; Gwinner, 1973). They grow to about 45 mm TL the first year, 80 mm the second, 115 the third, 160 the fourth, 195 the fifth, and attain average lengths of about 200 mm at the end of 6 years. Maximum life span is estimated at 8 years (Redmon and Krumholz, 1978). Full-grown rockbass average over 200 gm (about .5 lb). As in *A. ariommus*, a primarily benthic feeding behavior is indicated. Crayfishes, large insect nymphs, and small fishes dominate the diet (Probst et al., 1984). Rockbass are perhaps one of our most underfished game species as many anglers forego stream fishing in favor of one of the many and more accessible reservoirs, where rockbass are uncommon. Rewarding fishing awaits those who care to expend the effort casting spinners, flies, or crayfish baits along the margins of our better-quality streams. Stream populations of rockbass, as well as smallmouth and spotted bass, can often provide a hardy tussle and a tasty meal when reservoir fishing is nonproductive. The world angling record is 1.36 kg (3 lb), but Scott and Crossman (1973) mention a specimen of 1.65 kg (3 lb 10 oz) that was 340 mm (13.4 in) long. The Tennessee record of 1.13 kg (2.5 lb) is from Stones River, 1958, caught by Bill Sanford.

Distribution and Status: Widespread and abundant in Mississippi River, Great Lakes, and southern Hudson

Plate 185. *Ambloplites rupestris*, rockbass, 139 mm SL, Pigeon R. system, TN.



Range Map 178. *Ambloplites rupestris*, rock bass (Atlantic slope, New River, and Ozarkian populations represent introductions)

Bay basins. Also native from Connecticut through Delaware river drainages on Atlantic Coast, and introduced in more southerly Atlantic drainages to Virginia and North Carolina. In Tennessee it is absent from the Coastal Plain and Conasauga River system but is common elsewhere.

Similar Sympatric Species: The warmouth, *Lepomis gulosus*, has similar mottled coloration but has only 3 anal spines.

Etymology: *rupestris* = among the rocks.

Plate 186a. *Centrarchus macropterus*, flier, 105 mm SL, Hatchie R. system, TN.

Plate 186b. *Centrarchus macropterus*, flier, juvenile, 27 mm SL, Isom L., TN.

Genus *Centrarchus* Cuvier

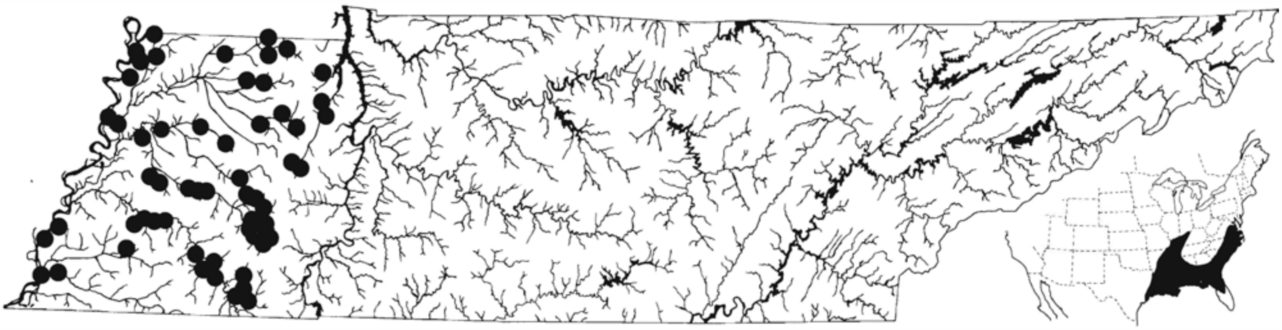
The genus contains a single species, discussed below.

Centrarchus macropterus (Lacepede).

Flier

Characters: Lateral-line scales 36–42. Dorsal fin with 11–13 spines and 12–14 soft rays. Anal fin with 7–9 spines and 14–16 soft rays. Pectoral fin rays 12–14. Gill rakers long and slender, 30–35. Branchiostegal rays 7. Vertebrae 31. Background color pale green to white. Juveniles are usually mottled and marked with interrupted rows of dark spots along the sides which become more continuous with maturity. A large "eye spot" or ocellus, black in the center with a pale to reddish periphery, is present in the posterior soft dorsal fin in specimens up to about 65 mm (2 in). The dark suborbital bar is distinctive on specimens of all sizes.

Biology: The flier is an inhabitant of sluggish streams, swamps, and natural lakes below the Fall Line. Its biology has not been well studied. According to Pflieger (1975), Missouri populations spawn in April. Specimens collected in western Tennessee during mid May still contained considerable numbers of eggs, though they were probably partially spent. Pflieger reported a life span of up to 7 years with age 1 specimens averaging about 50 mm TL and growth increments of 25–35 mm in succeeding years except during the seventh year when growth diminished. Stomachs of adult fliers from western Tennessee contained terrestrial insects, indicating a primarily surface-oriented feeding behavior. Young contained midge larvae and other benthic organ-



Range Map 179. *Centrarchus macropterus*, flier.

isms. Pflieger (1975) and Gunning and Lewis (1955) also reported adults feeding on insects and a few small fish, but young specimens contained primarily microcrustaceans (copepods). The flier is usually too small to be of interest to anglers. Maximum total length about 200 mm (8 in), but usually much smaller. Sternberg (1987) reported a .57 kg (1 lb 4 oz) specimen from South Carolina. Tennessee angling record is from Blair Lake, Madison County, 156 gm (5.5. oz), 1987, Hunter Henley.

Distribution and Status: Virtually restricted to Coastal Plain habitats from western tributaries to Chesapeake Bay south and west through San Jacinto River, Texas, and extending up Mississippi River Embayment to southern Illinois and Indiana. In Tennessee the flier is reasonably common in suitable habitats throughout the Coastal Plain in Mississippi River tributaries, and several Tennessee drainage records are available from the Big Sandy River system.

Similar Sympatric Species: The crappies (genus *Pomoxis*) are similar in body form and coloration but have only about half as many dorsal spines.

Systematics: Hypothesized to be closely related to *Archoplites* and *Pomoxis* (Bailey, 1938; Mabee, 1987).

Etymology: *Kentron* = spine, *archos* = anus; *macropterus* = large fin.

Genus *Lepomis* Rafinesque

The genus *Lepomis* contains 11 species of small to medium sized members of the sunfish family, including several popular panfish. All 11 species occur in Tennessee, although one or two are introduced. Generic characters are a relatively deep and compressed body, 3 anal fin spines, vomerine teeth, and 6 (rarely 5 or 7) branchiostegal rays. Eight subgenera were recognized in a broad study of the genus (Bailey, 1938). Mabee (1987) regarded the genus as paraphyletic (incomplete) unless members of the eastern Coastal Plain genus *Enneacanthus* are included as well, hypothesizing a closer relationship between these fishes and some species currently placed in *Lepomis* than those species have to other members of *Lepomis*.

Until very recently the generic name *Lepomis* was regarded as masculine in gender, and several associated species names ended in "us" (e.g., *macrochirus* etc.). However, Bailey and Robins (1988) argued that *Lepomis* is feminine, and strict adherence to rules of zoological nomenclature would demand emending many species epithets to the feminine "a" ending (i.e., *punctatus* becomes *punctata*). Etnier and Warren (1990) presented evidence that *Lepomis* can be considered classically masculine and have petitioned the International Commission for Zoological Nomenclature to treat it as such. The commission has the power to declare *Lepomis* as masculine in the interest of stability, regardless of its classical gender, and we are obliged under rules of zoological nomenclature to retain the traditional masculine endings until the commission has an opportunity to make a ruling.

There is considerable variation in members of *Lepomis*, and they can be difficult to identify even for experts. In most museum collections it takes little effort to locate misidentified specimens. This is compounded by the fact that natural hybrids (Pl. 187) are common and juveniles of most species (Fig. 130) often exhibit a similar barred color pattern on the sides. Perhaps this coloration has adaptive significance in serving to camouflage the young against a background of weeds or other cover with which they are usually associated. In

Plate 187. *Lepomis* hybrid, probable *L. cyanellus* x *L. megalotis*, 115 mm SL, Red R. system, TN.

any case, even small juveniles are often identifiable with certainty when large series of various sizes are available from a single locality, by progressive identification of smaller and smaller specimens. Hybrid *Lepomis* tend to grow faster and larger than the parental species involved and have been experimented with as potential food and game species for pond fisheries (Childers and Bennett, 1961).

Etymology: *Lepomis* = approximately "scale operculum."

Figure 130. Small juveniles of *Lepomis* spp.: a) *L. auritus*, 28 mm SL, Holston R. system, TN; b) *L. cyanellus*, 32 mm SL, Potomac R. system, VA; c) *L. gibbosus*, 38 mm SL, Potomac R. system, VA; d) *L. gulosus*, 50 mm SL, Hatchie R. system, TN; e) *L. humilis*, 40 mm SL, Running Reelfoot Bayou, TN; f) *L. macrochirus*, 29 mm SL, farm pond, Knox Co., TN; g) *L. marginatus*, 31 mm SL, Hatchie R. system, TN; h) *L. megalotis*, 30 mm SL, lower Tennessee R. system, TN; i) *L. microlophus*, 29 mm SL, farm pond, Blount Co., TN; j) *L. miniatus*, 27 mm SL, Tennessee R. system, AL; k) *L. symmetricus*, 40 mm SL, Lake Isom, TN.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b
c
d
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KEY TO THE TENNESSEE SPECIES

As with other characters in *Lepomis*, pectoral fin lengths are quite variable, and specimens having fin lengths very closely approaching the anterior rim of the eye (within 1–2 mm) should be considered under both alternatives to the couplet with careful attention to all other characters given in the Key (i.e., occasional specimens of *gibbosus* have pectoral fin lengths not quite reaching front of eye, etc.).

1. Pectoral fins long and moderately to sharply pointed, extending to or beyond anterior rim of eye when bent forward and depressed absolutely flat (Fig. 131) 2

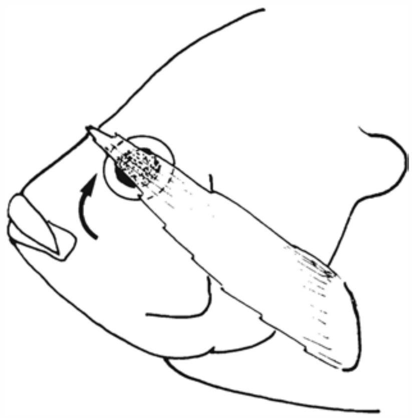


Figure 131. Forward depressed pectoral fin of a *Lepomis*.

Pectoral fins shorter, the tips rounded, not extending to anterior rim of eye when bent forward 5

2. A dark basal spot usually evident in posterior portion of soft dorsal fin (Pl. 193); sides of young usually with sets of double vertical bars; opercular lobe black to margin; longest gill rakers 4 or more times longer than their basal width (Fig. 132a) . . . . *L. macrochirus* p.417

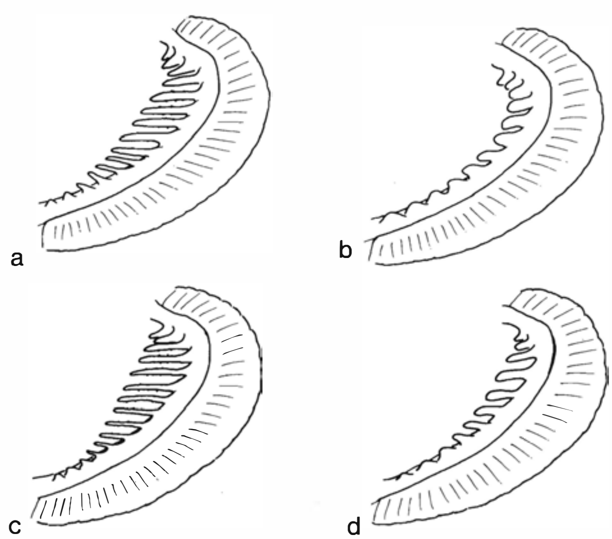


Figure 132. Gill rakers of *Lepomis* spp. showing length to basal width ratio of longest rakers: a) *L. macrochirus* (length 4X width); b) *L. microlophus* (2X); c) *L. cyanellus* (4-6X); d) *L. auritus* (2-3X).

No basal dark spot in posterior dorsal fin; sides usually with scattered dark spots (occasionally forming single vertical bars in young); opercular lobe with pale margin or spot at tip; gill rakers variable 3

3. Opercular lobe fleshy, the black portion flexible, elongate, and angled dorsad (Pl. 192); pectoral fin rays usually 15; length of longest gill rakers 4–5 times their basal width .... *L. humilis* p.415

Opercular lobes bony nearly to margin, the black portion inflexible, horizontal, and not elongate; pectoral fin rays usually 13–14; gill rakers shorter (Fig. 132b) 4

4. Pectoral fins very long, extending nearly to or beyond dorsal fin base when angled dorsad; body of adults somewhat elongate, the depth about 40% of SL; profile of head more or less pointed (Pl. 196) .... *L. microlophus* p.423

Pectoral fins shorter, extending to about 3–5 scale rows below dorsal fin base when angled dorsad; body of adults deeper, the depth about 50% of SL; profile of head in adults rounded (Pl. 190) .... *L. gibbosus* p.412

5. Tongue with a patch of teeth (easily felt by probing with a needle); 3–4 blackish bars radiating from eye across cheeks and opercles (Pl. 191) .... *L. gulosus* p.413

Tongue lacking teeth; cheeks lacking blackish bars 6

6. Lateral-line scales usually 43–50; mouth relatively large and moderately oblique, the maxilla extending well past anterior rim of eye (Fig. 133a) in larger specimens 7

Lateral-line scales usually 32–43; mouth small and moderately to very oblique, the maxilla seldom extending past anterior rim of eye (Fig. 133b) 8

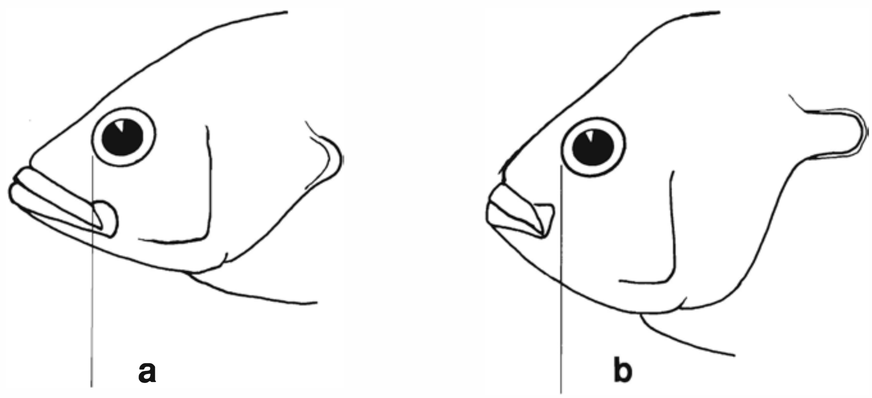


Figure 133. Relative jaw lengths of *Lepomis* spp.: a) *L. cyanellus*; b) *L. megalotis*.

7. Length of longest gill rakers 4–6 times their basal width (Fig. 132c); opercular lobe bony nearly to margin, the black portion inflexible and appearing as a round spot; a dark basal spot usually evident on posterior dorsal fin; body relatively elongate, robust, and "bass-like" (Pl. 189) .... *L. cyanellus* p.410

Length of longest gill rakers 2–3 times their basal width (Fig. 132d); opercular lobe fleshy, becoming elongate in adults; no basal dark spot on posterior dorsal fin; body deeper (Pl. 188) ..... *L. auritus* p.408

8. Opercular lobe bony nearly to margin, the black portion inflexible 9

Opercular lobe with the black portion flexible nearly throughout 10

9. Lateral line incomplete, 15–20 pored scales; scales in lateral series 32–35; length of longest gill rakers 5–6 times their basal width (Fig. 132c); a black ocellus present in posterior dorsal fin of young; sides mottled or barred (Pl. 198) .... *L. symmetricus* p.426

Lateral line complete with 34–39 scales; length of longest gill rakers 2–3 times their basal width (Fig. 132d); no black ocellus in posterior dorsal fin; sides with scattered dark spots (young) or with rows of dark or light spots (adults) (Pl. 197) .... *L. miniatus* and *L. punctatus* p.424

10. Black portion of opercular lobe with silver blotches in adults (Pl. 194); pectoral fin rays usually 12; cheek scale rows 3–4 (Fig. 134); body profile somewhat rounded, the greatest depth usually beneath or behind the dorsal fin origin; body depth usually about 50% of SL .... *L. marginatus* p.419

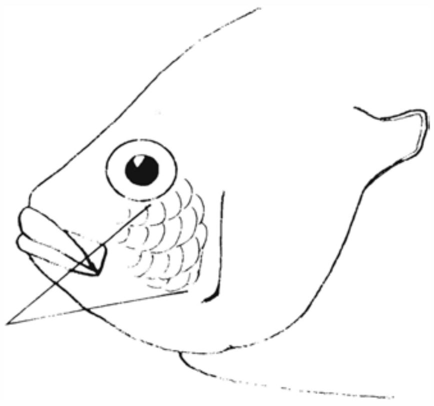


Figure 134. Cheek scale rows of *Lepomis marginatus.*

No silver blotches on black portion of opercular lobe in adults (Pl. 195); pectoral fin rays usually 14; cheek scale rows 5–6; body profile slightly more elongate, the greatest depth usually before the dorsal fin origin except in largest (150+ mm TL) specimens; body depth usually about 40–45% of SL .... *L. megalotis* p.421

Lepomis auritus (Linnaeus).

Redbreast sunfish

Characters: Lateral-line scales 42–51. Dorsal fin with 10 (10–11) spines and 11 (10–12) rays. Anal fin rays 10 (9–10). Pectoral fin rays 13–15. Gill rakers 9–12, length of longest rakers about twice their basal width in adults (Fig. 132d) and subadults, about four times basal width in young-of-year. Vertebrae 29–30. Body deep and moderately compressed. Palatine teeth present. Dorsal area blue-green shading to yellowish on the breast, belly, and lower head (bright red in breeding males). Soft dorsal fin and upper lobe of caudal fin with yellow margins, becoming bright orange to scarlet on nuptial males. Bright blue vermiculations usually apparent on the cheeks and preorbital areas. The black opercular lobe is fleshy, becomes very long in adults, and lacks a pale border. Young-of-year up to 25 mm or so (Fig. 130a) may have about 12 vertical dark bars on sides; these bars faint or absent in larger specimens.

Biology: The redbreast sunfish occurs in a variety of habitats from small creeks to rivers and reservoirs. Its biology has not been investigated in Tennessee but has been well studied in Atlantic Coast drainage populations. *L. auritus* apparently moves about very little except during the spawning season (Hudson and Hester, 1976). Spawning activity is greatest during June (J. Davis, 1972). Nests are constructed in flowing portions of streams in areas of sandy substrate and usually near some obstruction. Fecundity averages about 3,300 ova per female and increases greatly with size (Sandow et al., 1975). Larval development was described by Buynak and Mohr (1978b); larvae are about 5.2 mm at hatching and transform to juveniles at 18–20 mm TL. Young grow to about 60 mm the first year and grow an additional 30 mm or so per year until age 6. Several hybrid combinations involving redbreast sunfish are known (Schwartz, 1972). In Tennessee, *L. auritus* hybridizes occasionally with the bluegill, *L. macrochirus*, with which it most often occurs. The diet of adult redbreast sunfish is primarily composed of terrestrial insects and both immature and adult aquatic insects, particularly larger varieties such as mayflies and dragonflies; there is some utilization of crayfish and small fish (J. Davis, 1972; Sandow et al., 1975). Juveniles feed more heavily on benthic organisms such as dipteran larvae. Because of its relatively large size and excellent food qualities, it is a favored pan fish in areas where it is abundant and reaches large sizes. It appears to be increasing in abundance in east Tennessee. Redbreasts can be caught with techniques that are effective for bluegills, and are generally more aggressive, more surface oriented, and more active in cool waters than is the bluegill. World angling record .9 kg (2 lb). Tennessee record .6 kg (1 lb 5 oz) from Holston River, 1974, R. W. Gillespie.

Distribution and Status: Native to Atlantic Coast drainages from central New Brunswick south, and eastward in Gulf through Apalachicola drainage. Populations outside this area are considered to be introduced. In Tennessee, redbreast are well established in the Conasauga River system and the upper Tennessee River drainage downstream to the Chattanooga area. Also present in upper Cumberland River drainage, and known from the Forked Deer river and Big Sandy system in west Tennessee. Populations have become well established and are reproducing in many east Tennessee reservoirs (Fitz, 1966), and most east Tennessee streams and rivers have robust populations. Native populations of the ecologically similar longear sunfish, *L. megalotis*, appear to be disappearing or declining in east Tennessee, and circumstantial evidence suggests that direct competition is involved.

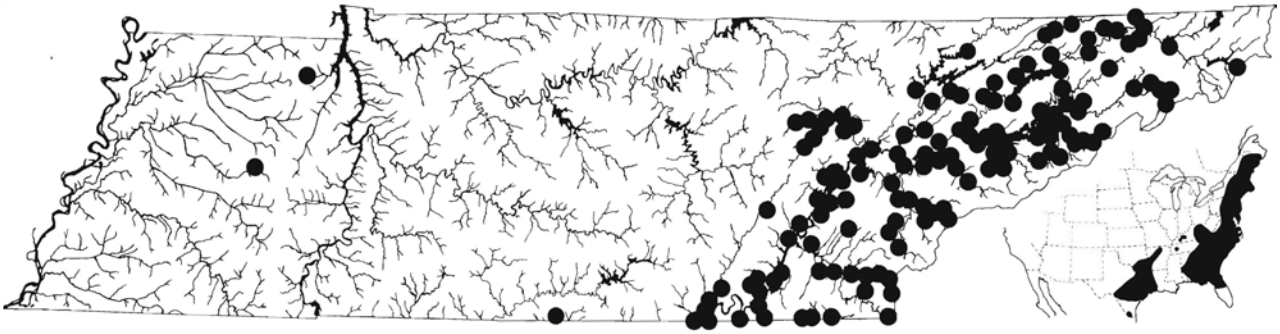
Plate 188a. *Lepomis auritus*, redbreast sunfish, 100 mm SL, Cumberland R. system, KY.

Similar Sympatric Species: The bluegill, when large, has similar yellowish coloration and a long black opercular lobe, but bluegills lack blue vermiculations on the cheek and are also easily separable on lateral-line scale counts and pectoral fin and gill raker length. The longear sunfish is similar in morphology and coloration but is separable on lateral-line scale counts, and further differs in having a narrow pale margin around the opercular lobe. Both of these species lack palatine teeth and the red-tipped soft dorsal and caudal fins of the redbreast sunfish. Young-of-year have reddish eyes, and the dark vertical bars on the sides are vague or absent (Fig. 130a). They are thus very similar in appearance to young green sunfish (Fig. 130b), which have more and slightly longer gill rakers, and young longears (Fig. 130h), which have fewer lateral-line scales and shorter gill rakers.

Systematics: Placed in a monotypic subgenus *Lepomis* Rafinesque by Bailey (1938). Branson and Moore (1962) hypothesized relationships with *L. megalotis* and *L. marginatus*, as did Mabee (1987), in addition to *gibbosus*, *microlophus*, and *punctatus*.

Etymology: *auritus* = eared.

Plate 188b. *Lepomis auritus*, redbreast sunfish, adult, 150 mm SL, Watts Bar Res., TN.



Range Map 180. *Lepomis auritus*, redbreast sunfish (populations other than those on Atlantic slope and eastern Gulf slope represent introductions).

Lepomis cyanellus Rafinesque.

Green sunfish

Characters: Lateral-line scales 43–52. Dorsal fin with 10 (9–11) spines and 11 (10–12) soft rays. Anal fin soft rays 9–10 (8–11). Pectoral fin rays 13–15. Gill rakers 11–14, length of longest rakers (Fig. 132c) about six times basal width (less slender in very large adults). Vertebrae 28–29. Palatine teeth present. Color of dorsolateral area blue-green to dusky, usually with small, randomly scattered black flecks. Belly white to yellowish. Females occasionally with dusky bars on sides. Dark basal spot usually present in posterior soft dorsal fin, and occasionally at posterior base of anal fin. Soft dorsal, anal, pelvic, and caudal fin of nuptial males with orange wash or bright orange submarginal areas and white margins. The anal fin has a striking color combination of black basally, orange and white distally. Young-of-year (Fig. 130b) uniformly gray on sides, lacking vertical banding.

Biology: The green sunfish is a highly successful species, occurring in a variety of habitats ranging from small intermittent streams to ponds and lakes and, occasionally, the margins of larger streams. It is a relatively sedentary fish with a very small home range. Spawning occurs from May to August. Hunter (1963) gave the following account of spawning behavior. Males, singularly or in colonies, construct nests in sunny areas near cover if possible. Depressions are hollowed out by vigorous caudal fin action. Nest territories are zealously defended with fighting often taking place between males. After nest construction, spawning usually occurs within 1 or 2 days. Those females which are not repelled by the males' aggressive behavior enter the nests of and spawn with several males. Males occasionally spawn with two females simultaneously. Sound production may be important during mating (Gerald, 1971). Males usually remain with the nest about a week while eggs are developing. Hybridization involving green sunfish is frequent; they are known to hybridize naturally

Plate 189. *Lepomis cyanellus*, green sunfish, 87 mm SL, Tennessee R. system, AL.

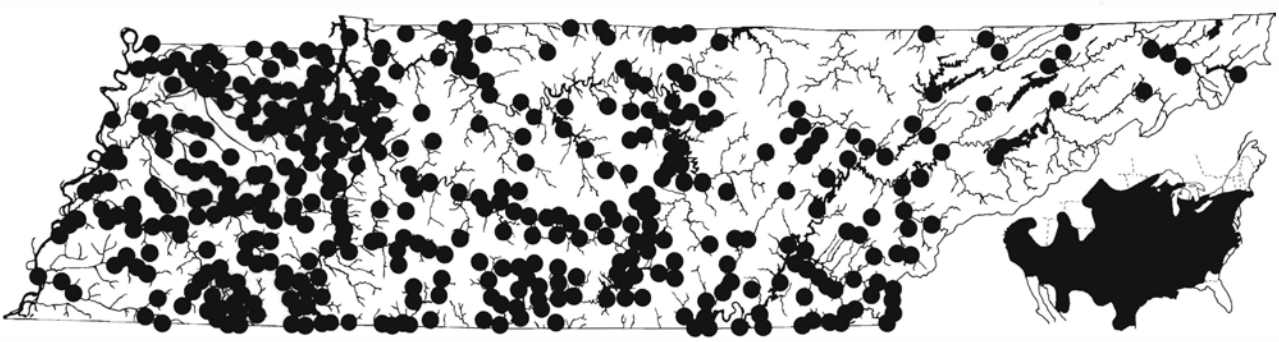
with at least seven other members of *Lepomis* (Childers, 1967). Hybrids are mostly males, tend to grow faster and to larger size than the parental species, but probably seldom reproduce in natural environments (Etnier, 1968). Growth rates of *L. cyanellus* vary widely between populations. There is a tendency toward overpopulation and stunting, especially in closed systems such as shallow ponds. Of the several published growth studies on green sunfish, populations in Tennessee appear to approximate more closely those studied by Purkett (1958) in Missouri, who found that juveniles attained total lengths of about 43 mm the first year with an additional 25–35 mm of growth per year through age 5. Similar growth was reported in a Kentucky stream with age 5 individuals averaging 160 mm TL (Redmon and Krumholz, 1978). Jenkins et al. (1955), studying Oklahoma populations, found a much greater growth rate of over 100 mm and 75 mm in the first and second years, respectively. Life span appears to be 4–6 years. Facilitated by its large mouth, *L. cyanellus* is a voracious predator on a variety of prey items—including terrestrial insects, immature aquatic insects, snails, crayfish, and small fish (Applegate et al., 1967; Etnier, 1971; Sadzikowski and Wallace, 1976). Juveniles feed most heavily on immature insects and microcrustaceans. Average prey size and growth increase dramatically if competition is reduced, demonstrating considerable niche flexibility (Werner and Hall, 1976). Green sunfish have been widely introduced, probably mostly accidentally along with bluegills and redear sunfish. Such populations often explode to high densities in ponds and small lakes, outcompeting more desirable species such as bass and bluegills. They also suppress native fish populations when introduced and established into new stream environments (Lemly, 1985). Green sunfish seldom reach sufficient size to be valued as pan fish but do provide plenty of action to anglers as even small specimens will attack almost any bait or lure offered. Maximum recorded size .97 kg (2 lb 2 oz), world angling records (tie) from Missouri and Kansas. These fish would have been about 305 mm (12 in) TL. Tennessee record 1/3 kg (11.75 oz), from a farm pond in Jackson, 1971, Frank Kitchens.

Distribution and Status: The green sunfish is indigenous to central North America but has been widely and often inadvertently introduced elsewhere. It is abundant in the lowland streams of western Tennessee but is less common in upland streams to the east. It is extremely tolerant of adverse conditions, such as drought, and has a great capacity for colonization and exploitation of new habitats. The green sunfish is a frequent invader of ponds and is considered a pest by those trying to manage balanced bass-bluegill populations.

Similar Sympatric Species: Occasionally sympatric in upland streams with the smallmouth bass, *Micropterus dolomieu*, which has similar uniform coloration and body form but has the dorsal fins nearly separate and many more lateral-line scales (69 or more). Sympatric with all other *Lepomis*, none of which has as slender a body shape, or as large a jaw—except the warmouth which differs in having black bars on the cheeks and opercles. The bluegill (long pectoral fins) and bantam sunfish (incomplete lateral line) are the only *Lepomis* that have a similar dark spot in the posterior portion of the dorsal fin. Young-of-year (Fig. 130b), usually dark gray and lacking vertical banding, are most similar to *auritus*, *marginatus*, and *megalotis* (Figs. 130a,g,h), which have much shorter gill rakers.

Systematics: Placed in monotypic subgenus *Apomotis* Rafinesque by Bailey (1938). Mabee (1987) regarded *cyanellus* as a primitive member of *Lepomis*, as did Branson and Moore (1962) who, additionally, have *symmetricus* as its sister species.

Etymology: *cyanellus* = blue.



Range Map 181. *Lepomis cyanellus*, green sunfish (not native to Atlantic or Pacific slopes or Southwest).

Lepomis gibbosus (Linnaeus).

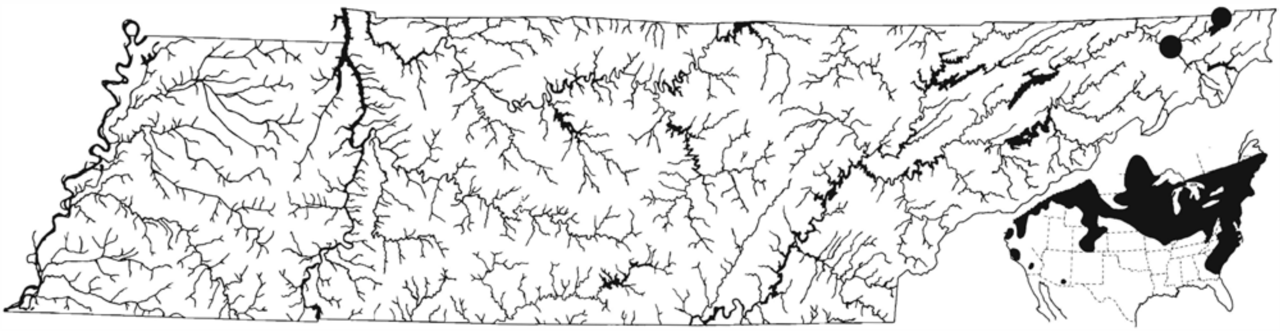
Pumpkinseed

Plate 190. *Lepomis gibbosus*, pumpkinseed, 80 mm SL, Potomac R. system, VA.

Characters: Lateral-line scales 35–43. Dorsal fin with 10 (10–11) spines and 11 (10–12) soft rays. Anal fin soft rays 9–10. Pectoral fin rays 13 (12–14). Gill rakers 9–12, length of longest rakers less than two times their basal width (adults) to about three or four times basal width in young-of-year. Vertebrae 28–29. Palatine teeth typically absent. Sides densely covered with dusky spots, either scattered or in rows, over a background of brassy yellow or olive green. Orange spots may also be present on the sides, and young specimens often have dark vertical bars. The breast is yellow to orange and the fins have a yellowish wash. Cheeks and opercles are marked by light blue vermiculations. The opercular lobe has a pale spot at the lower tip which becomes scarlet red in adults. Pigmentation of young shown in Figure 130c.

Biology: The pumpkinseed is an inhabitant of quiet, sluggish waters. Scarola (1973) reported reproduction occurs from June to August in New Hampshire; the spawning season is probably earlier in Tennessee. Males construct depression nests which are isolated or colonial in shallow water (less than 1 m). Females spawn in the nests of several males and are capable of producing from 600 to nearly 3,000 eggs during the spawning season. Small, non-nesting males may engage in "cuckoldry," racing into the nests of larger males to fertilize eggs (Gross, 1979). The nesting male guards the eggs until fry have hatched (3–10 days) and dispersed. Natural hybrids are known with warmouth, bluegill, and green, orangespotted, redbreast, and longear sunfish (Childers, 1967). Etnier (1966) reported pumpkinseeds in Minnesota growing to about 40 mm TL at age 1 with an additional 15 mm or so of growth per year through age 6. Growth diminished in 7-year-old fish, which averaged about 135 mm total length. Southern populations could be expected to grow faster but probably have shorter average life spans. Sadzikowski and Wallace (1976) reported young *L. gibbosus* fed most heavily on microcrustaceans (cladocerans, copepods) and chironomid dipteran larvae. They, along with Etnier (1971), reported adults feeding heavily on snails. The functional morphology of the pharyngeal apparatus and musculature has the capability for specialized activity patterns to feed on snails (Lauder, 1983). These findings indicate a primarily benthic-oriented feeding behavior. Stomachs of specimens from a Tennessee reservoir population contained chironomid dipteran larvae and a few terrestrial insects. These items, along with other benthic prey such as burrowing mayflies (Ephemeridae), may comprise the staples of their diet in Tennessee as snails are scarce in our reservoirs. Maximum size about 2.54 mm (10 in) TL and .45 kg (1 lb). World angling record .62 kg (1 lb 6 oz), New York.

Distribution and Status: The pumpkinseed is naturally distributed along the eastern seaboard and westward in the northern states and Canada through the upper Mississippi River, Great Lakes, and Hudson Bay drainages,



Range Map 182. *Lepomis gibbosus*, pumpkinseed (populations west of the Dakotas represent introductions; these extend northwest off the inset to southern Alberta and British Columbia).

but has been widely introduced elsewhere. In Tennessee, Fitz (1966) reported its apparently successful introduction into South Holston Reservoir, and it has moved downstream into Boone Reservoir in recent years. Reports of *L. gibbosus* occurring in Reelfoot Lake (Baker, 1937; Baker and Parker, 1938) are surely in error. While characters given approximate those of the pumpkinseed (possibly from the literature?), the specimen figured (1937) is clearly a hybrid combination involving other species of *Lepomis*.

Similar Sympatric Species: The redear sunfish, rarely sympatric, has similar coloration and other characters, but has longer pectoral fins, reaching to or beyond the dorsal fin base, and a more slender body. Young-of-year pumpkinseed (Fig. 130c) are similar to bluegill and redear sunfish (Figs. 130f,i); the bluegill never has red on the opercular lobe, but red is visible on pumpkinseeds as small as 35 mm SL or so.

Systematics: Placed in subgenus *Eupomotus* Gill and Jordan, along with *L. microlophus* by Bailey (1938). Branson and Moore (1962) and Mabee (1987) also hypothesized close relationships between these species.

Etymology: *gibbosus* = formed like the full moon.

Lepomis gulosus (Cuvier).

Warmouth

Characters: Lateral-line scales 36–44. Dorsal fin with 10 (9–11) spines and usually 10 soft rays. Anal fin soft rays 9–10. Pectoral fin rays 12–13. Gill rakers 9–13, length of longest rakers about four times (adults) to six times (young-of-year) their basal width. Palatine teeth present. Background color dark olivaceous to brassy yellow with profuse dark mottling on body and fins. Lower sides often with horizontal streaks or rows of small spots. Cheeks and opercles with 3–4 distinctive dark bars radiating posteriorly from eyes. The eye may be reddish, especially in breeding males. Young-of-year (Fig. 130d) with vertical dark bars with pale centers.

Biology: The warmouth, or "goggle-eye" as it is known in some areas, is an inhabitant of sluggish streams and lakes and is usually associated with areas of dense cover such as debris or weedbeds. It also occurs in brackish coastal systems (Desselle et al., 1978). Larimore (1957) has conducted a thorough study of the life history. Spawning occurs from May to July. Nest sites are generally selected near cover and are constructed in areas of silty debris rather than on cleaner substrates usually selected by other sunfishes. Larimore felt that warmouth were not colonial spawners by nature, but nests were necessarily crowded together when ample spawning habitat was not available. Ripe females allow themselves to be driven into the nest by the male whose coloration becomes very intensive during courtship. While circling the nest, the female periodically thumps the male on the side while simultaneously extruding eggs; presumably the male discharges milt at this time. The female enters the nest of one or several males repeatedly until all ripe eggs are extruded. After spawning, the male defends the nest for 5 days or so until the fry have hatched and dispersed. Natural hybrids are known between warmouth and several other sunfishes—including green, redbreast, and redear sunfish and pumpkinseed (Childers, 1967). In Illinois, young warmouth grew to about 40 mm TL at age 1, and averaged 84, 125, 162, 188, 203, 213 and 216 mm in the succeeding years through age 8, with males growing faster than females (Larimore, 1957). Germann et al. (1975) found similar patterns in southern Georgia warmouth populations except that growth was more accelerated in the initial years. Redmon and Krumholz

(1978) reported a much slower growth rate in a Kentucky stream population with age-4 individuals averaging only 133 mm TL. Young warmouth feed primarily on microcrustaceans and aquatic insect larvae. Larger specimens feed heavily on crayfish and other larger crustaceans, such as freshwater shrimp (*Palaemonetes*), and a few small fish (McCormick, 1940; Larimore, 1957; Germann et al., 1975; Desselle et al., 1978). These prey items indicate a bottom-oriented feeding behavior. None of the studies cited listed terrestrial insects or other evidence of surface feeding. Warmouth are marginal as pan fish because of their small size, and most are taken incidentally while in pursuit of other pan fishes. Maximum size usually less than 230 mm TL (9 in). World angling record 1.12 kg (2 lb 7 oz), Florida, 1985 (Sternberg, 1987). Tennessee record .79 kg (1 lb 12 oz), Nolichucky River, 1984, Frank Garrett.

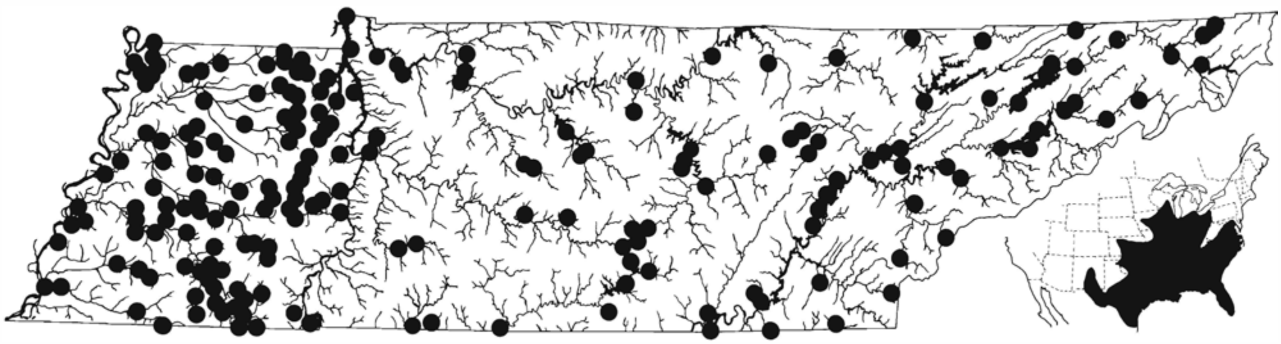
Plate 191a. *Lepomis gulosus*, warmouth, 93 mm SL, Reelfoot L., TN.

Distribution and Status: Mississippi River and Great Lakes basins, and in Atlantic and Gulf coastal drainages, above and below the Fall Line, from Chesapeake Bay through the Rio Grande. The warmouth is abundant in the lowland streams of western Tennessee and occurs less commonly in the fewer sluggish habitats that are afforded in eastern portions of the state, including reservoirs and large rivers. It is fairly abundant in Tennessee River reservoirs upstream as far as Watts Bar.

Similar Sympatric Species: In upland rivers, the warmouth may occasionally occur with the rockbass, *Ambloplites*, which has similar mottled coloration but has 5–7 anal spines. Young-of-year (Fig. 130d) have vertical banding similar to that of the bluegill (Fig. 130f), but are more darkly pigmented than other small *Lepomis*.

Systematics: Prior to the listing of Bailey et al. (1970), *Lepomis gulosus* appeared in the literature as *Chaenobryttus gulosus* (Cuvier). The synonymy of *Chaenobryttus* Gill with *Lepomis* by Bailey et al. was largely based on the high incidence of hybrids between the warmouth and members of *Lepomis* (West and Hester, 1966; Birdsong and Yerger, 1967; Childers, 1967; West, 1970). Results of biochemical systematic studies of Avise and Smith (1974a, 1977) were interpreted by them as indicative of a subgeneric relationship between these groups. However, some authors felt that sufficient

Plate 191b. *Lepomis gulosus*, warmouth, large male, 165 mm SL, Watts Bar Res., TN.



Range Map 183. *Lepomis gulosus*, warmouth (introduced populations on Pacific slope not shown in inset) .

morphological and genetic evidence existed to question this arrangement and therefore retained usage of *Chaenobryttus* (Merriner, 1971; Miller and Robison, 1973; Clay, 1975). Avise and Smith (1974a, 1977) placed *gulosus* within *Lepomis* as closest relative of *macrochirus* in their phenetic analyses of biochemical data. Mabee (1987) regarded it as the most primitive member of *Lepomis*.

In addition to the above situation, the warmouth also frequently appeared in the literature of the 1940s and 1950s as *Chaenobryttus coronarius* (Bartram). However, Bailey (1956) demonstrated the nomenclatoral priority of *gulosus*.

Bermingham and Avise (1986), based on DNA studies, found most warmouth populations investigated from the Mobile Basin and westward to constitute a separate lineage from those to the east.

Etymology: *gulosus* = large-mouthed.

Lepomis humilis (Girard).

Orangespotted sunfish

Characters: Lateral-line scales 32–42. Dorsal fin with 10 (9–11) spines and 10–11 soft rays. Anal fin soft rays 9. Pectoral fin rays 15 (14–15). Gill rakers 10–15, length of longest rakers about five times their basal width (young and adults). Vertebrae 29–30. Palatine teeth present. Unique among *Lepomis* in having the pair of sensory pores between the eyes situated in depressions or pits. Nuptial males may have a bright yellow or orange breast and belly. The opercular lobe is conspicuously outlined with a broad white or pale green border. Most specimens, particularly juveniles (Fig. 130e), will appear more subdued, having only scattered dark and orange spots. Juveniles have dusky bars on the sides.

Biology: *Lepomis humilis* is an inhabitant of turbid, sluggish waters. Barney and Anson (1922) have studied the life history. Spawning occurs from May to August. Female specimens collected from western Tennessee in August still contained many ripe ova. Small nests are constructed by the male in shallow, quiet water areas. Gerald (1971) indicated that sound production may be important during mating. After spawning, the male remains with and maintains the nest until hatching has occurred. Natural hybrids are known with bluegill, pumpkinseed, and longear and green sunfish (Childers, 1967). Growth data for Louisiana and Iowa specimens inferable from Barney and Anson (1922) indicate young grow to about 30 mm TL at age 1 and grow only about 10–12 mm per year thereafter through age 4. Populations from western Tennessee may approximate this growth rate; specimens over 1 year old (based on scale annulus formation) approaching the end of the second growing season (August) had attained an average of about 50 mm TL, and 2-, 3-, and 4-year-old fish had reached 60, 75, and 85 mm, respectively. Young-of-year were not present in the collection. Gonads had matured in 60 mm (2-year-old) specimens. Jenkins et al. (1955) tabulated comparable growth in several Oklahoma *L. humilis* populations. Barney and Anson's study indicated a diet composed chiefly of microcrustaceans and aquatic insect larvae, principally chironomid dipterans. Stomachs of Tennessee specimens contained both chironomid larvae and terrestrial insects, possibly indicating a varied feeding behavior between surface and bottom. The orangespotted sunfish is too small to be of much interest to anglers. Maximum size reported to be about 100 mm TL (4 in). The listed Tennessee angling record from the Nolichucky River is certainly based on a misidentification, as that area is well out of the range of *L. humilis*.

Distribution and Status: Central United States from the upper Mississippi River basin and southern Great

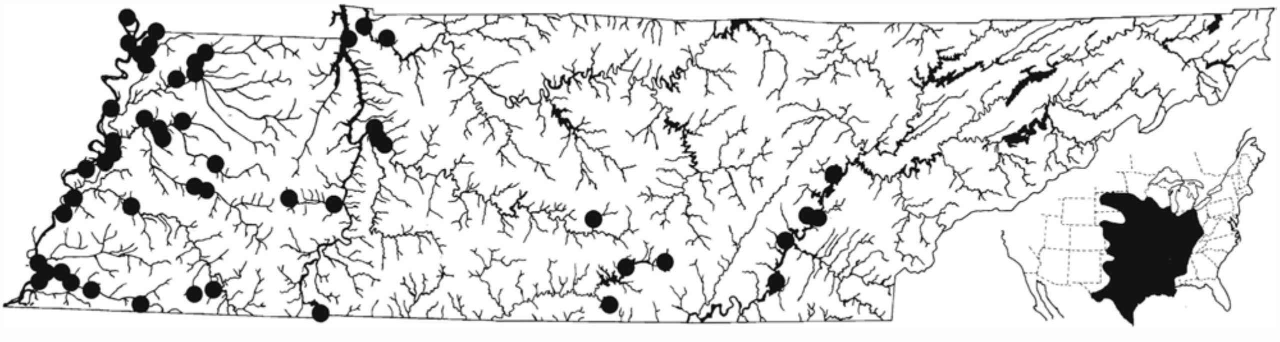
Lakes south, and in Gulf Coastal drainages from Mobile Bay through much of Texas. The orangespotted sunfish is locally common in turbid overflow swamps and backwaters of sluggish streams in western Tennessee and is also abundant in natural lakes of the Mississippi Floodplain. It also has apparently found a niche in reservoirs as it occurs in mainstream impoundments of the Tennessee and Cumberland rivers.

Plate 192a. *Lepomis humilis*, orangespotted sunfish, female, 58 mm SL, Reelfoot L., TN.

Similar Sympatric Species: Young specimens of the bluegill (*L. macrochirus*), redear sunfish (*L. microlophus*), dollar sunfish (*L. marginatus*), and longear sunfish (*L. megalotis*) (Figs. 130f–i) would be most likely confused with *L. humilis*. Young-of-year of *humilis* (Fig. 130e) have the entire caudal fin pigmented on rays and membranes. In other *Lepomis* (except *cyanellus* and *gulosus* over about 30 mm SL) the caudal fin of young is pale throughout or is pigmented only distally. Young *cyanellus* and *gulosus* have a darkly pigmented breast (pale in *humilis*).

Systematics: Placed in monotypic subgenus *Allotis* Hubbs by Bailey (1938). Branson and Moore (1962) and Avise and Smith (1977) hypothesized close rela-

Plate 192b. *Lepomis humilis*, orangespotted sunfish, breeding male, 62 mm SL, Reelfoot L., TN.



Range Map 184. *Lepomis humilis*, orangespotted sunfish.

tionship to *macrochirus*, but Mabee (1987) placed *humilis* as sister to a lineage containing *auritus*, *megalotis*, *gibbosus*, and several other species.

Etymology: *humilis* = humble, perhaps in reference to the small size.

Lepomis macrochirus Rafinesque.

Bluegill

Characters: Lateral-line scales 39–44. Dorsal fin with 10 (9–11) spines and 11 (10–12) soft rays. Anal fin soft rays 11–12 (10–12). Pectoral fin rays 13–14. Gill rakers 13–16, the longest four to five times as long as their basal width (Fig. 132a). Vertebrae 28–29. Palatine teeth typically absent. Color of dorsum olivaceous, breast and belly white to light orange. The sides are traversed by about 8–10 sets of double bluish vertical bars which may be chain-like in appearance. The opercular lobe is black throughout, and a dusky spot is present in the posterior soft dorsal fin in specimens larger than 50 mm SL. Pigmentation of young is shown in Figure 130f.

Plate 193a. *Lepomis macrochirus*, bluegill, 162 mm SL, Reelfoot L., TN.

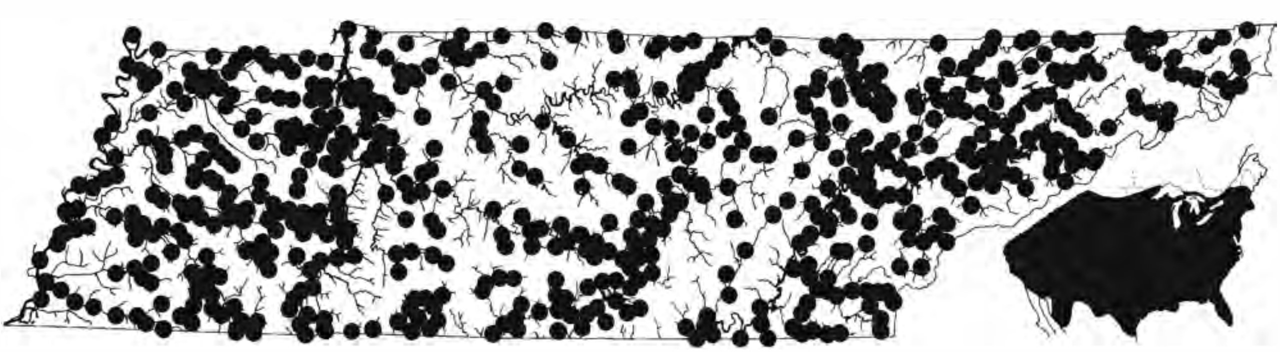
Biology: The bluegill is an inhabitant of both streams and lakes of all dimensions. It is most abundant in lakes and ponds where it frequents shallow water near the cover of vegetation, submerged wood, or rocks. It also occurs in less brackish portions of coastal estuaries (Desselle et al., 1978). Owing largely to its value as a food and game fish, the bluegill has had many studies conducted on its life history. Spawning occurs from late spring well into the summer. Colonies of nests are generally constructed by males in shallow water areas on varied substrates, preferably gravel (Stevenson et al., 1969). Spawning behavior is similar to that described for other members of *Lepomis* with females spawning in the nests of several males over the season. Dominey (1980, 1981) has reported that non–nest-building males occasionally mimic females by assuming their coloration and behavioral patterns, enter the nests of territorial males, and participate in circling with them as if spawning. When females enter the nests, the mimic apparently then participates in fertilization of eggs. These small

Plate 193b. *Lepomis macrochirus*, bluegill, breeding male, 176 mm SL, Tennessee River, TN.

males are also known to dash into established nests, apparently fertilizing eggs (Gross, 1979). Natural hybrids are known with eight other *Lepomis* species (Childers, 1967), perhaps partially as a result of this "cuckoldry" behavior. The nesting male guards and maintains the eggs until hatching has occurred. Growth is highly variable between populations. In confined populations, without adequate predation, overcrowding and stunting is common. This very often happens in shallow ponds and small lakes. Growth may range from about 40 mm (Pflieger, 1975) to as much as 90 mm TL (Jenkins et al., 1955) during the first year. Studies conducted in Reelfoot Lake, Tennessee, indicating over 140 mm growth in the first year (Schoffman, 1938, 1945, 1948) appear to be in error as a result of sampling deficiency for smaller specimens caused by using "inch and a half mesh traps." Most studies indicate growth increments averaging roughly 40 mm in the second and third years of life and 12–25 mm the fourth and fifth years. Five or 6 years is the indicated average life span. Young bluegill are gregarious and frequent weedbeds or other areas of heavy cover. Adults are somewhat more solitary, but appear to be more gregarious than other *Lepomis*. Feeding occurs primarily near vegetation or other cover. The diet is quite varied with heavy usage of midge larvae and microcrustaceans, particularly by younger individuals. There is heavy seasonal utilization of emergent aquatic insects and fallen terrestrial invertebrates (McCormick, 1940; Etnier, 1971; Sadzikowski and Wallace, 1976). There is also considerable, though perhaps incidental, ingestion of vegetable matter during summer. Wildhaber and Crowder (1991) demonstrated that bluegill are quick to shift feeding areas in response to food abundance. Experiments have also shown that bluegill select for larger prey items when prey is abundant but maximize foraging strategy by becoming less selective as abundance decreases (Werner and Hall, 1974). Goodyear and Bennett (1979) demonstrated that bluegill use sun-compass orientation to facilitate movements during predator avoidance maneuvers, a phenomenon probably pervasive in many fishes.

When one considers all methods of sport fishing, the bluegill probably accounts for more individual catches than any other game fish and has probably been the "first catch" of many children. It is commonly taken by bait anglers using worms, crickets, or grubs. Bluegill readily take spinners and small lures, and they provide great sport on fly rods on small popping bugs and wet or dry flies fished near vegetation or other cover. The bluegill is a tenacious fighter when hooked. Large specimens are fairly common in catches from western Tennessee, particularly from Reelfoot Lake or Kentucky Reservoir, and are abundant in well-managed ponds throughout the state. Specimens from streams and reservoirs in eastern portions of the state tend to be smaller, seldom exceeding 225 gr (.5 lb). Bluegills are often stocked in combination with largemouth bass and, occasionally, redear sunfish and channel catfish. This stocking strategy attempts to manage a balanced ecosystem in which the prolific young bluegill provide prey for the bass which prevent overcrowding and stunting of bluegill, thus increasing production of both species. The bluegill is an extraordinarily tasty panfish. Beheaded, gutted, and scaled, even smaller specimens provide morsels of firm white meat with a mild and distinctive flavor. With a little practice, one can quickly remove boneless fillets from larger fish. The world angling record, a whopping 2.16 kg (4 lb 12 oz) is from Ketona Lake, Alabama, 1950. The shared Tennessee record of 1.36 kg (3 lb) is from Fall Creek Falls Lake, 1977, Thelma Grissom, and a farm pond in Bledsoe County, 1987, Brad Pendergrass.

Distribution and Status: Native to eastern and central North America from Great Lakes area south to northern Mexico, but apparently not including Atlantic Coastal



Range Map 185. *Lepomis macrochirus*, bluegill (populations in western half of North America and northern Atlantic slope represent introductions).

drainages from Virginia northward. Widely introduced elsewhere, and now established throughout the United States and in many countries throughout the world. Common throughout Tennessee except in small Blue Ridge streams.

Similar Sympatric Species: The bluegill occurs sympatrically with all other members of *Lepomis*. The juveniles (e.g., Figs. 130d,i,k) of some other species have barred color patterns on the sides and may closely resemble the bluegill (Fig. 130f). Useful characters for distinguishing *macrochirus* specimens less than 50 mm SL from others include the lack of red or orange pigment in the eye, the pale breast and lower head, and the nonpigmented basal portion of the caudal fin.

Systematics: Placed in monotypic subgenus *Helioperca* Jordan by Bailey (1938). Closest relatives have been variously hypothesized as *humilis* (Branson and Moore, 1962), *gulosus* (Avise and Smith, 1977) and *symmetricus* (Mabee, 1987). Morphological (Felley, 1980) and genetic evidence (Avise and Smith, 1974b) support recognition of populations from peninsular Florida and southern Georgia as a distinct subspecies, *L. m. purpurescens* Cope.

Etymology: *macrochirus* = large hand, probably in reference to the body shape.

Lepomis marginatus (Holbrook).

Dollar sunfish

Characters: Lateral-line scales 34–41. Dorsal fin with 10 (9–11) spines and 11 (10–12) soft rays. Anal fin soft rays 9–10. Pectoral fin rays 12 (11–13). Cheek scale rows 3–4 (Fig. 133). Gill rakers 9–10, length of longest rakers equal to basal width (adults) to about twice basal width (young-of-year). Palatine teeth absent. Dorsum olivaceous, breast and belly pale yellowish to scarlet. In nuptial specimens, iridescent blue scales may be in evidence on the body and blue vermiculations usually adorn the cheeks and opercles. The eye is often reddish. The opercular lobe, which is generally expansive and angled somewhat dorsad in adults, is conspicuously outlined by white, and in adults from the Mississippi River basin there are consistently several silver or white blotches on the dark portion of the opercular lobe (B. M. Burr, pers. comm.). The distal halves of all fins often have an orange wash. Pigmentation of young is shown in Figure 130g.

Biology: The dollar sunfish is an inhabitant of good-quality lowland habitats such as unaltered sluggish streams, vegetated swamps, and natural lakes. Available life history information is not extensive, limited to that compiled in an unpublished study by McLane (1955) from work conducted in Florida, and by Lee and Burr (1985) in North Carolina. In North Carolina, dollar sunfish inhabit deeper water in winter and move to shallow water in May to spawn, with spawning continuing into August. Males construct nests on hard sand substrates, sometimes in high-density colonies. Males engage in considerable display and fighting, and smaller males are usually not successful in maintaining a nest. Spawning occurs repeatedly over the season, and males may be simultaneously guarding both eggs and broods of 150–200 larvae. Females, which remain in deeper water when not spawning, assume dark coloration (bars) when attempting to enter the nest area. Young attain a length of about 10 mm TL in one month. Size classes within a series from western Tennessee collected during August averaged 57 mm TL for age 1 (one scale annulus formed), 75 mm for 2, 83 for 3, and 95 for 4. No young-of-year were present in the collection. A life span of 6 years and sexual maturity at age 2 (60 mm) were indicated in the North Carolina study. McLane listed midge larvae and microcrustaceans as the major food items. Stomachs of specimens from Tennessee contained much detritus and filamentous algae and a few terrestrial insects (Homoptera, Hymenoptera), probably indicating both benthic- and surface-oriented feeding behavior. Dollar sunfish are too small to have much significance as pan fish. Maximum total length about 127 mm (5 in).

Distribution and Status: Atlantic and Gulf coastal drainages, mostly below Fall Line, from Pamlico Sound, North Carolina, through Brazos River, Texas. In Tennessee, restricted to the Coastal Plain. Due to its great similarity in appearance to younger specimens of the longear sunfish, *L. megalotis*, the distribution of *L. marginatus* has not been well understood in certain portions of its range. B. H. Bauer (pers. comm.), who has studied range-wide systematics of both species, has found many specimens cataloged interchangeably. Though sympatric over a wide area, the longear and dollar sunfishes seldom occur together as the former has more preference for flowing streams in this portion of its range. Channelization has doubtless altered many suitable habitats for *L. marginatus* in western Tennessee and, while still quite common locally, it may have formerly been much more abundant in the state.

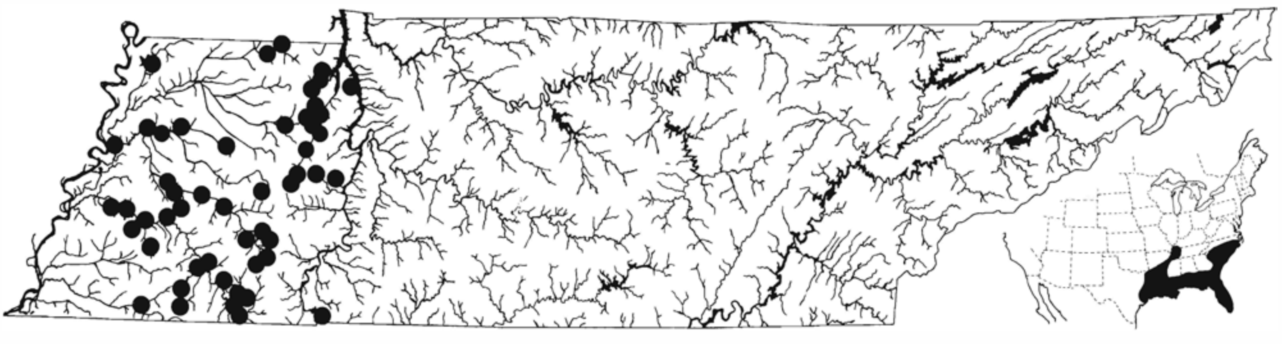
Plate 194a. *Lepomis marginatus*, dollar sunfish, 70 mm SL, Reelfoot L., TN.

Similar Sympatric Species: *Lepomis marginatus* and *L. megalotis* are sympatric in western Tennessee, and any candidate specimens from lowland habitats in this region which are less than 100 mm (4 in) or so in length should be carefully compared to characters given in the Key. Young of these species are very similar (Figs. 130g,h) but are separable on cheek scale rows and shape (see Key).

Systematics: Subgenus *Icthelis*, along with *L. megalotis* (Bailey, 1938), a close relationship agreed on by other students of centrarchid systematics previously cited.

Etymology: *marginatus* = edged, possibly in reference to the pale-bordered opercular lobe.

Plate 194b. *Lepomis marginatus*, dollar sunfish, breeding male, 87 mm SL, Hatchie R. system, TN.



Range Map 186. *Lepomis marginatus*, dollar sunfish.

Lepomis megalotis (Rafinesque).

Longear sunfish

Characters: Lateral-line scales 33–45. Dorsal fin with 10 (10–12) spines and 11–12 (10–12) soft rays. Anal fin soft rays 9–10. Pectoral fin rays 14 (13–15). Cheek scales in 4–6 rows. Gill rakers 9–11, length of longest rakers equal to their basal width (adults) to about two times basal width (young-of-year). Vertebrae 28–30. Palatine teeth absent. Adults attain brilliant coloration. Less colorful specimens are generally olivaceous dorsally and yellowish below. Blue vermiculations occur on the cheeks and opercles of freshly caught specimens. Juveniles (Fig. 130h) have reddish eyes and may have dusky vertical bars on the sides.

Plate 195a. *Lepomis megalotis*, longear sunfish, 81 mm SL, Mississippi R. slough, TN.

Biology: The longear sunfish occurs in a variety of habitats but is most common in moderately flowing streams where it occurs along the margins near cover such as vegetation, undercut banks, logs, or brush. Berra and Gunning (1972) have demonstrated that *L. megalotis* spends most of its life within a very small home range. However, they have the capacity to quickly redistribute themselves and repopulate stream segments from which they have been depleted (Berra and Gunning, 1970). Spawning occurs throughout early summer. Nests are often in evidence along the gravelly margins of streams where the brightly colored males can be seen devoutly guarding them. Longear are apparently social nesters, and large aggregations of nests may occur (Bietz, 1981). Witt and Marzolf (1954) and Huck and Gunning (1967) have described the spawning behavior. The brilliantly colored male circles about the nest, keeping the more drably colored female confined to the center. As in other *Lepomis*, the female periodically rolls on her side while eggs are extruded and fertilized. Gerald (1971) noted sound production during courtship and spawning. Females spawn in several nests, and fecundity may approach 4,000 ova per female (Carlander, 1977). After spawning, the male gently fans the nest, presumably mixing the eggs and sperm and cleansing the nest of excess milt and silt. This is followed by a period of violent fanning activity performed in a vertical tailstand position which may serve to drive the eggs into the gravel interstices for added protection. Witt and

Plate 195b. *Lepomis megalotis*, longear sunfish, breeding male, 110 mm SL, Barren R. system, TN.

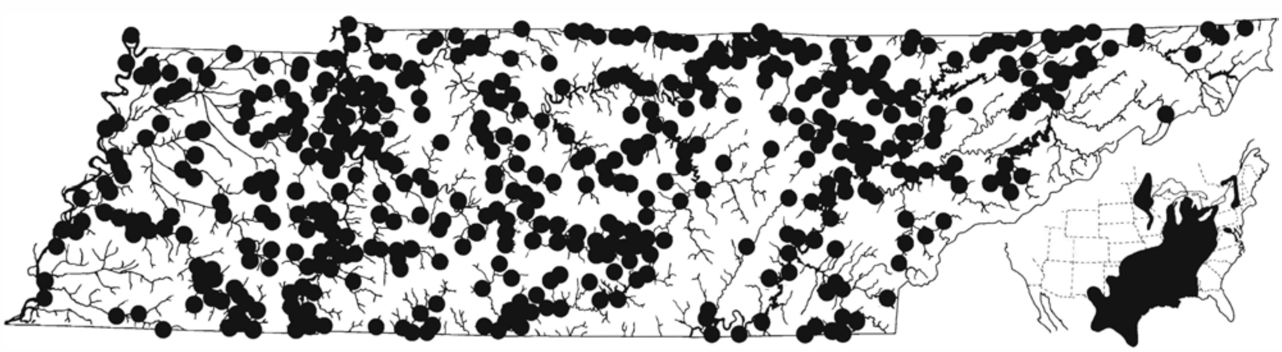
Marzolf also observed the male guarding the nest against all types of potential predators on the eggs, including large suckers. However, when approached by a sizable largemouth bass, the male fled, emphasizing its ability to distinguish between potential predators on itself and other large but nonpiscivorous species. Occasionally, however, gangs of smaller longear may successfully raid a nest and devour the eggs. Longears are known to hybridize naturally with bluegill, pumpkinseed, green, and orangespotted sunfishes (Childers, 1967). Growth of longear sunfish in Tennessee appears to approximate that tabulated by Jenkins et al. (1955) for specimens from Oklahoma populations which averaged 33, 69, 84, and 117 mm TL at ages 1 through 4, respectively. Specimens from a Tennessee stream population averaged 42 mm at age 1, and respective size classes thereafter corresponded closely to those given for Oklahoma specimens. Several larger specimens 130–150 mm TL were beginning their sixth year of life based on scale annuli. Reservoir populations from middle Tennessee apparently grow initially at a faster rate than stream populations. Specimens from Center Hill Reservoir studied by B. H. Bauer (pers. comm.) averaged 50, 79, 101, 114, 125, and 129 mm TL for age classes 1–6, respectively. Applegate et al. (1967) reported a diet of aquatic insects, entomostracans, fish eggs, and bryozoans, with adults feeding more heavily on terrestrial insects probably taken at the surface. Huck and Gunning (1967) observed predation on dragonflies and other insects that touched the water surface. Specimens from both streams and reservoirs may be taken by fishermen utilizing bait such as worms or crickets. They also will take small spinners, popping bugs, and dry flies. Most specimens are too small to serve as pan fish, but the occasional large specimens taken provide tasty morsels. This species doubtless accounts for much of the sport of anglers using light tackle in the small streams of middle and west Tennessee. Maximum size (Sternberg, 1987) .79 kg (1 lb 12 oz), New Mexico, 1985. The recognized Tennessee record is .36 kg (12.75 oz) from Overton County, 1985, Kay Forsberg.

Distribution and Status: Southern portion of Hudson Bay drainage (rare), Mississippi Basin, tributaries to lakes Huron, Michigan, and Erie, and Gulf Coastal drainages from Apalachicola River west through Rio Grande drainage in Mexico. The longear sunfish is widely distributed throughout Tennessee except in the highest portions of the Blue Ridge. It is much less common in the upper Tennessee drainage where it is broadly sympatric with, and possibly being supplanted by, the ecologically similar *L. auritus*. However, in the Conasauga (upper Coosa) system, these species continue to co-occur in roughly equal numbers. In addition to stream populations, the longear sunfish is abundant in some reservoirs in the Cumberland River drainage.

Similar Sympatric Species: The redbreast sunfish, *L. auritus*, sympatric in east Tennessee, is very similar in appearance but has palatine teeth, higher lateral-line scale counts (43–50) and lacks a pale margin on the opercular lobe. The dollar sunfish, *L. marginatus*, is sympatric with *L. megalotis* in west Tennessee and very closely resembles younger specimens of the longear. They are usually separable on pectoral ray counts, cheek scales, and body shape (see Key); *megalotis* lacks the white spots present on the dark portion of the opercular lobe of adult *marginatus*. Young-of-year (Fig. 130h) are separable from the very similar young of green and redbreast sunfishes (Figs. 130b,i) on the basis of lateral-line scale counts and their shorter gill rakers.

Systematics: See *L. marginatus*.

Etymology: *megalotis* = great ear, in reference to the large opercular lobe.



Range Map 187. *Lepomis megalotis*, longear sunfish (Atlantic slope populations represent introductions).

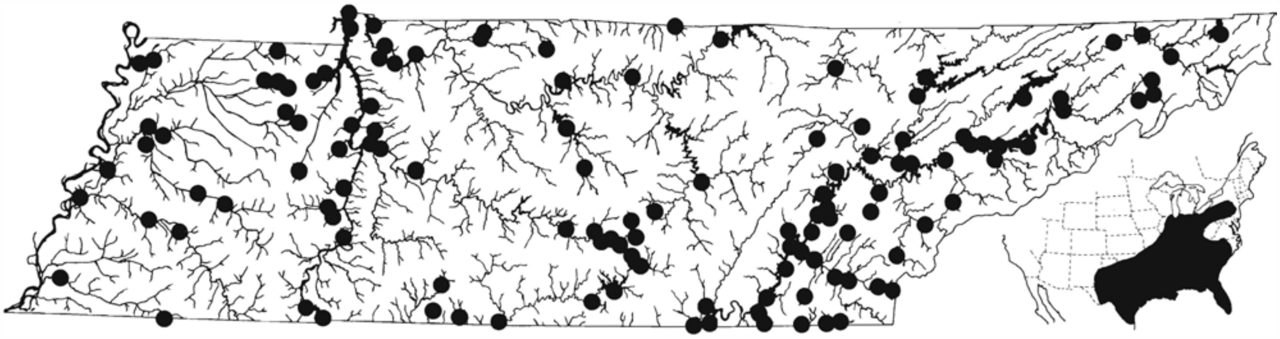
Lepomis microlophus (Guenther).

Redear sunfish

Plate 196. *Lepomis microlophus*, redear sunfish, 140 mm SL, Sulphur Fork R., TN.

Characters: Lateral-line scales 34–43. Dorsal fin with 10 (9–11) spines and 11 (10–12) soft rays. Anal fin soft rays 10 (9–11). Pectoral fin rays 13–14 (12–14). Gill rakers 9–11, length of longest rakers about twice their basal width (adults, Fig. 132b) to three times basal width (young-of-year). Palatine teeth absent. The redear is a less colorful fish than most other members of *Lepomis*. The body is gray to straw yellow with dusky spots. Nuptial specimens have orange tinges on the breast and fins and the eye is often reddish. A characteristic red spot appears at the tip of the short opercular lobe, lending to the redear's common name. Pigmentation of young is shown in Figure 130i.

Biology: The redear sunfish, or "shellcracker," is an inhabitant of sluggish waters such as lakes and backwaters of streams. It also occurs in less brackish portions of coastal environments (Desselle et al., 1978). Spawning occurs in May and June. Males construct nests, usually in colonies, in shallow water and, after spawning, presumably defend and maintain the nest until hatching has occurred. Gerald (1971) reported grunting sounds uttered during courtship. Fecundity of females ranges from 15,000 to 30,000 mature ova (Wilbur, 1969). Hybrids with at least four other species of *Lepomis* are known (Childers, 1967; Schwartz, 1972). Schoffman (1939) reported redear sunfish from Reelfoot Lake grew to over 50 mm the first year and attained a length of about 110 mm TL the second year. Studies in Oklahoma (Jenkins et al., 1955) and Florida (Wilbur, 1969) indicated that young grow to around 100 mm TL the first year and grow 35–40 mm per year through age 4; 5- and 6-year-old fish grow slower and average about 200–250 mm TL. Except in well-managed ponds, growth in most Tennessee populations is probably somewhat less than that reported in the Florida and Oklahoma studies as indicated in Schoffman's (1939) Reelfoot Lake report. Growth may be related to water clarity with populations from less turbid environments growing faster (Jenkins, et al., 1955). Redear sunfish feed primarily on benthic organisms. Midge larvae and burrowing mayflies comprise a major portion of the diet, and there is considerable consumption of snails, particularly in winter when other organisms are less abundant (McCormick, 1940; McLane, 1955; Wilbur, 1969). Young feed on microcrustaceans and small chironomid larvae. The pharyngeal arches of *L. microlophus* are modified, having extensive molar surfaces, and the musculature and muscle activity patterns are specialized for crushing mollusk shells (Lauder, 1983); this characteristic has caused them to become widely known as "shellcrackers." Tennessee reservoir populations are probably more reliant on chironomid larvae and burrowing mayflies as snails are scarce in these environments. Redear are often stocked in farm ponds, in combination with bass and bluegill, where they may grow to large size. Being principally benthic feeders, they fill a niche little utilized by their associates, and they do not tend to overcrowd and stunt as bluegills often do. The redear sunfish's fast growth rate, large size, and mild flavor make it a highly desirable pan fish. It is usually taken by fishing with live bait near the bottom but is occasionally taken on small lures. World angling record 2.18 kg (4 lb 13 oz) from Florida, 1986. Tennessee record 1.52 kg (3 lb 5.5 oz), farm pond, Hickman County, 1979, Annelise Houston.



Range Map 188. *Lepomis microlophus*, redear sunfish (many northern and western populations represent introductions).

Distribution and Status: The redear sunfish originally ranged from the southern Atlantic states to Texas and northward in the Mississippi Valley to Indiana and Illinois. However, it has been widely introduced elsewhere as a pan fish, and it is difficult to speculate on the natural limits of its range. In Tennessee, it is widespread but not abundant except in Reelfoot Lake and perhaps a few other natural lakes on the Mississippi Floodplain. It is also relatively common in the lower Duck River and some reservoirs.

Similar Sympatric Species: The redear sunfish occurs syntopically in Tennessee with the orangespotted sunfish, *L. humilis*, and possibly the pumpkinseed, *L. gibbosus*, both of which have similar coloration and pointed pectoral fins; however, *L. humilis* has palatine teeth, and neither of these species has the pectoral fin reaching to within 1–2 scale rows of the dorsal fin base. Young-of-year (Fig. 130i) show red on opercular lobes at about 30 mm SL and larger but are similar to young bluegill (Fig. 130f) in shape and coloration. However, their sides tend to be more spotted and less vertically banded than bluegill.

Systematics: See *L. gibbosus*. Bermingham and Avise (1986), in studying DNA variation in southern Atlantic and Gulf Coastal tributaries, found peninsular Florida populations distinctive, and Bailey (1938) considered these populations sufficiently distinct morphologically to warrant subspecies status.

Etymology: *microlophus* = small nape.

Lepomis punctatus (Valenciennes).

Spotted sunfish

Plate 197a. *Lepomis miniatus*, redspotted sunfish, 65 mm SL, Obion R. system, TN.

Plate 197b. *Lepomis punctatus*, spotted sunfish, breeding male, 113 mm SL, Conasauga R. system, TN (photo D.A. Etnier).

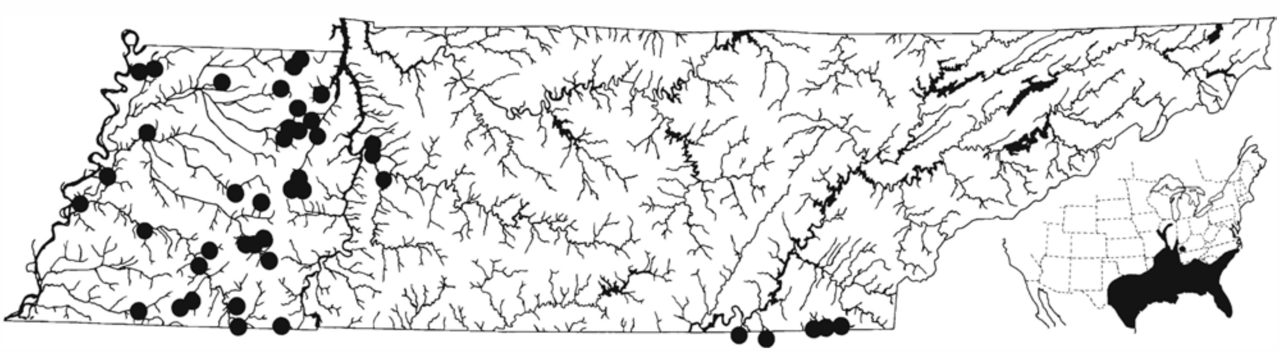
Characters: Lateral-line scales 34–40. Dorsal fin with 10 (10–11) spines and 10–11 (10–12) soft rays. Anal fin soft rays 10 (10–11). Pectoral fin rays 13 (13–15). Gill rakers 8–11, length of longest rakers about two times their basal width (adults) to three or four times basal width (young-of-year). Palatine teeth absent. Nuptial males are beautifully colored. Specimens in more drab states of coloration are dark olivaceous dorsally and pale yellow below. Younger specimens may have vertical bars of dark pigment on the sides and usually have scattered small dark spots on the sides of the body and head. Adult specimens from western Tennessee have rows of pale-centered scales on the sides which are often bright orange in life. Specimens from the Conasauga River system in southeastern Tennessee have horizontal rows of bicolored scales with a single vertically elongate intense black spot or a pair of smaller spots on each scale. The pale area on the anterior portion of the lateral line is characteristic of adults. Pigmentation of young is shown in Figure 130j.

Biology: The spotted sunfish, or "stumpknocker" as it is often called in the South, is an inhabitant of sluggish streams and swamps, as well as less brackish portions of coastal estuararies (Desselle et al., 1978). Spawning occurs from May to August. According to Carr (1946) and McLane (1955), males construct single or colonial nests in very shallow water near cover. As with other species of *Lepomis*, several females may spawn in the nest of a single male. Females aggressively attempt to enter nests but may be repelled by several males before being accepted. Gerald (1971) noted grunting sounds during courtship. Females deposit distinctive bluish eggs in the nest; eggs are guarded by the male until young have hatched and dispersed. Spotted sunfish are known to hybridize with bluegill (Childers, 1967). According to Finnell et al. (1956), young grow to about 33 mm TL in the first year, and subsequent age groups reach average lengths of 74, 114, and 150 mm. One-year-old fish in Tennessee collections examined averaged slightly larger, about 40 mm. Samples were insufficient to compare growth of other age classes. According to McLane (1955), spotted sunfish are highly insectivorous, feeding heavily on midge larvae and other immature insects. They also feed on microcrustaceans such as amphipods (*Hyalella*) and cladocerans. Most food items would appear to be of benthic origin, but there is minor utilization of surface prey items such as terrestrial insects. Spotted sunfish are often caught by "bream" anglers using crickets or worms as bait and also may be taken at the surface on popping bugs. While providing sport, the spotted sunfish is generally too small to be of much significance as a pan fish, though the flesh is firm and mild. Maximum total length about 200 mm (8 in).

Distribution and Status: Atlantic and Gulf coastal drainages from Cape Fear River drainage, North Carolina, through Rio Grande. Most abundant below fall line. The spotted sunfish is widespread in western Tennessee but seldom abundant except in habitats such as Reelfoot Lake and other natural lakes of the Mississippi Floodplain. Also occurs in Conasauga River in eastern Tennessee and South Chickamauga and Lookout creeks, tributary to the Tennessee River, in northern Georgia and perhaps Tennessee.

Similar Sympatric Species: Adults, with their stiff opercular lobes, pale spot on the anterior portion of the lateral line, and dark spots on the lower portion of the gill cover, are distinctive. Hybrids between green sunfish and bluegills are similar in general appearance but lack the above characters and usually have blue vermiculations on the cheek. Young-of-year (Fig. 130j), dark and lacking vertical dark bands, are most like *cyanellus*, *gulosus*, *marginatus*, and *megalotis* (Figs. 130b,c,g,h). They differ in tending to be deeper bodied than these species, and in having at least a few dark spots scattered along their sides.

Systematics: Placed in monotypic subgenus *Bryttus* by Bailey (1938). Branson and Moore (1962) and Mabee (1987) hypothesized a close relationship to *gibbosus* and *microlophus*, Avise and Smith (1977) to *auritus*. According to Bailey (1938), *L. punctatus* is divisible into two subspecies. The nominate subspecies, *L. p. punctatus*, which is distributed in the southern Atlantic states and westward through the Gulf Coastal drainages to Alabama, has rows of intense black spots on the



Range Map 189. *Lepomis miniatus,* redspotted sunfish, and *Lepomis punctatus,* spotted sunfish.

sides and scattered spots on the head. Adult specimens from the Conasauga River (Mobile drainage) in southeastern Tennessee appear referable to this form, although spots on the upper half of the body are much less distinct than those of specimens examined from southern Georgia and Alabama; they therefore appear somewhat intermediate between *L. p. punctatus* and the western subspecies, *L. p. miniatus* Jordan, which lacks black spots on the sides, having instead light orange spots. The latter subspecies inhabits the Mississippi Valley and occurs in western Tennessee. M. L. Warren (1992), based on morphological and biochemical evidence, hypothesized that *punctatus* and *miniatus* are separate species but upper Coosa system and Lookout Creek (Tennessee drainage) populations are of uncertain status. We tentatively allocate the problematic populations to *punctatus*, accept his recognition of *miniatus* at the species level, and, at this late date, must treat both taxa collectively. Bermingham and Avise (1986), studying DNA variation in *L. punctatus* in southern Atlantic and Gulf Coastal tributaries, found a genetic break between the Apalachicola drainage and those to the east.

Etymology: *punctatus* = spotted.

Lepomis symmetricus Forbes.

Bantam sunfish

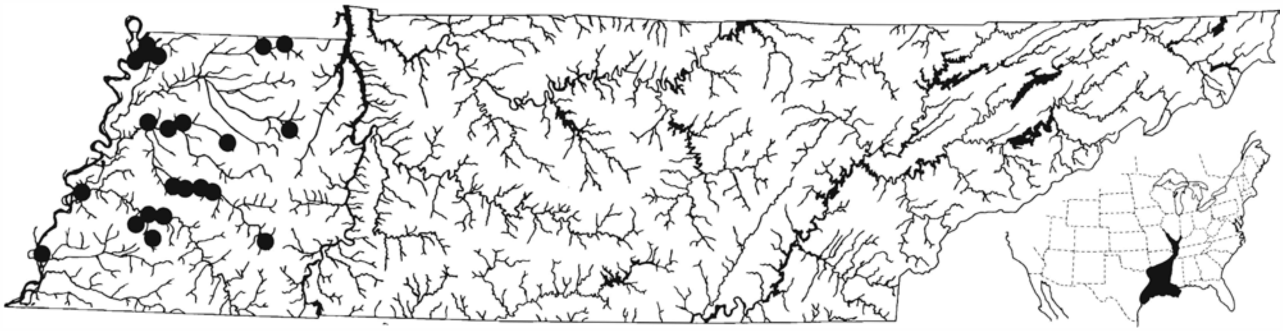
Plate 198. *Lepomis symmetricus*, bantam sunfish, 42 mm SL, Isom L., TN.

Characters: Lateral line usually incomplete or interrupted, with 20 or fewer pored scales, scales in lateral series 30–38. Dorsal fin with 10 (9–11) spines and 10 (9–12) soft rays. Anal fin soft rays 9–11. Pectoral fin rays 12–13 (11–13). Gill rakers 11–15, length of longest rakers about six to eight times their basal width. Palatine teeth present. Body dark olivaceous to brownish above and straw yellow below. Dark spots are scattered over the body, and vertical bars are often visible on the sides, especially in juveniles. Young specimens (Fig. 130k) have a distinctive basal ocellus in the posterior soft dorsal fin which has a dark center surrounded by a pale area which is sometimes reddish. This feature fades with maturity (about 60 mm SL) and appears as a dusky spot in adults or is absent altogether.

Biology: *Lepomis symmetricus* is a diminutive inhabitant of good quality (generally clear and well-vegetated) lowland habitats such as oxbow lakes and overflow swamps. The bantam sunfish is usually found in intimate association with submerged vegetation such as coontail (*Ceratophyllum*). Its systematics and biology have been well studied by Burr (1977). Spawning occurs in April and May. Nest building and consumated spawning behavior have not been observed but are believed similar to that of other members of *Lepomis*. The bantam sunfish is not known to hybridize with other sunfish. *Lepomis symmetricus* reaches about 45 mm TL at the end of the first year of growth and averages about 55 mm at age 2. Three-year-old specimens generally exceed 60 mm (2.3 in). Sexual maturity is reached at age 1. The young of bantam sunfish feed predominantly on small crustaceans (ostracods, amphipods, etc.), midge larvae, and small dragonfly nymphs. The diet of adults is similar but also contains snails and is supplemented by surface feeding on aquatic hemipterans and terrestrial insects. This species is much too small to be of significance as a pan fish, with a maximum total length of 93 mm (3.75 in).

Distribution and Status: Mostly below Fall Line in Gulf Coastal drainages from Jordan River of Mississippi west through Colorado River, Texas. The bantam sunfish is uncommon in Tennessee, persisting only in a few natural lakes and overflow swamps in west Tennessee, and it is still common in Reelfoot and Isom lakes. Channelization has probably destroyed many former habitats of this rather specialized and extremely interesting little sunfish, and it may have once enjoyed a more continuous distribution.

Similar Sympatric Species: The bantam sunfish would most likely be confused with younger specimens of the spotted sunfish, dollar sunfish (Figs. 130g,j), and possibly several other species in which the juveniles may have a barred color pattern. However, no other species of *Lepomis* has an incomplete lateral line. Fliers (*Centrarchus*) are our only other centrarchids with a dark spot in the posterior dorsal fin base in juveniles, but they have many more anal spines than the bantam sunfish.



Range Map 190. *Lepomis symmetricus*, bantam sunfish.

Systematics: Placed in monotypic subgenus *Lethogrammus* by Bailey (1938), who hypothesized *cyanellus* to be closest relative, as did Branson and Moore (1962). Mabee (1987) regarded *symmetricus* and *macrochirus* as sister species.

Etymology: *symmetricus* = symmetrical.

Genus *Micropterus* Lacepede
The Black Basses

The genus *Micropterus*, the black basses, contains some of our best-known game fishes, including the familiar large- and smallmouth basses. Four species occur in Tennessee. These "basses" of the sunfish family should not be confused with the temperate basses of the family Moronidae, which contains the striped and white basses and others, nor the sea basses of the family Serranidae. *Micropterus* is well differentiated from other genera of centrarchids and would be difficult to confuse with them. Generic characters include a relatively elongate body form, 3 anal spines, and usually 6 (6–7) branchiostegal rays. Unlike *Lepomis*, members of *Micropterus* do not frequently hybridize, but a few cases are documented (Whitmore and Hellier, 1988; Turner and Bulow, 1989). The taxonomy of the genus has been reviewed by Hubbs and Bailey (1940) and Bailey and Hubbs (1949). According to Ramsey (1975), the genus contains three "evolutionary lineages." The largemouth bass, *M. salmoides*, is the sole member of one lineage (equivalent to nominal genus *Huro* Cuvier); the smallmouth bass, *M. dolomieu*, and redeye bass, *M. coosae*, constitute a second lineage; and the third lineage is represented by the widely distributed spotted bass, *M. punctulatus*, and three more restricted species including an undescribed form (the "shoal bass") endemic to the Apalachicola drainage, the Suwannee bass, *M. notius* (Suwannee and Ochlockonee rivers, Florida), and the Guadalupe bass, *M. treculii* of central Texas. Relationships among these lineages were not postulated. Branson and Moore (1962) differed in surmizing that *coosae* was closest related to *notius* and other spotted bass-like members of the genus. Branson and Moore (1962) and Avise and Smith (1977) hypothesized a closer relationship of *Micropterus* to the genus *Lepomis* than to other sunfishes, a view not corroborated by Mabee (1987), who placed them in a separate phyletic lineage as a sister group to all other centrarchids.

All members of the genus *Micropterus* are highly predaceous and serve as top-level carnivores in their respective habitats. Their ferocity and generally good flavor have earned them great esteem as game and food fishes, and several species of *Micropterus* have been stocked in many parts of the world as sport fishes. Various aspects of the biologies of several species are treated in a compendium edited by Stroud and Clepper (1975). Adult bass are easily identified by characters given in the following key. In addition to characters given herein, an excellent discussion on identification of juvenile *Micropterus* appears in Ramsey and Smitherman (1972).

Etymology: *Micropterus* = small fin (in apparent reference to a torn fin on the type specimen which appeared as a small separate fin).

KEY TO THE TENNESSEE SPECIES

1. Sides of body with a distinct wide, often irregular, black lateral stripe or nearly confluent blotches 2
   Sides of body lacking a black midlateral stripe or blotches, being uniformly dusky or with vertical bars 3
2. Dorsal fins appearing well separated; length of shortest posterior spine less than half the length of the longest spine; lower sides without rows of spots (may have few scattered dusky spots); tongue without rectangular median tooth patch; soft dorsal and anal fin membranes lacking scales (a basal sheath one scale row wide may be present); mouth large, the maxillary extending behind eye in specimens over 150 mm TL; young-of-year (Pl. 202) lacking sharply contrasting caudal fin pigmentation . . . . *M. salmoides* p.433
   Dorsal fins not well separated, the length of the shortest posterior spine more than half the length of the longest spine; lower sides usually with rows of dark spots; tongue with a rectangular median tooth patch; basal one-third of soft dorsal and anal fin membranes with scales; mouth smaller, the maxillary not extending behind eye; young-of-year with sharply contrasting caudal fin pigmentation (Pl. 201) . . . . *M. punctulatus* p.432
3. Scales above lateral line 12–13; dorsal fin soft rays usually 13–14; lower sides rather uniform dusky; young-of-year with sharply contrasting caudal fin pigmentation (Pl. 200) . . . . *M. dolomieu* p.430
   Scales above lateral line 9–10; dorsal fin soft rays usually 11–12; lower sides usually with rows of dark spots; young-of-year lacking sharply contrasting caudal fin pigmentation (Pl. 199) . *M. coosae*

Micropterus coosae Hubbs and Bailey.

Redeye bass

Characters: Lateral-line scales 57–77. Dorsal fin with 10 (9–11) spines and 12 (11–13) soft rays. Anal fin soft rays 10 (9–11). Pectoral fin rays 15–16 (14–17). Developed gill rakers 6–8. Vertebrae 31–33. A circular patch of teeth is typically present on the tongue. Color olivaceous to bronze dorsally with dark mottling. Rows of dark spots are usually evident on the lower sides above the pale ventral area. Three dark bars are generally present on the cheeks of specimens of all sizes. The weakly patterned caudal fin of juveniles fades with maturity. The eyes are characteristically reddish, and tinges of red or orange may be present on the fins.

Biology: The redeye bass, or "Coosa bass," is an inhabitant of upland streams. It is a secretive fish usually remaining in proximity to heavy cover such as undercut banks, logs, and water willow (*Justicia*) beds. The biology of the redeye bass has been well studied in Tennessee (Parsons, 1954; Tatum, 1965; Cathey, 1973; Gwinner, 1973; Gwinner et al., 1975). Spawning occurs from April to June. Nests are constructed as shallow depressions in coarse gravel near the heads of pools. Where introduced into Cumberland Plateau streams, redeye bass have apparently occasionally hybridized with smallmouth bass (Turner and Bulow, 1989). After spawning, males remain with the nest until young have hatched and dispersed, which requires about 1 week. In their native habitat, the Conasauga River system (Mobile drainage), redeye bass grow to about 55 mm TL during the first year and grow an additional 25 mm or so per year through age 4; growth diminishes to 12–17 mm per year in the fifth and sixth years of life and to less than 6 mm annually thereafter. Maximum life span is 9–10 years. Adults average about 225 gr (.5 lb). Populations of *M. coosae* introduced into the Cumberland River system may have a somewhat higher growth rate than native populations (Gwinner et al., 1975). The redeye bass is a predator on terrestrial insects, crayfish, small fishes, salamanders, and aquatic insect larvae, indicating a varied feeding regime between surface and bottom. It is valued as a game fish because it fills the niche in cooler streams between cold-water trout and warmer-water species such as the spotted and largemouth basses. It is generally intolerant of impoundments. This attractive fish is taken on small lures and spinners, popping bugs and flies, and natural bait. Freshly molted (soft) crayfish would probably be a highly effective bait if allowed to drift beneath an undercut bank or log. Fishing for this species by wading, bank-walking, or canoeing in the Conasauga River watershed will provide an outing on some of the most beautiful streams remaining in Tennessee. Tennessee and world angling records are suspect due to frequent confusion with the smallmouth bass and the undescribed shoal bass of the Apalachicola drainage. Both of these species are much larger. Specimens over 360 mm (14 in) and about 1 kg (2.2 lb) are uncommon. The current Tennessee angling record listed from Little River may represent a smallmouth-spotted bass hybrid

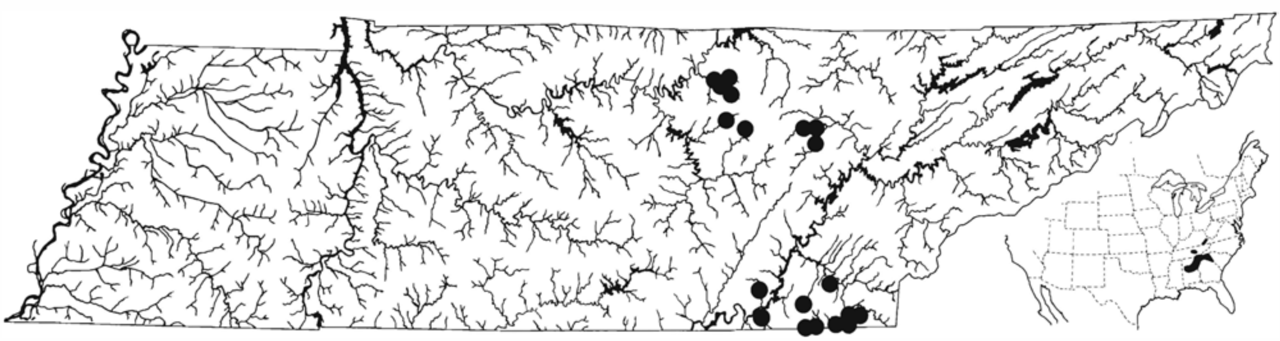
Plate 199a. *Micropterus coosae*, redeye bass, 158 mm SL, Conasauga R., TN.

Plate 199b. *Micropterus coosae*, redeye bass, juvenile, 38 mm SL, Conasauga R. system, TN.

(see comments below under Similar Sympatric Species).

Distribution and Status: The redeye bass is native to the Mobile Basin above the Fall Line and the extreme upper Chattahoochee, Altamaha, and Savannah drainages. In Tennessee, it is native only to the Conasauga River (Mobile Basin) and its tributaries. Populations in the adjacent Hiwassee system (Tennessee drainage) are the result of introductions dating back to 1943 (MacCrimmon and Robbins, 1975). Beginning in 1953, *M. coosae* was introduced into several streams draining the Eastern Highland Rim and Cumberland Plateau in Tennessee (Tatum, 1973) and appears to be successful there (Gwinner et al., 1975).

Similar Sympatric Species: The spotted bass, *M. punctulatus*, is somewhat similar in appearance, having rows of spots along the lower sides, but has a conspicuous, wide, black, midlateral stripe or nearly confluent blotches. In the Cumberland system, the smallmouth bass, *M. dolomieu*, is very similar in appearance but has smaller scales and more soft dorsal fin rays (see Key), and lacks spots on the lower sides. Young-of-year of both of these species have distinctly contrasting pigment patterns on the caudal fin, while in *coosae* there is little more than a dark submarginal band. Hybridization is occurring between redeye and smallmouth bass in some Cumberland Plateau streams (Turner and Bulow, 1989) with meristic counts presumably being somewhat intermediate. The infrequent hybrids between spotted and smallmouth bass are very similar to *M. coosae* in coloration and scale counts. The single specimen we have seen, from Little River, differs



Range Map 191. *Micropterus coosae*, redeye bass (disjunct Tennessee and Virginia populations represent introductions).

from *M. coosae* in having larger cheek and opercular scales, and in having the patch of teeth on the tongue about twice as long as wide.

Etymology: *coosae* = of the Coosa (river system).

Micropterus dolomieu Lacepede.

Smallmouth bass

Characters: Lateral-line scales 68–81. Dorsal fin with 10 (9–11) spines and 13–15 soft rays. Anal fin soft rays 11 (10–11). Pectoral fin rays 16–18. Developed gill rakers 6–8. Vertebrae 31–32. A small, round patch of teeth is typically present on the tongue in specimens from our area. Scales are present on the basal half of the soft dorsal and anal fins. Smallmouth bass are characteristically bronze-colored with dark dorsolateral blotches. Dark bars are often discernable on the sides, and three dark bars radiate from the vicinity of the eye across the cheeks and opercles. The eyes are usually reddish. Very young specimens are generally boldly patterned with vertical bars and blotches on the body and have a patterned caudal fin (Plate 200). This pattern disappears with maturity and specimens 50–75 mm TL are much more drab.

Biology: The smallmouth is an inhabitant of clear upland creeks, rivers, and lakes. Favored haunts are near submerged logs, stumps, or rock outcrops. In streams, such areas with some current are preferred (Probst et al., 1984). In reservoirs, steep rocky slopes along submerged river and creek channels are preferred and, in both streams and reservoirs, home ranges of several hundred meters, over which the bass wanders from cover to cover, may be established (Fajen, 1962; Hubert and Lackey, 1980). A great deal of biological information on this bass has been amassed by Carlander (1977). The smallmouth is an early spawner with most southeastern populations spawning in April or early May. Spawning is apparently induced by rising water temperatures and generally occurs at 15–18 C (Hubbs and Bailey, 1938). *Micropterus* hybrids are rare but documented (Whitmore and Hellier, 1988). We have one probable hybrid smallmouth-largemouth bass specimen from Watts Bar Reservoir and one smallmouth-spotted hybrid specimen from the Little River in Blount County; Turner and Bulow (1989) reported smallmouth hybridizing with introduced redeye bass in Cumberland Plateau streams. Differences in reproductive season and habitat preferences probably help limit spawning interaction between these species. Smallmouth nests are usually constructed in coarse gravel at depths less than 1 m (3 ft) near the margins of streams or lakes. As in other sunfishes, several females may spawn in the nest of a single male, resulting in several thousand eggs being deposited. Males guard the nest diligently until fry have hatched and dispersed. At normal temperatures, hatching requires about 4–6 days and fry swim up from the nest 5–6 days later (Neves, 1975). Transformation from larva to juvenile occurs at about 15 days (C. Wallace, 1972). Growth in Tennessee stream populations varies greatly with stream size and temperatures. In a population of a small, cool stream studied by Gwinner (1973), smallmouth bass grew to about 50 mm TL the first year, 99 mm the second, 120 the third, 165 the fourth, and had reached only about 200 mm TL at the end of 5 years. In a larger and warmer stream, growth was more than double that rate, with 5-year-old fish reaching 435 mm TL (Cathey, 1973). In reservoirs, probably due to higher average temperatures and longer growing season, greater food availability (particularly in the form of forage species such as shad), and less energy expenditure, smallmouth bass grow faster and to much larger size. In Norris Reservoir, growth averaged about 220 mm TL in the first year with successive lengths of 325, 367, 404, 440, 462, and 471 mm in the years thereafter (Eschmeyer, 1940; Stroud, 1948a). These studies were conducted during earlier, more productive years of Norris Reservoir, and growth is probably somewhat reduced from that rate today. *Micropterus dolomieu* is a heavy-bodied fish; mature specimens in the 470 mm (18 in) category generally weigh about 1.3 kg or more (3–4 lb). Beyond that length, the weight-to-length ratio increases greatly. In Canada, the smallmouth bass lives as long as 18 years, but the maximum life span is probably much less than that in the South. The smallmouth is a voracious predator, being highly piscivorous. There is also considerable consumption of insects and crayfish (Hubert, 1977), particularly in stream populations where this resource ranks first in the diet (Probst et al., 1984). Young smallmouth feed on microcrustaceans and small aquatic insect larvae but quickly assume a diet dominated by fish larvae (if available) and graduate quickly to successively larger fish prey.

The smallmouth bass is a favorite game fish. Millions of dollars are spent annually in this country on equipment, boats, travel, and other expenses by anglers in pursuit of bass, although a larger portion of this expenditure is doubtless by those in quest of the largemouth bass. The smallmouth is renowned for its fighting ability and relatively good pan qualities. Like other basses, it is taken by a number of methods—including casting

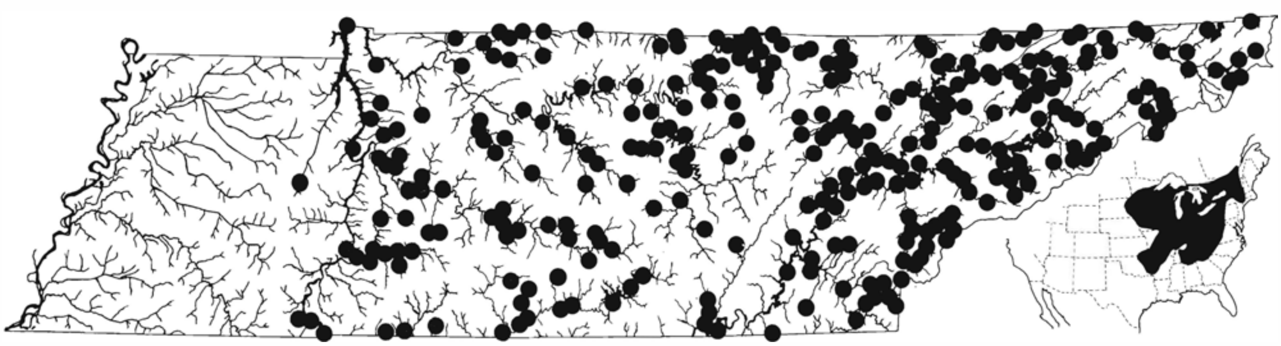
Plate 200a. *Micropterus dolomieu*, smallmouth bass, 185 mm SL, Woods Res., TN.

Plate 200b. *Micropterus dolomieu*, smallmouth bass, juvenile, 56 mm SL, Little R., TN.

of lures, spinners, jigs, and plastic worms. During the warmer months, it also attacks surface lures and popping bugs delivered by fly rod. Jigging (described under largemouth bass) is also occasionally successful. Minnows, soft crayfish, hellgramites, and salamanders are effective natural baits. While often taken in reservoirs, smallmouth fishing from canoes or small boats, or by wading, in Tennessee's upland rivers can be highly rewarding in sport and pan fare, as well as providing a scenic outing. Tennessee is near the southern extreme of the species's range, and the longer growing season has manifested itself in the form of many lunker specimens of smallmouth, including the world record of 5.2 kg (11 lb 15 oz), taken from the Kentucky portion of Dale Hollow Reservoir in 1955 by David L. Hayes, which is also listed as the Tennessee record.

Distribution and Status: The smallmouth bass was native to interior eastern North America west of the Appalachians but has been widely introduced elsewhere. MacCrimmon and Robbins (1975) stated that its native range "included all of Tennessee," but it is not known to occur in Tennessee west of the lower Tennessee River drainage and, considering the predominantly lowland characteristics (sandy-silty, low gradient) of tributaries to the Mississippi River in that region, it is doubtful that established populations ever occurred there in recent geological times.

Similar Sympatric Species: In some Cumberland River tributaries the smallmouth is syntopic and hybridizes with the introduced redeye bass, *M. coosae*, which is similar in appearance but has fewer soft dorsal rays (usually 12), larger scales, and rows of dark spots along the lower sides. Larger examples of the green sunfish, *Lepomis cyanellus*, resemble the smallmouth bass somewhat in body form and coloration but have fewer lateral-line scales (52 or fewer). Young-of-year are unique in having a boldly patterned caudal fin combined



Range Map 192. *Micropterus dolomieu*, smallmouth bass (widely introduced outside of approximate native range shown in inset).

with the absence of a dark lateral stripe. The hybrid smallmouth-largemouth bass specimen in our collection differs from both species in coloration. In life, the specimen was olive green overall with scattered dark spots over the midlateral region and three weak, dark stripes on the head radiating posteriorly from the eye. Scale counts are intermediate (65 in lateral line), pectoral rays are 15, only a few scales are present on the anal and dorsal fins, and teeth are lacking on the tongue. The smallmouth-spotted bass specimen in our collection was apparently uniformly olive green to gray in life, has very few dark spots scattered over the sides, and stripes posterior to the eye are extremely vague. It thus appears much as a smallmouth specimen but has noticeably much larger scales. Scale counts are intermediate (68 in lateral line), pectoral rays are 16, and an elongate, oval patch of teeth is on the tongue.

Systematics: Hubbs and Bailey (1940) recognized smallmouth populations from the Neosho portion of the Arkansas River system as a distinctive subspecies, *M. d. velox*. Deletion of the terminal "i" (often spelled as *dolomieui*) is mandated by recent changes in rules of zoological nomenclature (Bailey and Robins, 1988).

Etymology: *dolomieu* = a patronym for M. Dolomieu, a French naturalist.

Micropterus punctulatus (Rafinesque).

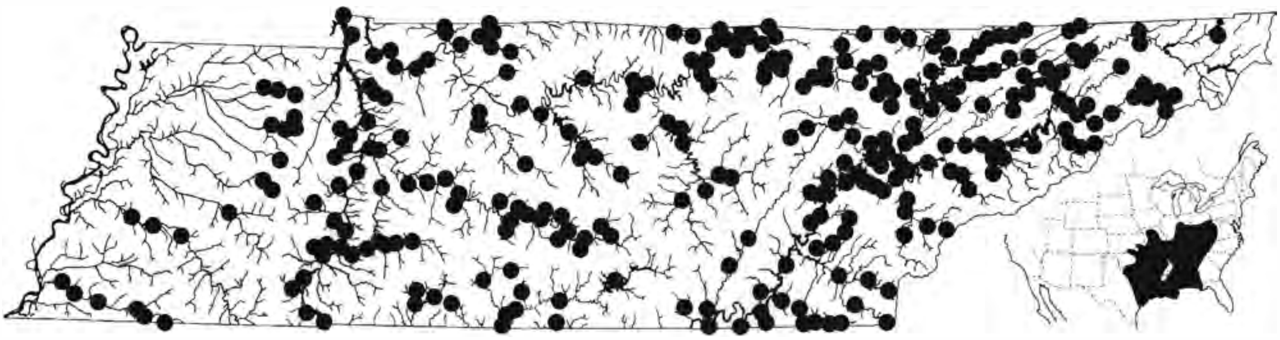
Spotted bass

Characters: Lateral-line scales 55–77. Dorsal fin with 10 (9–11) spines and 12 (11–13) soft rays. Anal fin soft rays 10 (9–11). Pectoral fin rays 14–17. Developed gill rakers 5–7. Vertebrae 31–33. Tongue with a rectangular tooth patch. Scales are present basally on the soft dorsal and anal fins. Dorsal area olivaceous and usually with dark blotching. Juveniles have a series of vertically elongate dark blotches along the sides which become more confluent with maturity, forming a wide irregular band. Three dusky bars are generally present on the cheeks and opercles. Juveniles have a boldly patterned tail. The eyes are usually reddish.

Biology: Spotted bass, also widely known as "Kentucky bass," are a smaller bass species inhabiting sluggish portions of streams of all dimensions and are also common in lakes and reservoirs. Spawning occurs in April and May; nests are constructed on either gravel or softer substrates (Viosca, 1931). Larger individuals often migrate into tributaries during the spawning season. The spawning habitat approximates that of the smallmouth bass, but the peak season is later in spring (Pflieger, 1975). We have recorded one smallmouth-spotted bass hybrid from Little River in Tennessee. Spotted bass males remain in the vicinity of the nest until fry have hatched. Growth in Tennessee reservoir populations averages about as follows: age 1, 160 mm TL; 2, 280; 3, 345; and 4, 390 (Eschmeyer, 1940; Stroud, 1948a;

Plate 201b. *Micropterus punctulatus*, spotted bass, juvenile, 65 mm SL, Red R. system, TN.

Plate 201a. *Micropterus punctulatus*, spotted bass, 180 mm SL, Norris Res., TN.



Range Map 193. *Micropterus punctulatus*, spotted bass (approximate native range, but eastern Gulf slope populations may represent introductions; additional introductions on Atlantic and Pacific slopes not shown).

Hargis, 1965). River populations generally grow at a slower rate. Respective lengths of age classes 1–5 in an Oklahoma stream population were 84, 165, 224, 277, and 320 mm TL (Finnell et al., 1956). Like large- and smallmouth bass, spotted bass are predacious on fish. In addition, crayfish and terrestrial insects supplement the diet, and younger specimens feed heavily on immature aquatic insects (Carlander, 1977). The spotted bass is another very important game species in Tennessee, being an integral part of both stream and reservoir catches. Spotted bass seasonally enter small streams (spring and summer) and can be readily taken on small lures or live bait such as minnows, crayfish, or salamanders. In reservoirs and larger rivers, they may be taken on similar tackle and often fall victim to jigging (see largemouth bass) during late winter or early spring when waters are turbid. Doubtless, a large portion of spotted bass taken are mistaken for the similar-appearing and better-known largemouth bass. While they do not attain the large maximum size of the large- or smallmouth basses, "two pounders" are not uncommon, and larger specimens are occasionally taken. Like its congeners, the spotted bass is a gamey fighter and a tasty pan fish. The listed world record is 3.91 kg (8 lb 10 oz) from Smith Lake, Alabama, 1972. Tennessee record 2.5 kg (5 lb 8 oz) from Center Hill Reservoir, 1989, Gary Martin. Specimens in the 5-lb range are not unusual in reservoirs of northern Georgia and Alabama.

Distribution and Status: Native to Gulf Coastal drainages from San Antonio Bay, Texas, east to but probably not including Apalachicola drainage. Common throughout Tennessee except in the Blue Ridge. Reservoir populations typically concentrated in rocky and headwater areas.

Similar Sympatric Species: The largemouth bass, *M. salmoides*, is quite similar in appearance but usually lacks rows of spots on the lower sides and is also easily separable on other morphological characters (see Key). Juveniles of the largemouth have a less bold tail pattern (Pl. 202) than that of spotted bass. See comments under *M. dolomieu* regarding characters of hybrids.

Systematics: Two subspecies of *Micropterus punctulatus* occur in Tennessee (Hubbs and Bailey, 1940). The nominate form, *M. p. punctulatus*, occurs in all drainages of the state exclusive of the Conasauga system, which contains the form endemic to the Mobile Basin, *M. p. henshalli*. The latter form has higher numbers of lateral-line scales (68–77 vs. 58–71) and caudal peduncle scale rows (26–29 vs. 22–27).

Etymology: *punctulatus* = dotted, in reference to the rows of spots on the lower sides.

Micropterus salmoides (Lacepede).

Largemouth bass

Characters: Lateral-line scales 55–68. Dorsal fin with 10 (9–11) spines and 12–14 soft rays. Anal fin soft rays 11 (10–12). Pectoral fin rays 14–15. Developed gill rakers 7–9. Vertebrae 30–32. Teeth absent from tongue. Scales are lacking on or confined to the extreme bases of the soft dorsal and anal fins. Color generally olivaceous green dorsally and pallid below with a wide black lateral stripe or nearly confluent blotches. There are usually a few scattered flecks of dark pigment on the lower sides. Eye color is brown. Juveniles with dark submarginal band on caudal fin.

Biology: The largemouth bass is a denizen of sluggish waters, particularly in larger streams and lakes. It is more tolerant of both turbidity and salinity than other members of the genus. A tremendous amount of biolog-

Plate 202a. *Micropterus salmoides*, largemouth bass, 255 mm SL, Reelfoot L., TN.

Plate 202b. *Micropterus salmoides*, largemouth bass, juvenile, 52 mm SL, Tennessee R. system, AL.

ical information has been published (summarized in Carlander, 1977) on this fish. The largemouth generally spawns from late April to June with nests being constructed on firm substrate along the shallow margins of rivers and lakes (Kramer and Smith, 1962). Hybrid *Micropterus* are rare, but we have recorded one smallmouth-largemouth bass hybrid from Watts Bar Reservoir. After constructing the nest, the male largemouth seeks out a ripe female and induces her to spawn through repeated physical contact. It is thought that most spawning encounters occur at dusk or dawn. The spawning pair make repeated passes over the nest, depositing eggs which become adhesive upon fertilization. This behavior continues until the female abruptly departs, leaving the male to guard the progeny (Carr, 1942). Several females may spawn in the nest of a single male. Fecundity of females varies greatly with size, ranging from 2,000 to 145,000 eggs (Carlander, 1977). The male devotes full time to guarding and maintenance of the nest for several weeks during the early development period of the young and does not feed during this time (Heidinger, 1975). Growth of largemouth bass in the Tennessee area averages better than 150 mm TL (nearly 6 in) in the first year; lengths reached at the end of years 2–8 average as follows: 268, 352, 404, 446, 484, 539, and 579 (Carlander, 1977). These averages represent a wide range of growth, with members of stream populations growing only slightly over 100 mm TL during the first year while some reservoir specimens may attain 170–190 mm. In Reelfoot Lake, Schoffman (1962) reported 2-year-old largemouth at 280 mm TL; growth in succeeding years averaged about 25 mm through age 11. The average maximum life span of Tennessee specimens is probably 10–12 years. At 350 mm (age 3), a healthy largemouth will average about 450 gr (1 lb). The rate of weight gain increases beyond that age with 4-year-olds weighing over 900 gr (2 lb). Ten- to 12-year-old specimens will generally tip the scales at 2.2–3 kg (about 5–7 lb) or more. Larger individuals are generally females as males either do not live as long or possibly undergo sex reversal as they become older (Heidinger, 1975). A hermaphroditic specimen has been reported (Penn and Parrish, 1979). Females are generally larger in every age group and seem better able to survive adverse conditions (Padfield, 1951). Largemouth bass feed both day and night. Feeding is motivated both by hunger and reflex ("striking") behavior (Vanderhorst, 1967). The latter may be most responsible for the effectiveness of artificial lures. Young bass feed on zooplankton, insects, small fishes, and are cannibalistic on one another; adults feed predominantly on fish and crayfish (Applegate and Mullan, 1967; Heidinger, 1975).

The largemouth rivals the rainbow trout as the most widely sought game fish in North America. Millions of dollars are spent annually that may be realistically or figuratively attributed to the pursuit of this species. Fishing methods are quite varied, including casting of scores of artificial lure designs. Artificial plastic worms are also very effective at times, fished with a bumping motion along the bottom, especially near obstructions or off rocky points in reservoirs. Bait anglers employ minnows, crayfish, and salamanders (especially effective if fished as noted for plastic worms). Popping bugs may be successful for fly rod anglers during the summer months, but largemouth seem less attracted to fly rod poppers than are smallmouth and spotted bass.

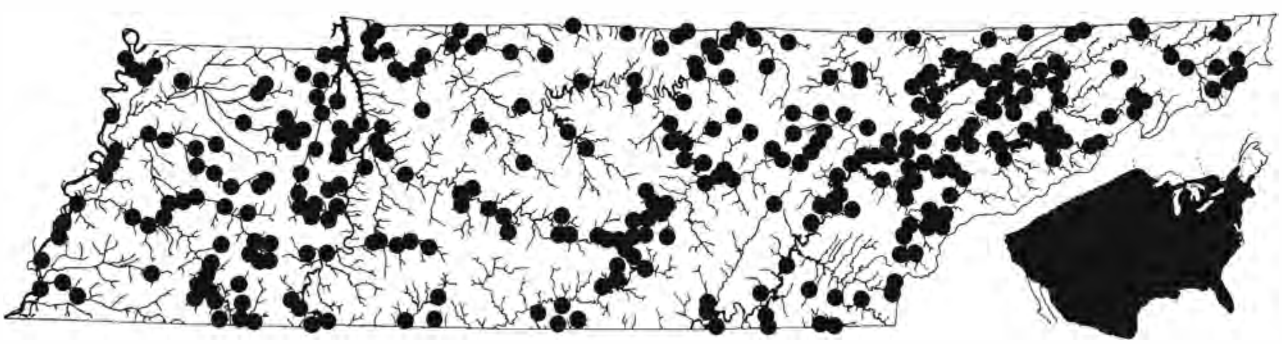
A unique method of fishing termed "jigging" has been devised in the region of Tennessee and is especially used in pursuit of large bass in local reservoirs. This is accomplished by attaching, by means of a heavy test line (40–50 lb), a large leadhead jig to a light but sturdy pole (cane poles will do, but commercially produced fiberglass jigging poles or heavy flyrods are better). The jig is baited with a mass of both live night crawlers and sections of artificial plastic worm; plastic skirts may also be attached. A large cork is placed on the line above. In early or late winter and early spring, after heavy rains, when waters are turbid and surface-layer temperatures are 45–58 F, this apparatus is bobbed up and down, causing it to quiver and pulsate, at depths of 1 to 3 feet along rocky and stumpy shorelines. This is best accomplished from a small boat quietly sculled along the shoreline, but an electric trolling motor can be used. If a bite is felt, the cork is set upon the water; when it sinks, a vicious strike is required to drive home the hook, at which time the victim is unceremoniously wrested into the boat. A relatively high percentage of bass caught in this way are lunkers. Besides largemouth, occasional specimens of spotted and smallmouth bass fall victim to jigging, as well as drum and catfish.

Largemouth bass generally do well in artificial lakes and ponds and are often stocked in combination with bluegill, redear sunfish, and catfish. Under ideal management conditions, the largemouth preys upon the bluegill, resulting in standing crops with many large individuals. This also enhances bluegill production by prevention of overcrowding and stunting. The world record of 10 kg (22.25 lb) is from Montgomery Lake, Georgia, 1932. The Tennessee record of 6.6 kg (14.5 lb) is from Sugar Creek, Lawrence County, 1954, Louge Barnett.

Distribution and Status: The largemouth bass was formerly indigenous to eastern and central North America but has been introduced in many parts of the world because of its sporting qualities. In Tennessee, it occurs statewide except in the higher-gradient streams of the Blue Ridge. It is most abundant in reservoirs.

Similar Sympatric Species: The spotted bass, *M. punctulatus*, is very similar in appearance, especially when taken from deep or turbid waters, but generally has discernible rows of dark spots posteriorly along the lower sides as well as other differences noted in the Key. Although largemouth from western portions of its range often have a few teeth on the tongue, they are not in the form of a rectangular patch and are rarely present in eastern populations. See comments under *M. dolomieu* regarding characters of hybrids.

Systematics: This morphologically most deviant member of the genus has been placed in the monotypic genus *Huro* Cuvier by many past workers (e.g., Hubbs and Bailey, 1940), a taxon generally regarded at the subgeneric level in recent decades. Populations from peninsular Florida are recognized as a valid subspecies, *M. s. floridanus* Bailey and Hubbs. It differs from the



Range Map 194. *Micropterus salmoides*, largemouth bass (native from Mississippi Basin and Great Lakes south to southern Atlantic slope and Gulf slope through northern Mexico; introduced populations extend off inset to southwestern Canada and South America).

nominate subspecies primarily in having smaller scales (65–75 lateral-line scales vs. 55–68, 28–32 rows of scales around caudal peduncle vs. 26–28), and in several additional scale counts (Bailey and Hubbs, 1949); it also has higher numbers of pyloric caecae (J. Buchanan, 1974). Supposed intergrades occur throughout Georgia (except for upper Coosa River system and Tennessee River drainage of northwest corner), southeast Alabama, and most of the Florida panhandle. The southern subspecies, because of its larger size, has attracted the attention of fishery biologists as potentially providing a "genetic boost" (better growth) for northern populations. Preliminary results of such experimentation are inconclusive, but not particularly encouraging (Warren, 1977).

Etymology: *salmoides*, from *salmo*, the trout, a name often formerly applied to this species in southern states.

Genus *Pomoxis* Rafinesque

The Crappies

The genus *Pomoxis* contains two widely distributed species; both are popular sport and food fishes. They are distinguished by very deep and compressed bodies, concave napes, presence of 5–7 anal spines, and contrasting black and white coloration. Closest relationships of *Pomoxis* are thought to lie with *Centrarchus* and *Archoplites* (Mabee, 1987). A recent compendium edited by Hooe (1991) provided abundant information on biology and management of these important lake and reservoir fishes.

Etymology: *Pomoxis* = sharp opercle.

KEY TO THE TENNESSEE SPECIES

1. Dorsal fin spines usually 5–6; dorsal fin soft rays 14; length of dorsal fin base much less than distance from dorsal fin origin to center of eye; dark mottling on sides usually forming discernable vertical bars . . . . *P. annularis*

   Dorsal fin spines usually 7–8; dorsal fin soft rays 15–16; length of dorsal fin base about equal to distance between dorsal fin origin and center of eye; sides randomly mottled with dark pigment (may be vertically barred in very young) . . . . *P. nigromaculatus* p.438

Pomoxis annularis Rafinesque.

White crappie

Plate 203. *Pomoxis annularis*, white crappie, 200 mm SL, Reelfoot L., TN.

Characters: Lateral-line scales 34–47. Dorsal fin with 6 (5–7) spines and 14–15 (13–16) soft rays. Anal fin with 6 (5–7) spines and 16–18 soft rays. Pectoral fin rays 14–16. Branchiostegal rays 7. Gill rakers 25–32, long and slender. Vertebrae 30–32. Body deep and laterally compressed. Color in life olivaceous to bright green or bluish gray dorsally and silvery on the sides with about 8–10 dark, irregular vertical bars and additional mottling. Specimens from turbid water may be quite pallid. Males become very dark during the breeding season.

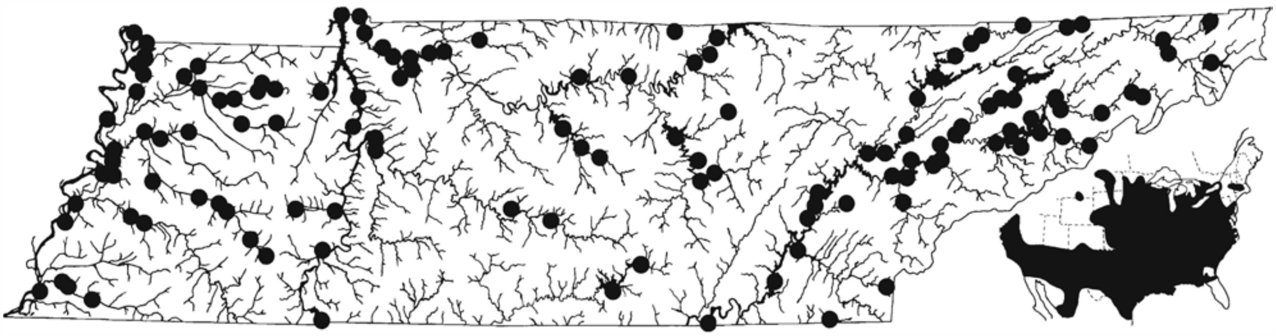
Biology: The white crappie is an inhabitant of sluggish streams and lakes and is quite tolerant of turbidity. It prefers areas having plentiful cover such as submerged brush or other obstructions. Spawning occurs from April to June. Spawning sites are generally in shallow protected areas such as coves or deeper overflow pools. Shallow nests are constructed near the cover of brush or overhanging banks and defended by the male. Females contain from 10,000 to 160,000 mature eggs depending on age and size and apparently spawn repeatedly in the nests of several males over the season. Hatching requires 2 to 5 days depending on water temperature; the males guard the nests until fry have dispersed (Seifert, 1968). Growth rates of white crappie vary greatly between populations, and overcrowding and stunting are common. Growth of individuals in those Tennessee reservoirs having relatively unconstrained growth rates averages 65–75 mm TL during the first year. Subsequent year classes average 180, 240, and 285 mm, respectively (Stroud, 1949; Fitz, 1965). Schoffman (1940, 1960) reported Reelfoot Lake specimens attaining about 230 mm TL at age 4 and maximum average lengths of 380 mm at age 9. Maximum life span is probably about 10 years, and sexual maturity is probably reached at age 2 by most individuals (Eschmeyer et al., 1944). Those individuals that survive to 5 or 6 years in reservoir populations would be expected to attain lengths of 300–400 mm (12–15 in) and weigh about 600–700 gr (1.5 lb) (inferable from Carlander, 1977). Adult crappie are piscivorous, feeding heavily on forage fishes such as shad. However, considerable amounts of microcrustacea and other plankton are also consumed. Younger crappie feed on small invertebrates, including microcrustaceans and small insects, but prey progressively more on fishes as they mature (Mathur and Robbins, 1971; Mathur, 1972).

Many thousands of white crappie are caught from Tennessee's lakes each spring in the weeks prior to spawning when, in apparent response to rising water temperatures or preparatory to spawning, these fishes go on a feeding spree. At this time, they are extremely vulnerable to anglers using small jigs, streamers, or minnows fished near underwater obstructions where they congregate. After the spawning season, crappie are seemingly more vulnerable to night fishing with minnows below lanterns until fall when they again are occasionally taken on lures. Due to their powers of proliferation, crappie are highly prone to overpopulation and stunting. Schoffman (1965) reported the Reelfoot Lake population overrun by smaller fish soon after the cessation of commercial fishing in 1955. It is apparently important to heavily fish crappie populations in artificial habitats as a management tool; in reservoirs, water-level fluctuations during spawning season have also been experimented with in this regard. Research has shown that harvest restrictions should definitely be avoided (Reed and Davies, 1991). To prevent over proliferation, hybrids between white and black crappie have been experimented with for stocking small impoundments (Hooe and Buck, 1991). Crappie are considered excellent pan fish by many and are one of our most obtainable fishery resources to the average fisher. World record 2.38 kg (5 lb 3 oz) from Mississippi, 1957. Tennessee record 2.3 kg (5 lb 1 oz), Dickson County, 1968, Bill Allen.

Distribution and Status: The white crappie was formerly indigenous to central North America east of the Rocky Mountains but probably did not occur in Atlantic drainages (inferable from Jordan and Evermann, 1896). Introductions have greatly expanded its range throughout the country. In Tennessee, the white crappie occurs statewide and is abundant in reservoirs or wherever sluggish turbid waters are found, excepting small streams where it is uncommon. It is much less common in habitats having clearer waters where the black crappie, *P. nigromaculatus*, may have a competitive advantage.

Similar Sympatric Species: The black crappie, *P. nigromaculatus*, is very similar but lacks bars on the sides and has more (7–8) dorsal spines. Even intensely darkened spawning male white crappies retain the vertical banding pattern. A black predorsal stripe, often present in black crappie, is apparently never present. The flier, *Centrarchus macropterus*, is also somewhat similar in appearance but has many more dorsal and anal spines.

Etymology: *annularis* = having rings, probably in reference to the bars on the body.



Range Map 195. *Pomoxis annularis*, white crappie (populations on Atlantic slope and in western half of North America represent introductions).

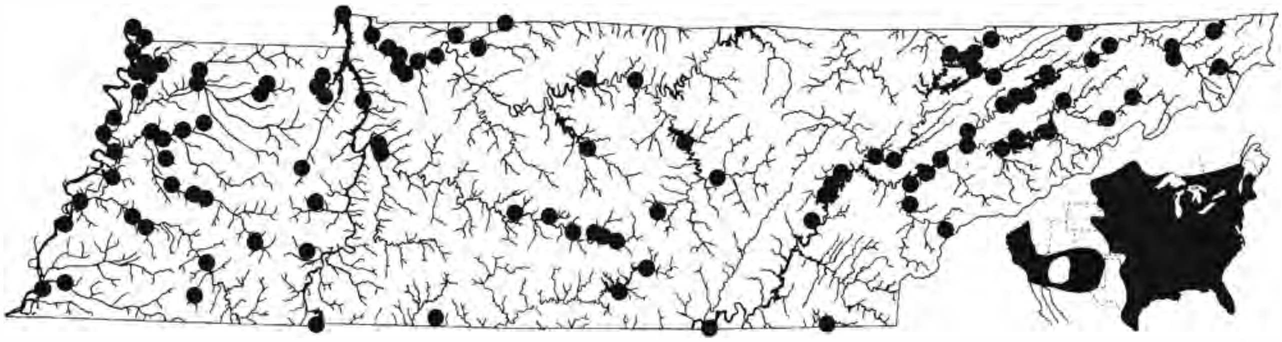
Pomoxis nigromaculatus (Lesueur).

Black crappie

Characters: Lateral-line scales 35–41. Dorsal fin with 7–8 (rarely 6) spines and 14–16 soft rays. Anal fin with 6–7 (5–7) spines and 16–19 soft rays. Pectoral fin rays 13–15. Branchiostegal rays 7. Gill rakers 27–32, long and slender. Vertebrae 31–33. Body deep and laterally compressed. Color olivaceous to bright green or bluish gray dorsally and silvery below with dark mottling. A black predorsal stripe, extending around the snout onto the chin, is present in about 30% of specimens in some areas (Buchanan and Bryant, 1973).

Biology: The black crappie closely resembles the white crappie, *P. annularis*, in its biology but has a decided preference for clearer waters, is much more abundant in natural lakes with clear waters and vegetation, and also does well in some of the less turbid reservoirs. Spawning behavior approximates that of the white crappie except that nests are more associated with vegetation where possible (Carlander, 1977) and it may have a preference for cleaner substrates. In Tennessee reservoirs, black crappie average about 80 mm TL after 1 year's growth with wide variation between populations (Carlander, 1977). Subsequent year classes average about 200, 250, 300, and 345 mm. This considerably exceeds estimates for a northern population reported by Vanderpuye and Carlander (1971). Schoffman (1940) reported 3-year-old black crappie averaging 200 mm TL in Reelfoot Lake; by age 8, individuals averaged 345 mm and weighed about 800 gr (1.75 lb). Maximum life

Plate 204. *Pomoxis nigromaculatus*, black crappie, 205 mm SL, Eagle Bend Hatchery, TN.



Range Map 196. *Pomoxis nigromaculatus*, black crappie (populations on northern Atlantic slope and in western half of North America represent introductions).

span is probably about 8 years, but few individuals attain it. Food habits of black crappie correspond closely to those of white crappie with young feeding on microcrustaceans and insects and with forage fishes becoming progressively more important in the diet as the fish matures. McCormick (1940) found primarily aquatic insects and freshwater shrimp in the diet of Reelfoot Lake specimens. Microcrustacea and other plankton may remain important in the diet of adults in some populations; the numerous long gill rakers are apparently well adapted to plankton feeding (Keast, 1968). Where common, the black crappie serves as an important game fish, with fishing techniques identical to those for the white crappie. Recent studies show that the black crappie may be supplanting the white crappie in abundance in Tennessee reservoirs that have developed extensive growths of aquatic vegetation (McDonough and Buchanan, 1991). World record 2.72 kg (6 lb), Louisiana, 1969. Tennessee record 1.93 kg (4 lb 4 oz), Browns Creek Lake, Henderson County, 1985, Clyde Freeman.

Distribution and Status: The black crappie was formerly indigenous to North America from the Mississippi Valley and Texas eastward excepting the Northeast. Its range has been greatly expanded by introductions. Due to its preference for clear and cooler waters, it has doubtless been replaced in abundance by the white crappie throughout certain portions of its range due to habitat alterations by humans which have resulted in higher turbidity. In Tennessee, it occurs sporadically statewide and does relatively well in the less turbid reservoirs; it is common in the less altered natural watercourses of western Tennessee. Like the white crappie, the black crappie is uncommon in small streams.

Similar Sympatric Species: See comments under white crappie, *P. annularis*.

Etymology: *nigromaculatus* = black spotted.

FAMILY PERCIDAE

The Perches

The percids are one of the largest families of fishes in North America, comprising about one-fifth of the fauna. They are outnumbered only by the speciose minnow family, Cyprinidae. They occur both in Eurasia and North America, with the genera *Gymnocephalus*, *Percarina*, *Romanichthys*, and *Zingel* restricted to Eurasia. The genera *Perca* (our yellow perch) and *Stizostedion* (sauger and walleye) have Eurasian counterparts. Darters (tribe Etheostomatini, genera *Ammocrypta*, *Etheostoma*, *Percina*) are restricted to North America. Darters may be related to the percin branch (*Gymnocephalus*, *Perca*, *Percarina*) of the family (Collette, 1963; Collette and Banarescu, 1977), the luciopercin branch (*Romanichthys*, *Stizostedion*, *Zingel*) (Page, 1985), or they may be paraphyletic with regard to Eurasian forms. One Eurasian species, the ruffe, *Gymnocephalus cernuus*, has recently become established in Lake Superior near Duluth, Minnesota, probably having hitchhiked to North America in the ballast water of a trans-Atlantic vessel.

The earliest fossils tentatively assigned to Percidae are those of the Eocene (38 million years ago) genus

Mioplosus Cope, known from the extensive Green River formations of the Utah-Wyoming region (see Grande, 1980). However, *Mioplosus* is considered to be a percichthyid rather than a percid by Cavender (1986), but percichthyids as now restricted (see under Moronidae) are not an appropriate repository for this genus either; the relationships of that genus thus remain unclear. The modern genera *Perca* and *Stizostedion* are represented in the upper Oligocene (23–25 million years ago) of Eurasia but are unknown in North America prior to the Pleistocene (Svetovidov and Dorofeeva, 1963). Like other perciform families accounted herein, the extrafamilial relationships of percids are unknown, although some authors have hypothesized that they were derived from a serranoid (sea bass–like) ancestor (e.g., Svetovidov and Dorofeeva, 1963; Collette and Banarescu, 1977). Additional works on the biology of percids are presented in Collette et al. (1977) and Craig (1987), and analytical overviews of reproductive biology and its implications with regard to phylogeny and distribution of these fishes is discussed by Balon et al. (1977) and Page (1985). Bailey and Gosline (1955) provided a thorough analysis of the varied vertebral counts among percids and their possible systematic significance. A similar survey was conducted by Collette (1965) on breeding tubercles.

Percids are characterized by separate or narrowly joined spinous and soft dorsal fins, only 1 or 2 anal spines, 5–8 branchiostegal rays, protractile or nonprotractile premaxilla, gill membranes free of isthmus, and a wide range (32–50) of vertebral counts. Cteni are well developed on scales, and a lateral line is present, though incomplete in several species. Swimbladders are absent or reduced in darters but well developed in *Perca* and *Stizostedion*. Breeding tubercles develop in many species.

Perches exist in a wide range of habitat types—from torrential to sluggish streams, to springs, swamps, and lakes. They exhibit a wide range of reproductive behavior. Percidae includes some of our most popular food and sport fishes as well as some of the most beautifully colored fishes in North America. In the latter category are many of the darters which exhibit bright chromatic coloration, especially in breeding males. Darters lead a primarily benthic- (bottom-) oriented lifestyle and generally have cryptic dorsal pigment patterns that camouflage them against the stream bottom upon which they usually rest. When disturbed, they may dart rapidly away to cover, hence their common name. They are diurnal, sight-oriented feeders, which consume primarily aquatic insect immatures and appear to be stimulated to feed primarily by prey movement (e.g., Orr, 1989). Because of their secretive habits and small size, darters are generally less well known to the casual outdoors person than the larger members of the family, the yellow perch, sauger, and walleye, which are highly sought sport fishes.

Classifications or studies of relationships among darters were presented by Bailey et al. (1954), Bailey and Gosline (1955), Page (1981) and Bailey and Etnier (1988). A type catalog of the darters was prepared by Collette and Knapp (1967). A recapitulation of their taxonomic history was prepared by Collette (1967). Biochemical studies on a broad selection of species were conducted by Page and Whitt (1973a,b). Morphology and histology of darter gill arches were treated by Branson and Ulrikson (1967). The lateralis sensory system of darters and its systematic implications were studied by Page (1977). Two recent books devoted exclusively to darters (Kuehne and Barbour, 1983; Page, 1983a) are welcome additions to the rapidly growing body of information on this fascinating group, and both are replete with color photos. Darters are interesting aquarium fishes, and most species will readily adapt to a diet of frozen brine shrimp, especially when in the presence of other fishes already attuned to this food source. Small earthworms, mealworms, "California blackworms," and other live foods are eagerly taken. Darters normally living in quiet waters sometimes breed successfully in aquaria, but techniques for successfully rearing young are not well established.

KEY TO THE TENNESSEE GENERA

1. Posterior margin of preopercle smooth (except in members of the subgenus *Hadropterus* of *Percina*); branchiostegal rays 5–6; maximum size usually less than 125 mm (5 in), occasionally to 175 mm (7 in); many species brightly colored: the darters (Etheostomatini) 2

   Posterior margin of preopercle strongly serrate; branchiostegal rays usually 7; adults larger, attaining lengths of 30 cm (12 in) or much more; colors generally more somber 4

2. Body very slender, the maximum depth usually contained 7 or more times in standard length; color pallid or translucent with dark pigment faintly developed; 1 anal spine; belly lacking scales .... *Ammocrypta*
Body slightly to much deeper, the maximum depth contained fewer than 7 times in standard length; dark pigment usually well developed; 1 or 2 anal spines; belly usually scaled 3
3. Breast and belly scales unmodified .... *Etheostoma* p.447
A large modified scale present between the bases of the pelvic fins (Fig. 135a); belly scales variable but often with a midventral row of modified, stellate scales (Fig. 135b) which may not be much in evidence except on males during the breeding season .... *Percina* p.560

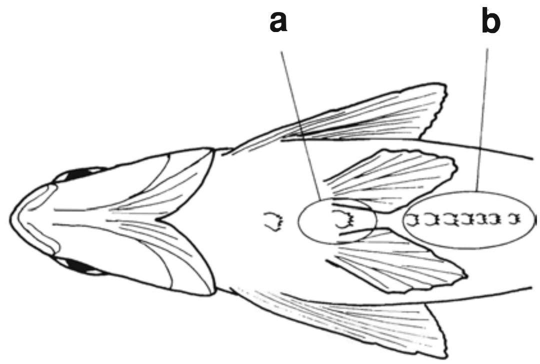


Figure 135. Ventral scalation of *Percina*: a) modified scale between bases of pelvic fins; b) modified midventral scales on belly.

4. Canine teeth well developed; anal fin soft rays 11 or more .... *Stizostedion* p.595
Canine teeth lacking; anal fin soft rays 8 or fewer .... *Perca* p.558

Genus *Ammocrypta* Jordan
The Sand Darters

The sand darters comprise a small genus of very distinctive fishes which are usually associated with sandy habitats. Their pallid coloration serves as camouflage against such substrates, and they often bury themselves in sand with only the eyes exposed. According to Jordan and Copeland (1877), this is accomplished by diving headfirst into the substrate while vigorously shaking the body, which stirs up a cloud of sand; the darter then sinks to the substrate, allowing the sand to settle on top of it. This behavior may be a predator avoidance mechanism but seems more related to stabilization of the darters' immediate environs under changing current conditions (Daniels, 1989). Burying behavior has also been noted in the darters *Etheostoma nigrum* and *E. vitreum* (Williams, 1975) and in the genus *Percina* in *P. caprodes* (our observations) and members of the subgenus *Imostoma* (Starnes, 1977). Trautman (1957) reported that sand darters (*A. pellucida*) periodically dash from their covert positions to snap up drifting food items. According to Forbes and Richardson (1920), Turner (1921), and our own investigations, midge larvae are the principal prey items.

Members of the genus *Ammocrypta* are characterized by their long slender bodies, pallid coloration, and scaleless bellies. The flesh is generally translucent, and the vertebrae can be seen in most freshly preserved specimens (except *A. asprella*). Shared generic characters include a single spine in the anal fin, 6 branchiostegal rays, separate gill membranes, complete lateral lines, uninterrupted lateralis canals on the head, posterior origin of dorsal fin relative to other percids, and the absence of a swimbladder. Sexual dimorphism is evident in the more pointed anal fin of males, and in fin pigmentation of males of several species.

The relationships of *Ammocrypta* to other darter genera have yet to be elucidated based on diverse data sets, and a sister group relationship between its two included subgenera has not been demonstrated (see further under genus *Etheostoma*). Therefore, efforts to subsume sand darters in the genus *Etheostoma* by some workers (e.g., A.M. Simons, in litt.) seem premature at this time.

Bailey and Gosline (1955) recognized two subgenera of sand darters. The monotypic subgenus *Crystallaria* Jordan and Gilbert (recognized as a genus by many) contains the widespread but rare *A. asprella*, which is characterized by large size (up to 150 mm), higher scale, dorsal fin soft ray, and caudal fin ray counts, the presence of palatine and vomerine teeth, and the presence of dark saddles on the dorsum. The remaining six species of sand darters are members of the subgenus *Ammocrypta*, whose members contrast with *Crystallaria* in the above characters. While this book was in press, Simons (1991), based on morphological comparisons, hypothesized that subgenera *Crystallaria* and *Ammocrypta* are phylogenetically remote, with *Crystallaria* sister to a lineage containing all other darters (genera *Etheostoma* plus *Percina*) with the six species contained in subgenus *Ammocrypta* considered closest relatives to the Atlantic slope sand-dwelling species, *Etheostoma* (*Ioa*) *vitreum*, placed together within a "*Boleosoma* group" (*E. nigrum* and relatives). While this hypothesis is quite possibly valid (but perhaps testable by additional data sets), at this late date we retain the previously accepted classification of *Ammocrypta*.

In addition to the three Tennessee *Ammocrypta* species, *A. bifascia* and *A. meridiana* occur in eastern Gulf Coast drainages, and *A. pellucida* occurs in the Ohio River drainage and Lake Erie tributaries. *Ammocrypta pellucida* has been recorded (Woolman, 1892) from the lower Cumberland River a few miles from the Tennessee border and probably occurred in the Tennessee portion of that river prior to impoundment. Many of Tennessee's streams are too rocky in character to afford much sand darter habitat, and many that formerly did have been drastically altered by human activities. Sand darters are currently very restricted in distribution in the state and are relatively rare where they occur. Their former distribution may never be well understood.

The following accounts have been based primarily on information in Linder (1959), a comprehensive work on the subgenus *Ammocrypta* (Williams, 1975), and our own data unless otherwise stated.

Etymology: *Ammocrypta* = sand concealed.

KEY TO TENNESSEE SPECIES

1. Dorsum with 4 broad saddles (sometimes indistinct); lateral-line scales more than 80; dorsal fin soft rays 12–16 . . . . . . (subgenus *Crystallaria)* . . . . . . *asprella* p.443
   Dorsum plain or with round spots, lacking broad saddles; lateral-line scales fewer than 80 (rarely 81); dorsal fin soft rays usually fewer than 12 . . . . . . (subgenus *Ammocrypta*) 2
2. Side of body with row of round or oval spots nearly as large as or larger than pupil; pelvic fins of males dusky; body relatively well scaled with 15–16 transverse scale rows (counted downward at 45° angle from second dorsal fin origin to anal fin base) 3
   Side of body plain or with small spots (much smaller than pupil) along midline; pelvic fins without black pigment; scales confined to midlateral area (3–6 transverse rows) 4
3. Long axis of lateral blotches vertical; dorsal fin of males with marginal and submarginal dark bands . . . . . . *vivax* p.446
   Long axis of lateral blotches horizontal; dorsal fin of males lacking dark bands . . . . . . (possibly extralimital) . . . . . . *pellucida*
4. Opercular spine present; cheeks and opercles partly scaled; fins lacking dark bands . . . . . . *clara* p.445
   Opercular spine absent; cheeks and opercles naked; unpaired fins of males with median dark band . . . . . . *beanii* p.444

Ammocrypta asprella (Jordan).

Crystal darter

Plate 205a. *Ammocrypta asprella*, crystal darter, male, 85 mm SL, Bayou Pierre, MS (photo S.R. Layman).

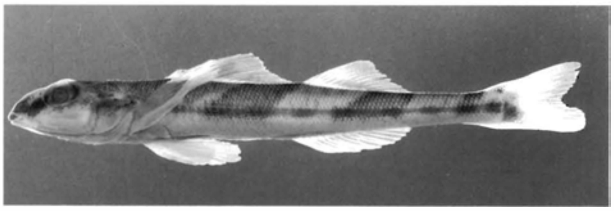
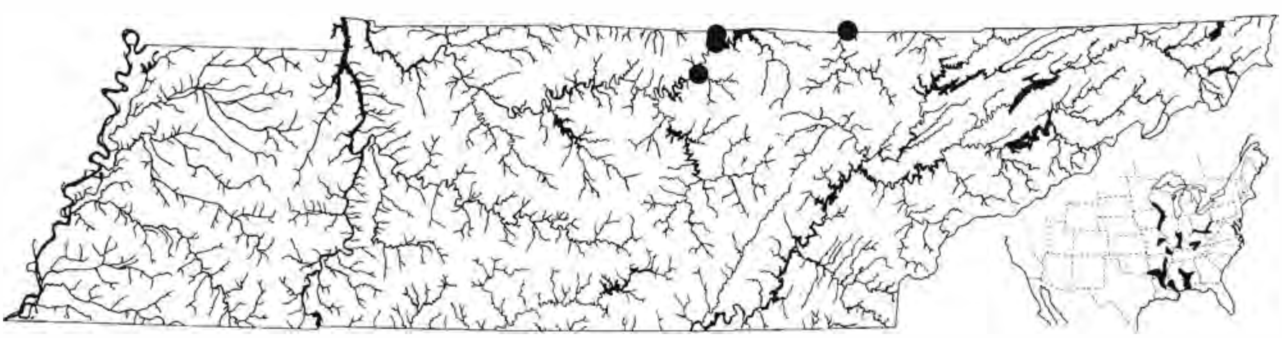


Plate 205b. *Ammocrypta asprella*, crystal darter, preserved specimen with well developed dorsal saddles, 58 mm SL, Saline R., AR.

Characters: Lateral-line scales 76–98, with 1–3 additional pored scales usually present at caudal fin base. Dorsal fin with 12–15 spines and 12–16 soft rays. Anal fin soft rays 12–15. Pectoral fin rays 15–17. Principal caudal fin rays 17–18. Gill rakers 12–15, blunt, with length of longest rakers about equal to their basal width. Vertebrae 45–58. Frenum present. Nape, opercles, and cheeks with exposed scales. Breast, belly, and prepectoral area naked. Teeth present on vomer and palatines. Opercular spine present. Slender, silvery fishes with a narrow, dark, midlateral band punctuated with about 8–10 elongate, oval blotches. Dorsum with four broad, dark saddles that angle anteriad. Fins clear or weakly speckled (caudal, soft dorsal, and pectoral fins) with brown. Nuptial males develop tubercles on ventral surfaces of pelvic fin rays 3–5 and all but the last 1–3 anal rays.

Biology: The biology of the striking and rarely collected crystal darter is essentially unknown. It inhabits swifter portions of clean sand and gravel shoal areas of medium to large rivers, and is probably intolerant of much siltation. Breeding tubercles develop in January and February (in Mississippi), suggesting an early spring spawning season. A mid-September series of 13 specimens in our collection, presumably the product of spawning the previous early spring or late winter, average 50 mm SL, and our smallest May specimens, presumably just over 1 year old, are about 70 mm SL. Data for Wisconsin specimens cited in Page (1983a) suggest similar first-year growth, and indicate a life span of about 3–4 years. Stomachs of specimens we examined from the Tombigbee River contained only heptageniid mayfly nymphs. Maximum length (Page, 1983a) 130 mm SL (about 153 mm TL, or 6 in), but growth data Page included for a Wisconsin population indicate total lengths up to 160 mm.

Distribution and Status: Widespread but with a very spotty distribution in the Mississippi and Ohio valleys north to southern Minnesota and Ohio, and Gulf Coastal drainages east through the Escambia River, Florida. The crystal darter has been rarely collected in Tennessee, with all records from the Cumberland River drainage. It was last collected in the state in 1939 from the Cumberland River in Clay County, and Roaring River, Jackson County (Shoup et al., 1941). An additional record, from about 1870, is available from the Big South Fork of the Cumberland River in Kentucky, just downstream from the Tennessee border (Comiskey and Etnier, 1972). Impoundments (Lake Cumberland, Cordell Hull and Dale Hollow reservoirs) have drastically altered big-river habitats in this region and have resulted in the apparent extirpation of these populations.



Range Map 197. *Ammocrypta asprella*, crystal darter.

The crystal darter is currently considered as extirpated from Tennessee, but a very remote possibility exists for its discovery in cleaner large tributaries to the lower Tennessee River (it is unknown from the entire Tennessee River drainage) or for its persistence somewhere within the Cumberland drainage.

Similar Sympatric Species: Easily separated from other *Ammocrypta* by characters in Key and species accounts. Similar in pigmentation to *Percina vigil*, which differs markedly in having 62 or fewer lateral-line scales and 2 anal spines, and is much less elongate.

Systematics: The subgenus *Crystallaria* has received generic recognition from authors of earlier decades (e.g., Moore, 1968), and several recent workers feel that the affinities of *asprella* may not lie with members of *Ammocrypta*.

Etymology: *asprella* is a diminutive of *Aspro*, a Eurasian percid (= *Zingel*) which this species resembles.

Ammocrypta beanii Jordan.

Naked sand darter

Plate 206. *Ammocrypta beanii,* naked sand darter, 50 mm SL, Hatchie R. system, TN.

Characters: Lateral-line scales 57–77 (58–68 in Tennessee). Dorsal fin with 8–11 (7–12) spines (9–11 in Tennessee) and 10–12 soft rays. Anal fin soft rays 9–10 (8–11). Pectoral fin rays 13 (12–14). Principal caudal fin rays 14–15. Gill rakers 5–6, length of longest rakers about twice their basal width. Vertebrae 39–41. Frenum absent. Scales absent except for caudal peduncle and several rows of scales extending to head along lateral-line area. No teeth on vomer or palatines. Opercular spine absent. Translucent pale yellowish in life, white to pale yellowish in preservative. Melanophores uniformly sprinkled along upper sides and fins (except pelvic fins), often forming blotches along dorsal midline, and forming median dark bands in unpaired fins, especially in nuptial males. Nuptial tubercles of males occur on ventral (occasionally dorsal) surface of pelvic fin spine and rays, and on rays of anal fin, typically with 1 tubercle per fin ray segment.

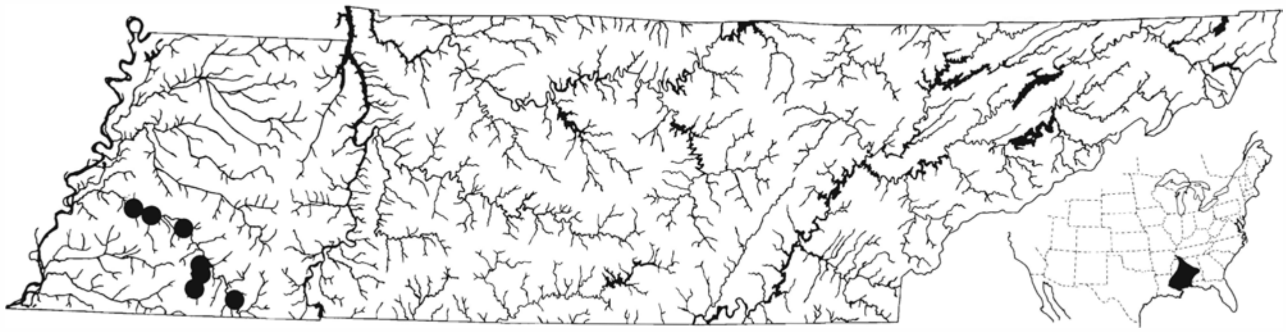
Biology: The naked sand darter is a denizen of shifting sand habitats with moderate current, and is generally found in rivers or medium to large creeks. Heins and Rooks (1984) studied several populations in southeastern Mississippi. They found specimens in breeding condition from late February through early October, with peak activity in May based on mean egg size and relative ovarian weight. Females 35–48 mm SL collected during April and May contained 27–120 mature ova. Both sexes reach sexual maturity at 32–34 mm SL, and a few individuals may reproduce at the end of their first summer. All are mature at age 1, and a 2-year life span was indicated. Specimens in our collection had fed exclusively on midge larvae, one of the few food items available in the sand darter's barren habitat. Maximum total length 60 mm (2.3 in).

Distribution and Status: Occurs below the Fall Line in eastern tributaries to the Mississippi River from the Big Black River, Mississippi, south, and in Gulf Coastal drainages eastward through Mobile Basin. The Hatchie River population in Tennessee is disjunct, and may be a relict of what once was a continuous range in eastern Mississippi River tributaries below the Fall Line prior to massive deposition of alluvium in that region or channelization of rivers by people. Headwater transfer from the adjacent Tombigbee headwaters of the Mobile Basin is an alternate hypothesis (Starnes, 1973), but this seems less likely since Hatchie River populations of *A. vivax* are also disjunct from those in southern Mississippi, and the Tombigbee River is occupied by *A. meridiana* rather than *A. vivax*. Although fairly common in suitable habitats in the Hatchie River and several of its larger tributaries, the naked sand darter is accorded Special Concern status in Tennessee (Starnes and Etnier, 1980) because of its restricted distribution.

Similar Sympatric Species: The scaly sand darter, *A. vivax*, is syntopic in the Hatchie River system, and is separable on color pattern and scalation as noted in the key.

Systematics: Williams (1975) hypothesizes two species groups within the subgenus *Ammocrypta,* with *A. beanii* grouped with *A. bifascia* of western Florida panhandle drainages and *A. clara* of central United States.

Etymology: *beanii* is a patronym for Tarleton H. Bean, ichthyologist, who collected the types of this species.



Range Map 198. *Ammocrypta beanii,* naked sand darter.

Ammocrypta clara Jordan and Meek.

Western sand darter

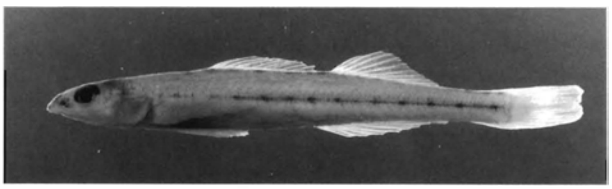


Plate 207. *Ammocrypta clara*, western sand darter, preserved specimen, 46 mm SL, Big R., MO.

Characters: Lateral-line scales 63–84. Dorsal fin with 10–12 (9–13) spines and 10–12 (9–13) soft rays. Anal fin soft rays 8–10. Pectoral fin rays 13–14 (12–15). Principal caudal fin rays 15–16. Gill rakers 10–12, length of longest rakers about 3 times their basal width. Vertebrae 39–40 (38–42). Frenum absent. Scales present on cheeks, opercles, caudal peduncle, and forming about three scale rows along lateral-line canal and continuing onto temporal area of head. Nape scaled or naked. Teeth absent from vomer and palatines. Opercular spine well developed. Body translucent yellowish to white in life. Small dusky blotches usually appear along the middorsal line, and a row of 12–16 spots is situated midlaterally. Cheeks and opercles may be iridescent greenish. Fins clear. Males have breeding tubercles on pelvic and anal fin spines and soft rays and on the lower 3–4 caudal fin rays.

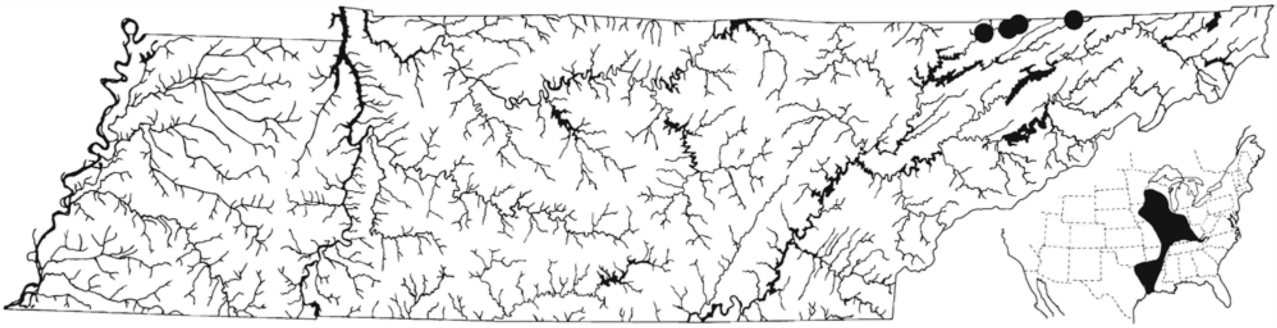
Biology: The western sand darter inhabits medium to large streams where it occurs in sandy areas with moderate current. Powell River, Tennessee, specimens were taken from a slight depression in bedrock which contained deposits of silty sand; water depth averaged about 1 m. Breeding season is probably July to August, based on tuberculation. Stomachs of specimens from Powell River contained exclusively midge larvae. Data summarized in Page (1983a) indicate a more variable diet of small aquatic insects, fecundity of 61–324 ova per female, and total lengths of 44, 56, and 61 mm after the first through third years of growth. Maximum total length 70 mm (2.75 in).

Distribution and Status: Widespread but with spotty distribution in larger rivers of the Mississippi River basin north to southern Minnesota, and in the Sabine River drainage of Texas and Louisiana. In Tennessee, *A. clara* is known only from the Powell and Clinch rivers, Claiborne and Hancock counties. It was probably first collected in Tennessee in Powell River in 1890 (reported as *A. pellucida*) by Woolman (1892), who reported it to be the most common darter. None of these specimens has been located, and the veracity of this report had been doubted until rediscovery in the Powell River in 1976 (Starnes et al., 1977) and subsequent collection of a few specimens in the upper Clinch River by TVA biologists. It is apparently exceedingly rare in these two well-collected areas, with collections perhaps corresponding to years of peak abundance. It is regarded as an Endangered Species in Tennessee (Starnes and Etnier, 1980). Both the Powell and Clinch river habitats are jeopardized by coal-related pollution originating in Virginia, and local gravel-removal operations pose an additional threat to the Powell River population.

Similar Sympatric Species: None in Tennessee.

Systematics: In *A. beanii* species group (*beanii, bifascia,* and *clara*) (Williams, 1975).

Etymology: *clara* = clear, in reference to the translucent flesh.



Range Map 199. *Ammocrypta clara*, western sand darter.

Ammocrypta vivax Hay.

Scaly sand darter

Plate 208. *Ammocrypta vivax*, scaly sand darter, 53 mm SL, Hatchie R., TN.

Characters: Lateral-line scales 58–79. Dorsal fin with 10–13 (8–14) spines and 9–11 (9–12) soft rays. Anal fin rays 8–10 (7–10). Pectoral fin rays 14–15 (13–17). Principal caudal fin rays 14–15. Gill rakers 8–10, length of longest rakers slightly longer than their basal width. Vertebrae 41–43. Breast and belly naked. Nape usually partially naked; remainder of body, including cheeks, opercles, and prepectoral area, scaled. Teeth absent from vomer and palatines. Opercular spine absent. Body pale yellowish to white with a middorsal row of 12–14 blotches and a row of brown spots midlaterally. Males generally have a narrow marginal band and a median band of dark pigment in the spinous dorsal fin. The cheeks and opercles may be iridescent greenish in life. Nuptial tubercles of males occur on spines and soft rays of the pelvic and anal fins.

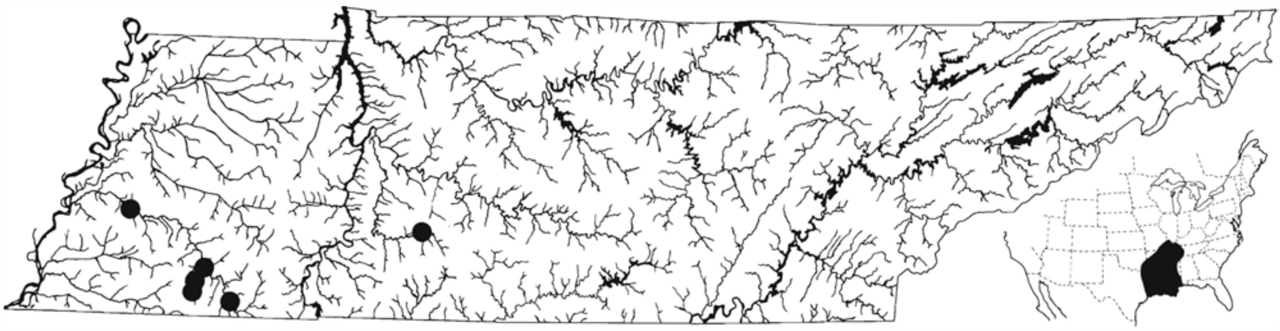
Biology: The scaly sand darter inhabits sandy portions of medium to large streams with moderate current. According to Williams (1975), breeding occurs during midsummer. We have fully gravid specimens in our collection from late May (Arkansas). Fecundity of these specimens appears to be 60–70 ova per female; stomachs contained only midge larvae. Maximum total length 72 mm (2.8 in).

Distribution and Status: Primarily Coastal Plain habitats in Gulf Coastal drainages from Pascagoula River drainage, Mississippi, west through San Jacinto River, Texas, and extending up Mississippi River basin to southeastern Missouri and western Kentucky. *Ammocrypta vivax* is known in Tennessee only from the Hatchie River system, and from a single specimen from the Buffalo River (Starnes et al., 1977). It formerly occurred in western tributaries to the lower Tennessee River just north of Tennessee in Kentucky, and may have been present in the main channel prior to impoundment. It may have also been a former inhabitant of the Forked Deer and Obion river systems of west Tennessee. In the Hatchie River it is more restricted to the main channel than is *A. beanii,* and is generally less common than that species (Starnes, 1973). Because of its limited Tennessee distribution, it is included in Tennessee's list of Rare Wildlife (Starnes and Etnier, 1980).

Similar Sympatric Species: Adults of the naked sand darter, *A. beanii,* differ markedly in virtually lacking evident pigmentation on the body. Juveniles are easily separated using magnification and characters listed in the Key.

Systematics: A member of the *pellucida* species group, along with *A. meridiana* (Williams, 1975).

Etymology: *vivax* is a variation of *vivious*, meaning vigorous.



Range Map 200. *Ammocrypta vivax*, scaly sand darter.

Genus *Etheostoma* Rafinesque

Under current concepts, *Etheostoma* (ca. 115 species) is the most speciose genus of North American freshwater fishes. Neither the exact number of species of *Etheostoma* nor the number of Tennessee *Etheostoma* (about 69) can be stated with certainty at present. New species continue to be "discovered," but most of these are so similar to recognized species (cryptic species) that they have been overlooked by earlier workers. In other cases, taxa formerly considered to be subspecies or mere variations are being treated as full species on the basis of recent information. Discovery of additional distinctive but unknown species of *Etheostoma* is unlikely, but the remote possibility that exciting finds of this nature await future collectors certainly exists.

Darters of the genus *Etheostoma* have radiated into a wide variety of habitats—ranging from the stagnant waters and organic substrates of swamps to shoreline areas of lakes, from pools and sandy areas to boulder riffles, large creeks and rivers, tiny streams, and springs. Breeding behavior is equally varied, but the true random spawning of the larger percids has been completely replaced by precise spawning-site selection and, in some species, parental care of the eggs. Egg deposition sites range from both the upper and lower surfaces of rocks to stems of aquatic plants to the inner walls of discarded cans; many species bury their eggs in deposits of sand or fine gravel. Males of most species display brilliant colors, especially during the breeding season. Food of all species for which data are available consists primarily of benthic arthropods, especially the immature stages of aquatic insects. The single known exception, *Etheostoma sellare* (Radcliffe and Welsh), feeds heavily on snails (Knapp, 1976). The brilliant colors, fascinating breeding habits, and extreme diversity of the genus have combined to make darters a favorite group with many North American ichthyologists. They do reasonably well in aquaria, and most species will adapt to a diet of frozen brine shrimp. Successful reproduction in aquaria is uncommon in most species. The eminent North American ichthyologist Stephen Forbes (1880) was likely thinking mostly of this genus when he stated that darters did "not seem to be dwarfed so much as concentrated fishes."

Etheostoma may contain the most highly evolved species of the family Percidae. While the genus is thought to be monophyletic (Bailey and Etnier, 1988), its relationships to other darter genera, such as *Ammocrypta*, remain unclear. Its members differ consistently from *Percina* in lacking modified scales along the ventral midline, but most are of smaller maximum size and have lower scale and fin ray counts than *Percina* species.

Etymology: *Etheo* = strain, *stoma* = mouth (possibly in reference to small mouth size?).

Since *Etheostoma* is so large and diverse, there is considerable utility in formally recognizing various, presumably monophyletic, subgroups as subgenera. Following is a summary of the currently recognized subgenera derived from Bailey et al. (1954), Bailey and Gosline (1955), Collette and Knapp (1967), Page (1981), and Bailey and Etnier (1988). For the most part, relationships among these subgeneric groupings and, in some cases their constituents, remain unresolved. There remain points of disagreement between some of the above workers and more recent ones on what may constitute natural subgroups of *Etheostoma* and whether members of the genus *Ammocrypta* may constitute a lineage within the present grouping (e.g., Simons, 1991). Clearly, there is need for further study of relationships among these fishes as more kinds of data become available and it would not be surprising to see groupings currently recognized as subgenera re-elevated to generic level over the next decade as has recently been done for many eastern North American minnow groups.

Subgenus *Etheostoma* Rafinesque

Relatively large, cylindrical species with greatly expanded pectoral fins, broad heads, complete lateral lines, high scale and fin ray counts, swift riffle habitats in medium to large creeks and rivers, predominantly green and dark red nuptial colors, little sexual dimorphism, four to seven regular dorsal saddles, anterior saddle well separated from occiput, complete cephalic canals, and broadly connected gill membranes. Breeding tubercles occur on ventral scales of males (and occasionally females) of all species except *histrio*, *lynceum*, *rupestre* and *zonale*. Tennessee species include *blennioides*, *blennius*, *histrio*, *rupestre*, *swannanoa*, and in our opinion, *lynceum* and *zonale*, but see comments under *E. zonale* for alternate views. Additional species are *euzonum* and *tetrazonum* of the Ozarks, *inscriptum* of the Savannah and Oconee rivers, *kanawhae* and *osburni* of the New River of North Carolina, Virginia, and West Virginia, the exceedingly rare *sellare* of the Susquehanna drainage in Maryland, *thalassinum* of the Atlantic Piedmont, and *variatum* of the middle Ohio River drainage.

Subgenus *Ulocentra Jordan*

Small, slightly laterally compressed species with complete lateral lines; broadly connected gill membranes; habitats in slack-water areas or gentle riffles in small to moderate-sized streams; moderate scale and fin ray counts; eight or more dorsal saddles, anterior saddle touching occiput; striking sexual dimorphism; and red, yellow, green, and blue nuptial colors. Breeding tubercles are absent. Tennessee species include *baileyi*, *barrenense*, *brevirostrum*, *coosae*, *duryi*, *etnieri*, *flavum*, *pyrrhogaster*, *simoterum*, and *zonistium*. *Etheostoma rafinesquei* occurs in the Green River system of Kentucky, *E. tallapoosae* Suttkus and Etnier (1991) in the Tallapoosa River system of Georgia and Alabama, and additional undescribed species may include at least one species in the Yazoo River system of Mississippi, one each in the Black Warrior and Cahaba river systems of Alabama, one in the upper Coosa River system near Marietta, Georgia, and one species widespread in Gulf Coastal drainages. Page (1981) included these darters in the nominal subgenus *Nanostoma* Jordan, along with *E. zonale* (including *E. lynceum*, since elevated), but Bailey and Etnier (1988) have hypothesized that *Ulocentra* and *Etheostoma* s.s. are each monophyletic and are sister groups to one another, with *zonale* and *lynceum* as members of the latter.

Subgenus *Litocara* Bailey

Large, cylindrical inhabitants of pool and riffle areas of small to moderate streams. Snout long and pointed, lateral line complete or nearly so, nuptial tubercles present on scales of male in area above anal fin base. A pair of black basicaudal spots present. Males with bright blue and red breeding colors. Formerly placed in the subgenus *Oligocephalus*. Currently hypothesized to be the sister group to *Etheostoma* s.s. plus *Ulocentra* (Bailey and Etnier, 1988). *Etheostoma sagitta* of Tennessee and Kentucky and *E. nianguae* of central Missouri are the included species.

Subgenus *Doration* Jordan

Small to moderate-sized cylindrical species with predominantly red and blue nuptial colors, 2 anal spines, complete or incomplete lateral lines, six dorsal saddles, and narrowly joined gill membranes. Nuptial males with tubercles on anal and pelvic fins and on lower body scales. Included with subgenus *Boleosoma* by some earlier authors. Habitats are sandy areas with moderate current in medium to large streams. The subgenus consists of *E. stigmaeum* and two nominal (*jessiae*, *meadiae*) and two undescribed forms of uncertain taxonomic status. Systematics studied by Howell (1968).

Subgenus *Boleosoma* DeKay

Small, cylindrical species often with a single anal spine and an incomplete lateral line. Gill membranes broadly joined, nuptial males very darkened on body and fins, nuptial females with bilobed urogenital papilla not shared by related subgenera. Habitats are sandy areas with slow to moderate currents in small to large streams, and sand and gravel shorelines of lakes. Eggs are deposited on the undersurface of rocks or similar objects. Reproductive habits, including egg-mimicking (Bart and Page, 1991), and intense melanism of breeding males are uniquely shared with subgenus *Catonotus*, but a close relationship between these two groups has not been proposed. The only Tennessee species, *E. nigrum*, has several distinct forms in our state. Additional species (*longimanum*, *olmstedi*, and *podostemone*) occur in Atlantic Coastal drainages.

Subgenus *Vaillantia* Jordan

Similar to *Boleosoma* but differing in lacking a bilobed female urogenital papilla, and in having the cheeks and opercles densely covered with exposed scales. Includes the Tennessee species *chlorosoma* and *E. davisoni* of the Gulf Coast. Bailey and Etnier (1988) hypothesized a relationship with *Boleosoma*.

Subgenus *Psychromaster* Jordan and Evermann

Small, laterally compressed inhabitants of springs and spring runs. Anal spine single, lateral line incomplete, no chromatic breeding colors. Branchiostegal membranes scaled. Supratemporal and interorbital areas of head also scaled. No close affinities apparent with other subgenera. *Etheostoma tuscumbia* is the only species.

Subgenus *Allohistium* Bailey

The single species, *E. cinereum*, is a large, laterally flattened inhabitant of boulder-strewn pool areas of medium-sized rivers. Lateral line complete, gill membranes separate, snout long and pointed, soft dorsal fin of nuptial male greatly enlarged, upper sides marked with a series of wavy, red-brown horizontal lines, gill rakers vestigial. No clear affinities with other subgenera and thought to be a primitive member of *Etheostoma* (Page, 1977; Bailey and Etnier, 1988).

Subgenus *Nothonotus* Putnam

Small to moderate-sized, laterally flattened inhabitants of swift riffles in medium to large creeks and rivers. Lateral line usually complete, head canals complete, scale and fin ray counts relatively high, gill membranes separate, branchiostegal rays 6, dorsal saddles nine or more or not apparent, frenum well developed. Sexual dimorphism often striking, eggs attached to undersides of rocks or buried in gravel. Most species with fine, dark horizontal lines along posterior sides. Tennessee species include *acuticeps*, *aquali*, *bellum*, *camurum*, *chlorobranchium*, *jordani*, *microlepidum*, *rufilineatum*, *sanguifluum*, *tippecanoe*, *vulneratum*, *wapiti*, and possibly *maculatum*. Additional species are *juliae* and *moorei* of the Ozark region and *rubrum* from Bayou Pierre in western Mississippi. Etnier and Williams (1989) presented evidence for the monophyly of the group and hypothesized relationships of the included species.

Subgenus *Oligocephalus* Girard

Small, laterally flattened inhabitants of habitats ranging from quiet waters to gentle riffles of large rivers to tiny streams and springs. Males brilliantly colored in reds, blues, and greens on body and dorsal fin. Lateral line incomplete, scale counts low to moderate, gill membranes never broadly joined, dorsal saddles eight or more or inconspicuous. Until recently (Page, 1981), this subgenus had been treated as including many unrelated species (thus being polyphyletic) and was the home for "leftover" species of uncertain affinities. We concur with Page that restricting the subgenus to the following species results in something much closer to a monophyletic assemblage than did earlier treatments. Tennessee species are *asprigene*, *caeruleum*, *ditrema*, *luteovinctum*, *spectabile*, and *swaini*. Additional species are *australe, grahami, lepidum,* and *pottsii* of the Texas-Mexico area; *collettei* and *radiosum* of the Ouachita region; *hopkinsi* of Atlantic drainages in Georgia and South Carolina; *nuchale* from springs near Birmingham, Alabama; and *whiplii* of the lower Mississippi and western Gulf Coast drainages. Bailey and Etnier (1988) provisionally included *E. exile* of the upper Midwest and Canada and *E. okaloosae* of the Florida panhandle region in this group; the latter had been formerly placed in the subgenera *Villora* (Fowler, 1941; Collette and Yerger, 1962), and *Belophlox* (Page, 1981).

Subgenus *Ozarka* Williams and Robison

Typically small, nearly cylindrical inhabitants of slackwater areas of small rivers, streams, and spring runs. Formerly included within *Oligocephalus*, but differing from that subgenus in lacking chromatic colors in soft dorsal fin, sharing similar nuptial tubercle patterns, and in their unique breeding behavior. Adults ascend tributary streams in high-water periods of late winter and move into the very shallow and eutrophic waters of flooded fields and ditches to spawn in terrestrial or semi-aquatic vegetation. Tennessee species are *boschungi* and *trisella*. Additional species (*cragini*, *pallididorsum*, *punctulatum*) occur in the Ozark region.

Subgenus *Fuscatelum* Page

The only species, *E. parvipinne*, has formerly been treated as a member of the subgenus *Oligocephalus*. It differs from that subgenus in lacking chromatic breeding colors, having broadly joined gill membranes, and in having 1 or 2 anal spines (2 in *Oligocephalus* except *E. australe*), and in often having a complete lateral line. Bailey and Etnier (1988) suggested possible affinities with members of *Ozarka*.

Subgenus *Catonotus* Agassiz:

A large grouping of small, laterally flattened species that typically occur in small streams. Lateral line incomplete, infraorbital and supratemporal canals typically interrupted, spinous dorsal fin with 10 or fewer spines, dorsal fin of nuptial males with soft, fleshy knobs on spines or soft rays, or with soft rays extending well past membranes. Chromatic breeding colors, when present, are reds and yellows. All species except one (*E. chienense*) occur in Tennessee, and the group includes *barbouri*, *chienense*, *corona*, *crossopterum*, *flabellare*, *forbesi*, *kennicotti*, *neopterum*, *nigripinne*, *obeyense*, *olivaceum*, *oophylax*, *pseudovulatum*, *smithi*, *squamiceps*, *striatulum*, *virgatum*, and an undescribed species related to *E. flabellare*. Behavior has been well studied, with all species laying eggs in a single layer on the underside of a flattened rock. The yellowish swellings on tips of dorsal fin elements of nuptial males may be "egg mimics," used for enticing females (which prefer to spawn in nests with eggs already present) into nests (Page and Swofford, 1984; Knapp and Sargent, 1989; Page and Bart, 1989; Bart and Page, 1991). Swollen head and nape tissues of nuptial males are being investigated for their potential fungicidal properties. Systematics studied by Page (1975b) and Braasch and Mayden (1985), and Page et al. (1992).

Subgenus *Hololepis* Agassiz
Small, laterally flattened species of vegetated swamps and sluggish areas of streams and rivers below the Fall Line. Lateral line arched upward anteriad and incomplete. Nuptial tubercles present, chromatic breeding colors of greens and reds present or absent. Page (1981) has suggested that the northern species *E. exile*, formerly placed in *Oligocephalus*, shows affinities with *Hololepis* of prior authors (e.g. Hubbs and Cannon, 1935; Collette, 1962) rather than with *Oligocephalus*. He further indicated that *E. collis* and *E. saludae* (formerly *Hololepis*) are more closely related to the subgenus *Microperca* than to other *Hololepis*, and combined *E. exile* plus *Hololepis* and *Microperca* in subgenus *Boleichthys* Girard, the oldest available genus group name for any of these species. Bailey and Etnier (1988) argued that *saludae* and *collis* are not more closely related to *Microperca* than to other *Hololepis*, and that *E. exile* shares as many derived characters with *Oligocephalus* as with *Hololepis*. They retained the traditional subgenera *Hololepis* and *Microperca* and provisionally allocated *exile* to *Oligocephalus*. Tennessee species in *Hololepis* include *E. fusiforme* and *E. gracile*. Additional species are *collis*, *saludae*, *serrifer*, and *zonifer*, all of the Atlantic and Gulf coastal plains.

Subgenus *Microperca* Putnam
These, the smallest of the darters, are laterally flattened inhabitants of vegetated areas in quiet waters of swamps, springs, and small streams. Lateral line developed on about ten or fewer scales, males with enlarged pelvic fins and with nuptial tubercles, eggs attached to stems of aquatic plants. Systematics studied by Burr (1978) and Buth et al. (1980). See comments above under the subgenus *Hololepis* for recent ideas concerning the synonymy of the subgenera *Boleichthys*, *Hololepis*, and *Microperca*. Tennessee species include *microperca* and *proeliare*. The only additional species, *E. fonticola*, occurs in springs in the Edwards Plateau area of Texas.

Additional groups not occurring in Tennessee:
Subgenus *Ioa* Jordan and Brayton includes a single species, *E. vitreum*, of the Atlantic Piedmont and Coastal Plain from Maryland to North Carolina; *Belophlox* Fowler, recognized by Page (1981) to include *E. mariae* and *E. fricksium* of the Georgia and South Carolina Coastal Plain; subgenus *Villora* Hubbs and Cannon includes a single species, *E. edwini*, of the Alabama and Florida Coastal Plain.

KEY TO THE TENNESSEE SPECIES

The following Key and synopsis concerns the largest and most difficult genus of fishes in the state. The reasons for much of this difficulty are that the distribution of the species within the state has been rather poorly recorded in the literature, and that most species are extremely variable in the meristic characteristics (lateral-line scales, fin ray counts) that are so often used for species identification in other groups. Because the group is so difficult, we do not expect that this analysis will be sufficiently flawless to allow an inexperienced fish taxonomist to accurately identify single preserved specimens from Tennessee. When several specimens are available, collection locality is known, and the material is reasonably fresh or is accompanied by color notes, results should be good. Most of the taxonomic characters used in the Key are adequately described or illustrated here or elsewhere in this book. Some of the characters used require additional discussion. The presence or absence of scales on the nape, belly, breast, cheeks, and opercles is a very important and initially difficult character. The reader is advised to dry these areas thoroughly, and then use the point of a fine needle to see if any embedded scales are present under the epidermis. The sensory canal system of the head is best seen after the areas in question have been exposed to a fine spray of compressed air for a short period of time. The difficulty of the key is compounded by the presence of several species in the state that are so variable in the characters used herein that given specimens may "key out" in several places. In most cases we have attempted to warn the reader of these difficulties. If the range, written description, and illustration of the presumed species do not agree with the specimen in hand, the reader is advised to start the keying process over, trying alternate choices whenever some uncertainty is encountered.

1. Dorsal fin spines modally 10 or more, or if 9, dorsal fin soft rays usually 11 or fewer 20
   Dorsal fin spines modally 8 or fewer, or if 9, dorsal fin soft rays usually 12 or more 2
2. Belly fully scaled, or if naked anteriad the longest dorsal fin spine is only about half as long as the longest dorsal fin soft ray: subgenus *Catonotus* 3
   Belly naked anteriad; longest dorsal fin spine more than 3/4 as long as longest dorsal fin soft ray 18
3. Postorbital bar angles dorsad and forms the dorsal margin of a pale, oblique bar on the cheek (Pls. 213, 253); first 3 or 4 interradial membranes of spiny dorsal fin black at base 4
   Postorbital bar horizontal or absent; oblique pale bar absent from cheek; bases of anterior interradial membranes of spiny dorsal fin not darker than more posterior membranes 8
4. Sides marked with distinct fine, dark, horizontal lines (Pls. 257, 263) 5
   Sides lacking linear horizontal pigmentation (may be traces of such lines in *E. barbouri*, Barren River system) 6
5. Lateral line developed on 13 or more scales; pectoral fin rays 12; anterior segment of infraorbital canal with 4 pores; Cumberland River system of middle Tennessee .... *E. virgatum* p.546
   Lateral line with pores present on 12 or fewer scales; pectoral fin rays usually 11; only 3 pores on anterior segment of infraorbital canal; restricted to tributaries of middle and upper Duck River .... *E. striatulum* p.537
6. Lateral line developed on 14 or more scales; 4 pores on anterior segment of infraorbital canal .... *E. obeyense* p.512
   Lateral line developed on 13 or fewer scales; only 3 pores on anterior segment on infraorbital canal 7
7. Suborbital bar black and distinct (Pl. 213); Barren River system .... *E. barbouri* p.464
   Suborbital bar faint or wanting (Pl. 253); Cumberland and lower Tennessee River drainages . *E. smithi* p.528
8. Opercles with scales, at least on dorsal portion 9
   Opercles entirely naked 15
9. Breast usually naked; bright red or orange pigment on throat and/or fins; caudal fin base with a vertical C- or trident-shaped mark (Pls. 219, 254) 10
   Breast always with at least some scales; no bright orange or red pigment on body or fins; caudal fin base with a vertical row of 3–4 dark spots, some of which may fuse to form a vertical bar 11
10. Males with orange or red in anal fin; infraorbital canal complete; principal caudal fin rays modally 17; upper sides lacking traces of horizontal lines; usually 6 or more (5–7) oblique bars posterior to anal fin origin (this last character is useless west of the Mississippi River): specimens with 9 dorsal spines may key here .... *E.* (*Oligocephalus*) *caeruleum* p.473
    Males lacking orange or red in anal fin; infraorbital canal typically interrupted under eye; principal caudal fin rays 16 or fewer; upper sides with faint horizontal lines; usually 5 or fewer (4–6) oblique bars posterior to anal fin origin (but see note in couplet 10a): specimens with 9 dorsal spines may key here .... *E.* (*Oligocephalus*) *spectabile* p.529
11. Modal number of dorsal fin rays 11; infraorbital canal often complete; nuptial males with elongate soft dorsal fin rays that are greatly swollen at tips (Pl. 240b); dorsal fin soft rays two-branched, the branches not or scarcely separated by membrane (adnate) .... *E. neopterum* group p.506
    Modal number of dorsal fin rays 12 or more; infraorbital canal interrupted under eye; nuptial males with soft dorsal fin rays slightly or not at all swollen at tips; some dorsal fin soft rays of adult males (50 mm SL or larger) with three branches, divergent, and separated by membrane 12

12. Mean dorsal fin soft rays usually 13 or more; Tennessee River drainage above mouth of Duck River, upper and lower Duck River system, and upper Caney Fork system 13
Mean dorsal fin soft rays usually fewer than 13; not known from Tennessee drainage except in Duck River and Shoal Creek 14
13. Soft dorsal fin of nuptial male with yellow margin; restricted to Cypress Creek system, Wayne Co., or upper Caney Fork system .... *E. corona* and *E. forbesi* p.557, 508
Soft dorsal fin of nuptial male with black margin; middle Tennessee River drainage downstream through Duck River, but absent from Cypress Creek system .... *E. nigripinne* p.508
14. Soft dorsal fin of nuptial males with rays well produced, pale distally with black tips, and lacking terminal knobs (Pl. 225); absent from Barren River system of Ohio drainage and Red River system of Cumberland drainage .... *E. crossopterum* p.483
Soft dorsal fin of nuptial males with rays moderately produced and with pale knobs at tips (Pl. 255b); Red River system of Cumberland drainage and Barren River system of Ohio drainage .... *E. squamiceps* p.532
15. Infraorbital canal complete (Fig. 136) with 8 or more pores; restricted to tributaries of lower Caney Fork River and immediately adjacent Cumberland River .... *E. olivaceum* p.514

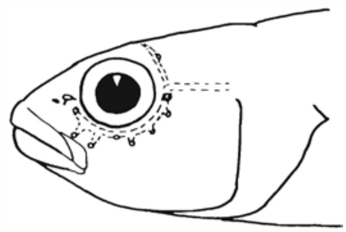


Figure 136. Infraorbital canal of *Etheostoma olivaceum* (complete, 8 pores).

Infraorbital canal widely interrupted under eye, with 6 or fewer pores (Fig. 137) 16

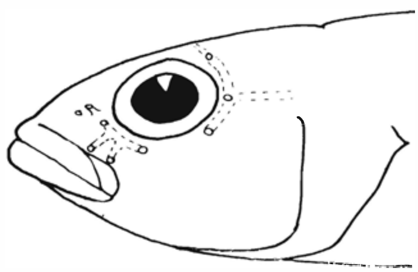


Figure. 137. Infraorbital canal of *Etheostoma flabellare* (incomplete).

16. Soft dorsal fin rays 13–14 (rarely 12); scales in lateral series 42–56; gill membranes broadly joined, meeting at the midline to form an angle of 90° or greater (Fig. 138a), with the angle formed by their union approximately at the level of the posterior edge of the preoperculum ...... *E. flabellare* p.489
Soft dorsal fin rays 11–12 (rarely 13); scales in lateral series 38–48; gill membranes less broadly joined, meeting at the midline at an angle of less than 90° (Fig. 138c), with the angle formed by the union of the gill membranes as close to the level of the posterior orbital rim as to the level of the posterior edge of the preoperculum 17

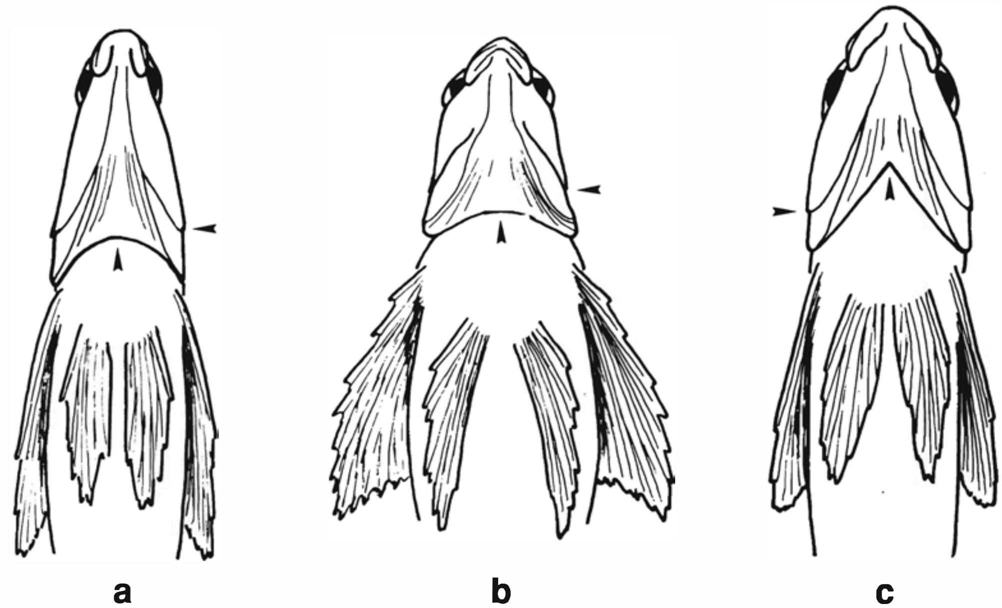


Figure 138. Gill membrane connections of *Etheostoma* spp.: a) *E. flabellare* (broadly connected); b) *E. zonale* (very broadly connected); c) *E. kennicotti* (separate to narrowly joined).

17. Lateral blotches rounded, about 7–9, and restricted to lateral-line area; caudal fin vertically striped (Pl. 235) .... *E. kennicotti* p.498
Lateral blotches about 11–14, and extending from just below the lateral line to the dorsum; caudal fin dusted with melanophores but not vertically striped (Pl. 269) .... *E.* (*Catonotus*) sp., "duskytail darter" p.555
18. More than 10 pored scales in lateral line (specimens from direct tributaries to the Mississippi River will key here) .... *E.* (*Boleosoma*) *nigrum* p.510
Fewer than 10 pored scales in lateral line: subgenus *Microperca* 19
19. Both cheeks and opercles scaled .... *E. proeliare* p.516
Cheeks and usually opercles lacking scales .... *E. microperca* p.505
20. Lateral line complete (but beware of difficulties presented by species in 20b) 21
Lateral line incomplete (may be nearly complete in members of the *E. stigmaeum* complex, which have 6 hour-glass shaped dorsal saddles; *E. sagitta* which has 10–12 anal fin soft rays, a sharply pointed snout, and more than 60 scales in lateral series; *E. swaini* which has a pale streak from the dorsal fin origin to the occiput; and *E. parvipinne*, which would key to the subgenus *Nothonotus* but has connected gill membranes and lacks the pointed snout and bright colors of these species) 52
21. Dorsal saddles distinct, most often 6 (3 in *trisella*, 4 in *blennius*, often 7 in *blennioides*) 22
Dorsal saddles 8 or more, or indistinct (5 in juvenile *E. cinereum*) 31
22. Dorsal saddles 3; Conasauga River and its tributaries .... *E.* (*Ozarka*) *trisella* p.543
Dorsal saddles 4, 6, or 7: subgenus *Etheostoma* 23

23. Dorsal saddles 4, angling anteriad . . . . *E. blennius* p.470
Dorsal saddles 6 or 7 24
24. Cheeks well scaled 25
Scales few or absent on cheeks 27
25. Dorsal fin spines plus soft rays 26 or more (rarely 25); sides marked with U-shaped blotches . . . . *E. b. blennioides* and *E. b. newmani* p.468
Dorsal fin spines and soft rays 24 or fewer (rarely 25); sides marked with vertical bars 26
26. Lateral-line scales 43 or fewer (rarely to 47); direct tributaries to Mississippi River in west Tennessee . . . . *E. lynceum* p.502
Lateral-line scales 46 or more (rarely 43–45); Tennessee, Cumberland, and Ohio drainages of east and middle Tennessee . . . . *E. zonale* p.550
27. Cheeks and opercles entirely naked . . . . *E. swannanoa* p.540
At least some scales present on either cheeks or opercles 28
28. Belly fully scaled (occasional specimens of *E. zonale* from the Nolichucky or Watauga river systems may have naked areas on the anterior portion of the belly); specimens with naked or very weakly scaled cheeks will key here . . . . *E. zonale* p.550
Belly with naked areas anteriad or completely naked 29
29. Caudal fin base with two large black blotches that coalesce on midline and entirely cover caudal base . . . . *E. histrio* p.496
Caudal fin base with less pigment, usually in the form of four small blotches (specimens of *E.* (*Boleosoma*) *nigrum* with complete lateral lines may key here) 30
30. Dorsal fin soft rays 11–12 (rarely 13); Conasauga River . . . . *E. rupestre* p.521
Dorsal fin soft rays 13 or more; Pigeon and Hiwassee rivers, Slickrock Creek . . . . *E. blennioides gutselli* and *E. b. gutselli* x *E. b newmani* intergrades p.468
31. Gill membranes separate, or if slightly connected they meet at an angle of less than 90° (Fig. 138c); frenum well developed (Fig. 14) 32
Gill membranes broadly connected (Figs. 138a,b), meeting at an angle of much more than 90°; frenum absent (Fig. 139) or very narrow: subgenus *Ulocentra* 33

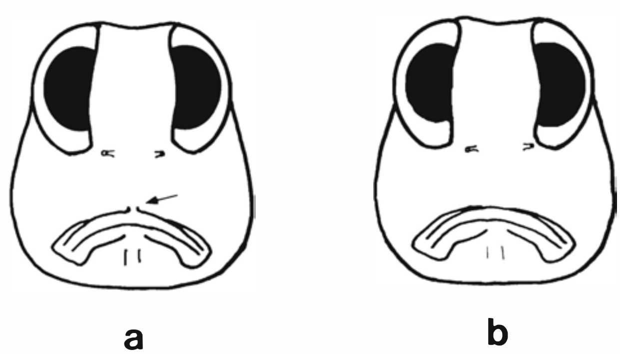


Figure 139. Premaxillae of darters of subgenus *Ulocentra*: a) with very narrow frenum; b) frenum absent.

32. Midlateral band distinct, separating the wavy dorsolateral lines from the immaculate or lightly shaded ventrolateral area (Pl. 223) . . . . *E.* (*Allohistium*) *cinereum* p.480
No midlateral band; ventrolateral pigmentation similar to dorsolateral pigmentation, especially on caudal peduncle: subgenus *Nothonotus* (in part) 42
33. A definite but narrow frenum (Fig. 14) present (needle gently slid around groove above upper jaw meets definite resistance at tip of snout); prevomerine teeth absent except in *etnieri* 34
Frenum completely absent (needle slides freely around the snout in the groove above the upper jaw); prevomerine teeth often present 37

34. Area above lateral line with horizontal lines, either in the form of a single red-brown line 1–1.5 scale rows wide immediately above the lateral line, or in the form of 3–5 fine horizontal lines (Pls. 214, 228); confined to the Barren River system in Clay, Macon, and Sumner counties, or the Caney Fork system in Putnam, Van Buren, White, DeKalb, and Warren counties 35
Area above lateral line lacking horizontal lines of pigment; widespread in Cumberland and Tennessee river drainages 36

35. Adult males with red, orange, or yellow on breast; horizontal red-brown line 1–1.5 scale rows wide immediately above lateral line; Barren River system (Pl. 214) . . . . *E. barrenense* p.465
Adult males with gray or green breast; 3–5 dark horizontal lines on upper side (Pl. 228); upper Caney Fork system . . . . *E. etnieri* p.488

36. Lower half of first interradial membrane of spiny dorsal fin with scattered melanophores; sides with orange and brown pigments predominant (Pl. 252); widespread in the Tennessee and middle and lower Cumberland river drainages . . . . *E. s. simoterum* and *E. s. atripinne* p.526
This membrane jet black; sides greenish (Pl. 212); Cumberland River drainage from the Big South Fork upstream . . . . *E. baileyi* p.463

37. Lateral pigment band about 1 scale row wide above and often below lateral line continuous from operculum to caudal base (Pls. 247, 267); confined to western tributaries to the lower Tennessee River (and a few eastern tributaries) and tributaries to the Mississippi River 38
Horizontal pigment bands associated with the lateral line absent, or restricted to a band above the lateral line on posterior half of body; east and middle Tennessee 39

38. Adult male lacking broad red band in anal fin; spiny dorsal fin with a narrow marginal green band under which are five alternating clear and dark bands of about the same width (Pl. 267); lateral-line scales usually 42 or more (40–50); Hatchie River, and many western and a few eastern tributaries to the lower Tennessee River . . . . *E. zonistium* p.552
Adult male with broad median red band in anal fin; spiny dorsal fin with narrow green marginal band under which are but two distinct bands—broad median red and basal dark (Pl. 247); lateral-line scales usually 42 or fewer (37–45); Obion and Forked Deer river systems . . . . *E. pyrrhogaster* p.518

39. Pectoral fins darkly mottled; vertical bands (green in life) encircle caudal peduncle (Pl. 268); Conasauga River . . . . *E. brevirostrum* p.554
Pectoral fins faintly banded to immaculate; caudal peduncle not encircled by vertical bands 40

40. Horizontal band of red spots of uniform size and shape in spiny dorsal fin of adult males (Pl. 224); branchiostegal rays 6; Conasauga River system . . . . *E. coosae* p.482
Red in spiny dorsal fin never in form of a continuous band of spots; branchiostegal rays 5; Tennessee and Cumberland river drainages 41

41. Fresh specimens with orange spot above and/or below dark basicaudal spot, lips never orange (Pl. 227); total of dorsal saddles and lateral blotches (both sides) 26 or more; dorsal fin soft rays modally 12; adult males with 3–6 horizontal rows of brick red vermiculations or spots in spinous dorsal fin . . . . *E. duryi* p.486
Fresh specimens with lips orange but lacking orange spot above or below basicaudal dark spot (Pl. 230); total of dorsal saddles and lateral blotches 25 or fewer; dorsal fin soft rays modally 11; adult males with middle portion of spinous dorsal fin concolorous brown or brown with oblique darker markings . . . . *E. flavum* p.492

42. Operculum with some scales; widespread 43
Operculum entirely naked; Nolichucky River . . . . *E. acuticeps* p.458

43. Cheeks with horizontal black marks (Pl. 248); lips orange in fresh specimens . . . . *E. rufilineatum* p.519
Cheek markings in form of a vertical suborbital bar and a postorbital spot, or wanting; lips not orange (except in occasional males of *E. jordani* from the Conasauga River system) 44

44. Sides of body marked with dark horizontal lines, especially posteriad; Tennessee, Cumberland, and Ohio river drainages 45
Sides of body lacking dark horizontal lines (Pl. 234); Conasauga River . . . . *E. jordani* p.497
45. Suborbital bar dusky or wanting; bases of membranes of spiny dorsal fin conspicuously darker anteriad; Tennessee and Cumberland river drainages 46
Suborbital bar very dark and conspicuous; bases of membranes of spiny dorsal fin not darkened anteriad (Pl. 215); Barren River system, Clay, Macon, and Sumner counties (*E. maculatum*, known from the Barren River system of Kentucky, may eventually be taken in the Tennessee portion of that system. It has characters described in first half of couplet, and is further discussed under *E. bellum*, Similar Sympatric Species) . . . . *E. bellum* p.466
46. Black marginal bands absent from soft dorsal, caudal, and anal fins of adults and juveniles of both sexes; adult males with orange to red anal fins 47
Adult and subadult males with black marginal bands on soft dorsal, caudal, and anal fins; these marginal bands also present on adult females, but may be weak in *E. microlepidum* and *E. vulneratum;* anal fin of males not red or orange except in *E. camurum* 48
47. Cheeks with several wavy copper-colored lines in fresh specimens (Pl. 210); lateral-line scales usually 60 or more (57–67); Duck and Buffalo river systems . . . . *E. aquali* p.460
Cheeks uniformly gray, often with a darker suborbital bar (Pl. 251); lateral-line scales usually 59 or fewer (50–67); Cumberland River drainage . . . . *E. sanguifluum* p.524
48. Cheeks with about 1–4 embedded scales underlying dark spot just behind eye; soft dorsal, caudal, and anal fin of both sexes lacking distinct submarginal pale bands, or if such bands are present (male *E. microlepidum*) their proximal margins are poorly defined; males with bright red or orange on caudal fin in life; soft dorsal, caudal, and anal fins spotted in females 49
Cheeks lacking scales; soft dorsal, caudal, and anal fins of both sexes similar and with pale submarginal bands that are sharply defined proximally; no red on caudal fin except in *E. camurum* 51
49. Dorsal, caudal, and anal fins of adult males with orange submarginal bands and green bases in life (Pl. 238); females with brown spots on anal fin and paired fins; Red, Harpeth, and Stones rivers of the Cumberland River drainage . . . . *E. microlepidum* p.503
Dorsal, caudal, and anal fins of adult males lacking submarginal bands; females lacking discrete spots on anal and paired fins; Tennessee River drainage 50
50. Adult males with red spots on sides and red on dorsal and caudal fins (Pl. 264); mean lateral-line scales fewer than 60; upper Tennessee River drainage downstream through Little Tennessee River system and Whites Creek (Roane and Meigs counties) . . . . *E. vulneratum* p.548
Adult males lacking red on body or fins (Pl. 265); mean lateral-line scales 60 or more; Elk River and possibly Shoal Creek of lower Tennessee River drainage . . . . *E. wapiti* p.549
51. Bases of median fins and most of body flushed with dark green in fresh males (Pl. 221); trout stream habitats from the Watauga River southwest to the Little Tennessee and probably the Hiwassee rivers . . . . *E. chlorobranchium* p.478
Bases of median fins gray to reddish gray; green pigments not developed on fins or body (Pl. 220); lower elevation streams and rivers, Tennessee and Cumberland river drainages . . . . *E. camurum* p.475
52. Nape, cheeks, *and* anterior portion of belly naked; frenum present . . . . *E. (Nothonotus) tippecanoe* p.541
Scales present on at least one of these areas; or frenum absent 53
53. Lateral line arched upward anteriad (Pls. 231, 232), leaving only 3 scale rows between the lateral line and the spiny dorsal fin base: subgenus *Hololepis* 66
Lateral line horizontal or nearly so, with 4 or more scale rows between lateral line and dorsal fin base 54
54. Scales absent from top of head, or restricted to posterolateral corners of head; scales absent from branchiostegal membranes 55
Scales covering entire posterodorsal portion of head, extending forward to posterior rims of orbits; scales often present on branchiostegal membranes . . . . *E. (Psychromaster) tuscumbia* p.545

55. Dorsal saddles 3 (anterior to spiny dorsal fin, at end of spiny dorsal, and at end of soft dorsal); upper Buffalo River, Flint River tributaries, and Shoal and Cypress creek systems of middle Tennessee; rare . . . . . *E.* (*Ozarka*) *boschungi* p.472
Dorsal saddles 6 or more, or indistinct 56
56. Dorsal saddles 6, of uniform intensity and spacing, and anterior saddles constricted on the midline (hourglass shaped); sides pale brown with darker W-shaped marks along lateral line (often with blue blotches in breeding males) 64
Dorsal saddles absent or 7 or more that are irregular in shape, spacing, and/or intensity; lateral pigmentation variable, but not as above 57
57. Scales in lateral series 60 or more; anal fin soft rays 10–12; snout sharply pointed (Pl. 250); eastern tributaries to Big South Fork of Cumberland and upper Cumberland drainage of Scott, Campbell, and Claiborne counties . . . . . *E.* (*Litocara*) *sagitta* p.522
Scales in lateral series 55 or fewer; anal fin soft rays 9 or fewer; snout not sharply pointed 58
58. Gill membranes broadly joined (Fig. 138a); lacking bright colors (Pl. 245) . . . . . *E.* (*Fuscatelum*) *parvipinne* p.515
Gill membranes separate to narrowly joined (Fig. 138c); red and blue colors usually well developed: subgenus *Oligocephalus*) 59
59. Cheeks covered with scales (these scales may be embedded, but can be detected by inserting a needle under the skin and lifting up) 60
Cheeks naked, or with a few scales posterior to the eyes 63
60. Breast naked; west Tennessee 61
Breast scaled, at least on posterior half; east and middle Tennessee 62
61. Markings on sides vertical (Pl. 211); dorsal saddles evident from occiput backward; confined to the Mississippi River and its overflow pools, and the lower reaches of its larger tributaries; and western tributaries to the lower Tennessee River in Benton and Henry counties . . . . . *E. asprigene* p.461
Markings on sides vaguely horizontal (Pl. 258); nape depigmented from occiput to spinous dorsal fin; tributaries to Mississippi River in west Tennessee . . . . . *E. swaini* p.538
62. Scales in lateral series 49 or more; middle Tennessee . . . . . *E. luteovinctum* p.500
Scales in lateral series 48 or fewer; Conasauga River system . . . . . *E. ditrema* p.485
63. Males with red or orange in anal fin (Pl. 219); infraorbital canal complete; upper sides lacking traces of horizontal lines; principal caudal fin rays modally 17; usually 6 or more (5–7) oblique bars posterior to anal fin origin (does not apply west of Mississippi River) . . . . . *E. caeruleum* p.473
Males lacking orange or red in anal fin (Pl. 254); infraorbital canal interrupted under eye; fine horizontal lines usually evident on upper sides; principal caudal fin rays 16 or fewer; usually 5 or fewer (4–6) oblique bars posterior to anal fin origin (east of Miss. R. only) . . . . . *E. spectabile* p.529
64. Breast and cheeks fully scaled; preorbital bar continuous around snout (Fig. 140) . . . . . (*Vaillantia*) *chlorosoma* p.479

Figure 140. Snout pigmentation of *Etheostoma chlorosomum.*

Breast and at least lower cheeks naked; preorbital bar not continuous around snout 65

65. Belly partially naked; anal fin with 1 spine; no red or blue breeding colors ... *E.* (*Boleosoma*) *nigrum* p.510
Belly fully scaled; anal fin with 2 spines; adults with some red and/or blue colors during most of year:
subgenus *Doration* .... *E. stigmaeum* complex p.533
66. Exposed scales on breast and covering top of head from occiput to orbital region .... *E. fusiforme* p.493
These areas naked .... *E. gracile* p.495

Etheostoma acuticeps Bailey.

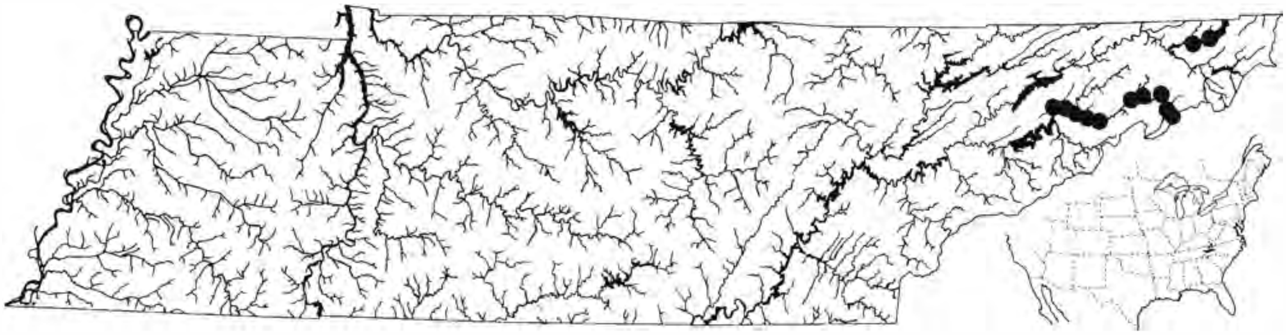
Sharphead darter

Characters: Lateral line complete with 55–62 (53–65) scales. Dorsal fin with 11–13 spines and 12–13 (11–13) soft rays. Anal fin with 2 spines and 7–9 soft rays. Pectoral fin rays 13–14 (12–14). Principal caudal fin rays modally 17 (16–18). Gill rakers 12–16, length of longest rakers about 4 times their basal width. Vertebrae 38–39. Branchiostegal rays 6. Gill membranes separate to narrowly joined. Frenum present. Scales absent from cheeks, opercles, nape, breast, and prepectoral area. Infraorbital and supratemporal canals complete. Adults with about 12–14 narrow, vertical to slightly oblique dark bars extending from back to venter. Juveniles with a vertical row of four dark spots at caudal fin base. Fins dusky, but never spotted or conspicuously banded. Sexes similar but spring and summer males with green on fins and some orange on throat region.

Plate 209a. *Etheostoma acuticeps*, sharphead darter, female, 53 mm SL, Nolichucky R., TN.

Biology: The extremely localized sharphead darter typically occurs over rubble and boulder substrates in swift riffle habitats with surface current velocities of 1–2 m/sec and depths of 15–36 cm. Densest populations in the lower Nolichucky River occur in areas with heavy growths of riverweed (*Podostemum*). Riverweed is also present in sharphead darter habitats in the Cane River, North Carolina, but is absent where they occur in South Fork Holston River, Virginia. The typically very common and closely related redline darter (*Etheostoma rufilineatum*) is rare in portions of the Nolichucky where *E. acuticeps* occurs. Biological information that follows has been abstracted from Bryant (1979). Breeding occurs from late June through mid August, and eggs are apparently buried shallowly in sand deposits near the base of a large rock. Females produce from 100 to 300 eggs per year. Young reach lengths of about 32–35 mm SL and sexual maturity at the end of 1 year's growth and about 45–55 mm SL after 2 years. Maximum life span is 3 years, at which time males are up to 65 mm SL; females rarely exceed 55 mm SL. Males are apparently territorial and very aggressive during the breeding season, and during this time males with tattered caudal fins, presumably caused by bites from other males, were not uncommon. On an annual basis, food in the Nolichucky River consisted of 31% blackfly larvae (Simuliidae), 30% mayfly nymphs (mostly *Baetis*), and 26% midge larvae (Chironomidae). Maximum total length 81 mm (3.2 in).

Plate 209b. *Etheostoma acuticeps*, sharphead darter, male, 62 mm SL, Nolichucky R., TN.



Range Map 201. *Etheostoma acuticeps*, sharphead darter.

Distribution and Status: The sharphead darter, originally described from six specimens from an area now impounded by South Holston Reservoir (Bailey, 1959b) has had an interesting history. Considered as possibly extinct at the time of its description, the report of 21 specimens from South Fork Holston River near Bluff City, Tenn., and seven from North Toe River above Spruce Pine, North Carolina (Nolichucky River system) by Zorach and Raney (1967) and Zorach (1972) renewed hopes for finding extant populations, even though these specimens had been collected in 1930. Three specimens from South Fork Holston River taken just above South Holston Reservoir near Alvarado, Virginia, in 1972 (Jenkins and Burkhead, 1975) confirmed its continued existence. While searching for additional populations of the snail darter, TVA biologists discovered an additional population of sharpheads in Nolichucky River between Davy Crockett Reservoir and Douglas Reservoir in 1975 (Saylor and Etnier, 1976). Bryant (1979) found this population to be extensive. Bryant et al. (1979b) reported an extant population in Cane River, an upper Nolichucky River tributary, Yancey Co., North Carolina. Since both Cane River and South Fork Holston River populations were restricted in both geographical area and population size, and the lower Nolichucky population was threatened by possible failure of Davy Crockett Dam (the reservoir is nearly filled with silt, and dam failure would release this silt into the downstream sharphead darter habitat), the outlook for the darter's future was much improved relative to "possibly extinct," but still not assured. Haxo and Neves (1984) found an additional site in South Fork Holston River, a more extensive population in Cane River than earlier reports indicated, and localities in Nolichucky River from just above Davy Crockett Reservoir to above Erwin, Tenn. These finds, especially those in the upper Nolichucky, remove the sharphead from any imminent threat of extinction. This darter has apparently responded quickly to water quality improvement in the upper Nolichucky, where our rather extensive efforts to locate this species during the 1970s were unsuccessful. Mica silt from abandoned and active mines in North Carolina had resulted in an unstable and abrasive environment, and sharphead darters had apparently been reduced to numbers so low as to be undetectable, in spite of the fact that most collections in that area were made with concentration on potential sharphead habitat. An alternate possibility is that this portion of the river has been recolonized by downstream movement of the persistent Cane River population. We have collected other *Nothonotus* (*camurum* and *rufilineatum*) in Fort Loudoun Reservoir during lowered winter water levels in gravelly areas just above George's Creek, at least 5 river miles below the closest known reproducing populations in Little River and the lower Holston River. The history of the sharphead darter certainly emphasizes the continued need for adequate surveys of riverine fish populations as well as the ability of populations of stream fishes to quickly repopulate areas where adequate habitat quality has been restored.

Similar Sympatric Species: Other sympatric *Nothonotus* (*camurum*, *chlorobranchium*, *rufilineatum*, *vulneratum*) have red spots on adult males (lacking in *acuticeps*), and scales on the operculum. Further differing from *camurum* and *chlorobranchium* in having a much more sharply pointed snout and in lacking marginal and submarginal bands on median fins. Male *rufilineatum* also have dark marginal and pale submarginal bands on median fins, and male *vulneratum* have dark marginal bands on these fins. Further differing from female and juvenile *rufilineatum* and *vulneratum* in lacking dark spots on the soft dorsal and caudal fins.

Systematics: Subgenus *Nothonotus*. Relationships unclear. Bryant (1979) considered it to be more closely related to *camurum*, *chlorobranchium*, and *rufilineatum* than to the *E. maculatum* species group, based primarily on its inferred reproductive behavior (buries eggs in gravel rather than clumping them on the underside of rocks), but this behavior is probably primitive within the subgenus and thus not an indication of close relationships.

Etymology: *acute* = sharp, *ceps* = head.

Etheostoma aquali Williams and Etnier.

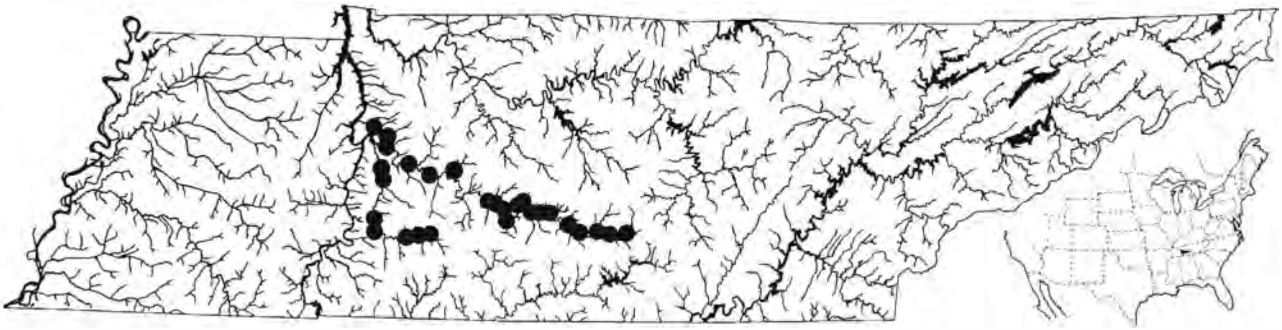
Coppercheek darter

Characters: Lateral line complete with 59–67 (57–67) scales. Dorsal fin with 12–14 spines and 12–14 (11–14) soft rays. Anal fin with 2 spines and 9–10 (8–10) soft rays. Pectoral fin rays 13–14 (12–16). Principal caudal fin rays 17 (16–19). Gill rakers 14–17 (12–18), length of longest rakers about 4 times their basal width. Vertebrae 38–40, modally 39. Branchiostegal rays 6. Gill membranes separate to narrowly joined. Frenum present. Scales absent from nape, breast, prepectoral area, and occasionally anterior belly. Opercles scaled. Cheeks with a few scales underlying postorbital spot. Infraorbital and supratemporal canals complete. Males with bright red spots on sides and in spiny dorsal fin, and orange to red anal fin. Females brownish with pale yellow background color on median fins and ventral areas, all fins covered with small brown spots. Adults of both sexes with coppery reticulations on cheeks.

Plate 210a. *Etheostoma aquali*, coppercheek darter, female, 52 mm SL, Duck R., TN.

Biology: As is typical for members of the *Etheostoma maculatum* species-group, the coppercheek darter frequents deep riffles, runs, and flowing pools of larger streams with an abundance of boulder or large rubble substrates. Some inhabited creeks, tributary to the Duck River, experience very reduced flows in summer with riffles reduced to near trickles. The breeding season extends from early May to mid June. Page et al. (1982) have reported on reproductive behavior which is similar to that reported for the closely related *E. maculatum* by Raney and Lachner (1939). Nests, which are guarded and presumably prepared by a male, are located on the underside of a slab-rock or flattened boulder. In aquaria, females were observed to wedge themselves in a nearly upright position into the interface between the substrate and the buried portion of the rock while ovipositing. Many of the eggs adhere to the ventral surface of the rock, resulting in a multilayered egg mass rather than the single layer of eggs deposited by the inverted females of *Boleosoma* and *Catonotus* species. A nest examined in the Buffalo River, 5 May, at water temperature of 22 C, contained 551 eggs that averaged 1.8 mm diameter. Eggs were in various stages of development, indicating several females may contribute to a single nest. Larvae that hatched from eggs returned to the laboratory were 6.5 mm TL, had well-developed pectoral fins and jaws, and had a series of bright gold flecks extending down the dorsal midline. Stomachs of 44 specimens collected from April through November contained about 30% hydropsychid caddis larvae, 20% midge larvae, 16% mayfly nymphs (baetids, heptageniids, *Isonychia*), 7% blackfly larvae, and a wide variety of additional aquatic insect immatures plus a few snails (R. T. Bryant, pers. comm.). Lengths of late fall and early spring specimens in our collection suggest that standard lengths of about 30, 45, and 60 mm are attained at ages 1, 2, and 3, with males attaining larger

Plate 210b. *Etheostoma aquali*, coppercheek darter, male, 69 mm SL, Duck R. system, TN.



Range Map 202. *Etheostoma aquali*, coppercheek darter.

sizes than females. Maximum total length 80 mm (69 mm SL) or 3.2 in.

Distribution and Status: Restricted to the Duck and Buffalo rivers and their larger tributaries, where it appears to be rare but is probably more abundant than records indicate due to the difficulty of effectively seining in its preferred habitat. Because of its limited range, the coppercheek darter is treated as a Threatened Species in Tennessee (Starnes and Etnier, 1980), and it warrants that status on the federal list. Completion of Columbia Reservoir on the middle Duck River would eliminate many Duck River populations.

Similar Sympatric Species: All stages of *E. camurum* larger than 25 mm SL and adult male *E. rufilineatum* have dark marginal and pale submarginal bands on median fins. Females and juveniles of *E. aquali* differ from comparable *E. rufilineatum* in lacking black horizontal marks on cheeks and opercles, and in having spots on median fins small and brown on a yellowish background rather than large and black on a clear background.

Systematics: Subgenus *Nothonotus*, member of *E. maculatum* species group (Etnier and Williams, 1989). The three small specimens from Elk River and Shoal Creek mentioned in the original description (Williams and Etnier, 1978) have recently been confirmed as representing a new species, *E. wapiti*, treated herein. The earlier report of *E. microlepidum* from the Duck River (Raney and Zorach, 1967) was based on misidentification of specimens of *E. aquali*.

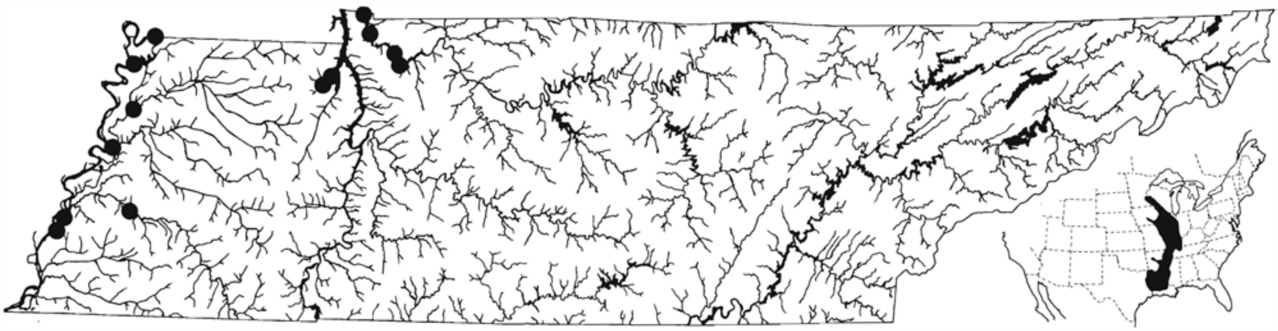
Etymology: Derived from the Cherokee "agaquali" = cheek, and referring to the diagnostic copper colored markings on the cheek.

Etheostoma asprigene (Forbes).

Mud darter

Plate 211. *Etheostoma asprigene*, mud darter, 40 mm SL, Mississippi R., TN.

Characters: Lateral line incomplete with 34–43 (28–43) pored scales and 45–52 (43–54) scales in lateral series. Dorsal fin with 10–11 (9–12) spines and 10–14 soft rays. Anal fin with 2 spines and 7–8 (7–9) soft rays. Pectoral fin rays 13–14 (12–15). Principal caudal fin rays 16–17. Gill rakers 11–14, length of longest rakers about 3–4 times their basal width. Vertebrae 36–39. Branchiostegal rays 6. Gill membranes separate. Frenum present. In Tennessee populations, scales are present on the cheeks, opercles, nape, belly, and prepectoral area, but are absent from the breast. Breast and belly squamation somewhat variable elsewhere. Supratemporal and infraorbital canals complete. The dorsum is dull greenish to yellowish with about ten dark saddles. Beginning at the anal fin origin, five or six vertical dark bars are present on the sides and venter. Scales on the upper half of the body may have pigmented centers, creating a pattern of longitudinal lines. Three basicaudal spots are usually present, often forming a characteristic trident-shaped mark. The suborbital bar ranges from weak to well developed. The spinous dorsal fin has a dark marginal band, a red submarginal band, and a broad dark median band that extends to the fin base and is darkest posteriad. Both of the dark bands may have blue highlights in nuptial males. Soft dorsal



Range Map 203. *Etheostoma asprigene*, mud darter.

fin with a median orange band in nuptial males. The remaining fins are clear to dusky. Mud darters are drab throughout most of the year, but males typically show some red on the spinous dorsal fin and belly region. Nuptial males have bright red bellies, alternating blue and red bars posteriorly on the sides and caudal peduncle, and intensified fin coloration. Breeding tubercles are absent.

Biology: The mud darter is an inhabitant of primarily larger Coastal Plain and Mississippi Valley creeks and rivers where it is usually found in sluggish current over a variety of substrates ranging from sand and detritus to silty gravel. Mud darters also occur in overflow swamps, oxbow lakes, and reservoirs. Cummings et al. (1984) have studied the life history in Illinois. They noted movements from riffles in the daytime to pools at night. Spawning occurs from March to May. Page et al. (1982) and Cummings et al. observed spawning in aquaria. Males did not defend specific territories but were generally aggressive towards other males. Males court females by circling and fin erection. Females select spawning sites on elevated surfaces, or eggs are released over vegetation and fertilized after the male has mounted her in an S-shaped configuration. One to three eggs per spawning act were deposited directly on underwater plants, or five to ten were released above vegetation. Objects such as sticks are probably utilized in natural habitats, which often lack vegetation. At 22 C hatching requires about 5–6 days; larvae are 4.2 mm at hatching. Mud darters attain about 40–45 mm TL at age 1, 50–55 at age 2, and 60 mm or more at age 3, the maximum indicated life span. Lutterbie (1979), studying Wisconsin populations, determined similar growth with lengths at ages 1 and 2 averaging 41.5 and 52 mm based on analysis of scale annuli. Principal food items are midge and caddisfly larvae, mayfly nymphs, and isopods. Maximum total length 65 mm (2.6 in).

Distribution and Status: The mud darter occurs in the Mississippi Valley from southern Minnesota southward and on the Coastal Plain from a few eastern tributaries to the Mississippi River westward to the Neches River, Texas. Its distributional relationship to the similar-appearing *E. swaini* in the lower Mississippi Valley region has been confused in the past but was clarified by Starnes (1980). In Tennessee, the mud darter is moderately abundant locally in the Mississippi River in areas with gravel and moderate currents. It is occasionally taken in backwaters and overflow pools of the Mississippi River and near the mouths of its larger tributaries, and in impoundments and creek mouths in the lower Tennessee and Cumberland rivers. Such habitats are not often collected for small fishes, and its true abundance is difficult to assess.

Similar Sympatric Species: The gulf darter, *E. swaini*, is similar in appearance and occurs in tributaries to the Mississippi River in west Tennessee. Thus far, these two darters have not been collected together, with the gulf darter apparently restricted to the higher Coastal Plain. They differ in pigmentation, with Tennessee gulf darters lacking dark pigment on the nape whereas the mud darter has saddles in this area. The posteriorly expanded and darkened median band in the spinous dorsal fin of the mud darter is distinctive (nearly uniform in width and intensity in *swaini*). Also similar to *E. caeruleum*, which may be sympatric in the Midwest; in *caeruleum* the cheeks are naked.

Systematics: Subgenus *Oligocephalus*.

Etymology: *aspri* = rough, *gene* = cheek, in reference to the well-scaled cheeks.

Etheostoma baileyi Page and Burr.

Emerald darter

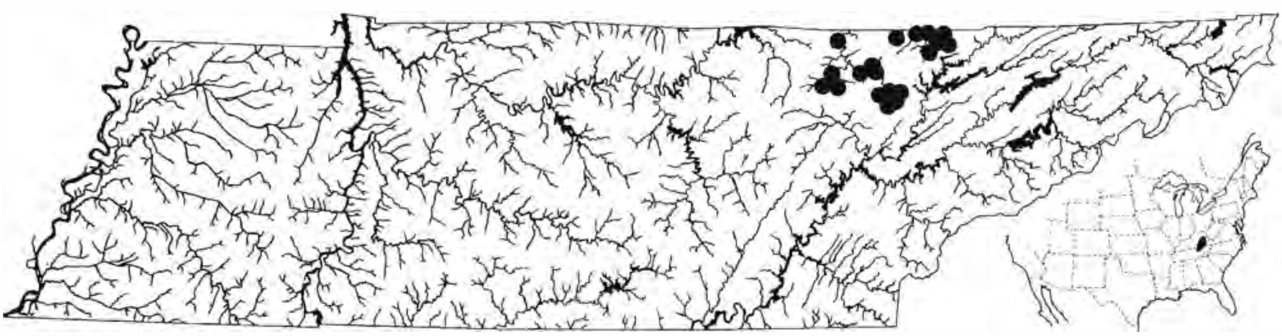
Plate 212a. *Etheostoma baileyi*, emerald darter, female, 40 mm SL, upper Cumberland R. system, TN.

Plate 212b. *Etheostoma baileyi*, emerald darter, male, 43 mm SL, upper Cumberland R. system, TN.

Characters: Lateral line complete with 46–54 (43–56) scales. Dorsal fin with modally 11 (9–13) spines and modally 11 (10–13) soft rays. Anal fin with 2 spines and modally 7 (6–8) soft rays. Pectoral fin rays 14–15 (13–16). Principal caudal fin rays 16–17 (13–18). Gill rakers 8–10, length of longest rakers about 3 times their basal width. Vertebrae 38–41. Branchiostegal rays 5 (5–6). Prepectoral area, belly, cheeks, opercles, and nape usually fully scaled, but gill cover and nape occasionally only partially scaled. Breast naked. Cephalic sensory system complete. Frenum narrow but consistently present. Dorsum with seven to ten saddles. Sides with 7–11 midlateral blotches. Background color olivaceous above, yellowish below. Nuptial males with green on cheeks, opercles, anal fin, pelvic fins, basal half of spinous dorsal fin, basal fifth of soft dorsal fin, dorsal and ventral insertions of caudal fin, and lateral blotches. Dorsal half of spinous dorsal fin red, with red brightest in anterior and posterior membranes.

Biology: As is typical for the subgenus *Ulocentra*, emerald darters occur in rocky pool areas and runs of creeks and small rivers. In warmer months moderately flowing raceways and riffles are inhabited with a movement to deeper, calmer water in winter. Clayton (1985) has studied life history. Spawning occurs from April to June at temperatures of about 18–20 C, apparently in gravel-cobble raceways. Actual spawning was not observed though males attempted to spawn repeatedly with various females. Gravid females contained 110–240 eggs with an average of 35 ripe ova. Hatching of eggs required 12–13 days at spawning temperature. Larvae are 6.2–6.4 mm at hatching. At age 1, an average total length of about 38 mm is reached, and age 2 and 3 individuals average about 45 and 53 mm, respectively. A 3-year life span is indicated. Midge larvae and pupae were by far the dominant food items with some utilization of caddisfly and mayfly immatures and microcrustaceans. Maximum length 50 mm SL (about 60 mm TL, or 2.3 in).

Distribution and Status: Upper Kentucky River (Ohio drainage), and Cumberland drainage of Kentucky and Tennessee above Cumberland Falls, and below Cumberland Falls in Rockcastle and Big South Fork systems. Although it is fairly common in the Kentucky and Rockcastle rivers in Kentucky, the emerald darter is nowhere abundant in Tennessee. Much of its range is in portions of the Cumberland Plateau heavily mined for coal, and its numbers have certainly been reduced by stream degradation associated with these activities. It has not been accorded Protected Status in either Tennessee or Kentucky, but Tennessee populations may warrant protection now or in the near future. Recent establishment of the Big South Fork as a National Recre-



Range Map 204. *Etheostoma baileyi*, emerald darter.

ation Area will certainly offer some security for populations occurring in that system.

Similar Sympatric Species: The lateral U-shaped markings and extremely blunt snout are shared by the much larger *E. blennioides,* but its six to seven (vs. usually eight or more) dorsal saddles will separate juveniles of that species from *baileyi,* in addition to other characters available from the key and the *E. blennioides* account. This is the only *Ulocentra* in the Cumberland River system from the Big South Fork system upstream. *Etheostoma simoterum atripinne* formerly occurred in the Little South Fork of the Cumberland River in Kentucky but has not been taken there since about the turn of the century (Comiskey and Etnier, 1972). Adult males of these two species differ in that *atripinne* has chromatic colors predominantly orange and red, while the emerald darter is predominantly green except for the broad red band in the spinous dorsal fin. The emerald darter has modally 11 dorsal fin spines (12 in *atripinne*) and fewer lateral-line scales (usually 54 or more in *atripinne*).

Systematics: Subgenus *Ulocentra*, and a member of the *E. simoterum* species group (Bailey and Etnier, 1988). Page and Burr (1982) and Clayton (1985) compared Kentucky and Cumberland river populations and found no significant differences.

Etymology: *baileyi* is a patronym for Reeve M. Bailey, University of Michigan, who has contributed greatly to our knowledge of North American fishes.

Etheostoma barbouri Kuehne and Small.

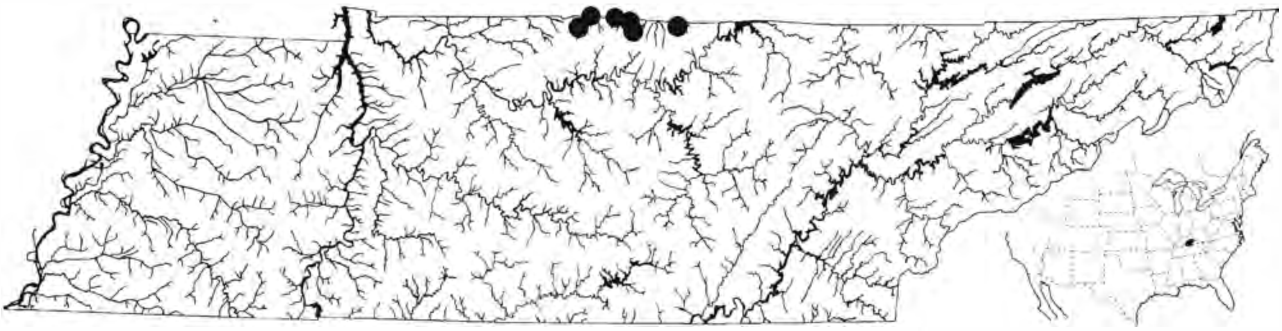
Teardrop darter

Plate 213. *Etheostoma barbouri*, teardrop darter, 44 mm SL, Barren R. system, TN.

Characters: Lateral-line incomplete with 0–7 (0–12) pored scales and 41–47 (40–49) scales in lateral series. Dorsal fin with 9 (8–10) spines and 12–14 (11–15) soft rays. Anal fin with 2 spines and modally 9 (7–10) soft rays. Pectoral fin rays 12 (10–13). Principal caudal fin rays 16 (14–17). Gill rakers 10–12 (8–13), length of longest rakers 3.5 times their basal width. Vertebrae 35–37. Branchiostegal rays 6. Gill membranes separate to narrowly joined. Scales absent from breast, prepectoral area, nape, cheeks, and opercles. Belly well scaled to mostly naked. Infraorbital and supratemporal canals interrupted. Background color brownish yellow. Dorsum with five or six saddles from junction of dorsal fins posteriad, and dark reticulations on anterior portion of back. Sides with about ten lateral blotches on or slightly below midline, each of which is formed from three or four darkened scales. Dark spots on scale centers on posterior half of body forming weak pattern of broken horizontal lines. Suborbital bar dark and angling backward. Cheek with iridescent pearly area margined by black. Spinous dorsal fin with basal half of first four or five interradial membranes black. Nuptial males with the remainder of the spinous dorsal fin and the anal fin (except for a narrow black to blue margin) orange. Caudal and soft dorsal fins yellowish orange with darker spots on membranes. Pelvic fins black, pectoral fin with black lower border and with rows of brownish spots on membranes.

Biology: Within its restricted range the teardrop darter is an inhabitant of sandy pool areas in small to medium streams with abundant small flat stones which are used as cover (Kuehne and Small, 1971; Page and Schemske, 1978). Page et al. (1982) located two nests on the undersides of slabrocks on 29 May. Eggs, numbering 70 and 42, had been laid in a monolayer as is typical for the subgenus *Catonotus*, and a guardian male was observed at one of the nests. Spawning probably extends from April through May, based on gonadal development. Flynn and Hoyt (1979) reported annual egg production of 17–48 eggs per female, indicating that several females may contribute to the same nest. They found the diet to consist of midge and blackfly larvae, copepods and cladocerans, and immature mayflies and caddisflies. Life span was estimated at 2.5 years. Maximum size of 60 mm SL (= 72 mm TL, or 2.8 in) reported in Kuehne and Barbour (1983).

Distribution and Status: Confined to the Barren River system and the upper portion of the Green River system (Ohio River drainage) of Kentucky and Tennessee, where it is moderately common. Like other fishes endemic to this small geographical area (blackfin sucker, splendid darter, orangefin darter), teardrop darter populations appear to be under no immediate threat. All of these species have very limited ranges in Tennessee, and are listed among Tennessee's rare vertebrates for that reason (Starnes and Etnier, 1980).



Range Map 205. *Etheostoma barbouri*, teardrop darter.

Similar Sympatric Species: Sympatric with *E. flabellare* in the Barren River system in Tennessee, and with that species plus *kennicotti* and *squamiceps* in Kentucky. It differs from all of these sympatric *Catonotus* in having only 12 or fewer pored lateral-line scales, and in having red and blue nuptial colors and a pearly, iridescent bar on the cheek.

Systematics: A member of the barcheek group of the subgenus *Catonotus*; hypothesized to be sister species to *E. smithi* (Braasch and Mayden, 1985).

Etymology: *barbouri* is a patronym for Dr. Roger Barbour, a well-known vertebrate zoologist from the University of Kentucky.

Etheostoma barrenense Burr and Page.

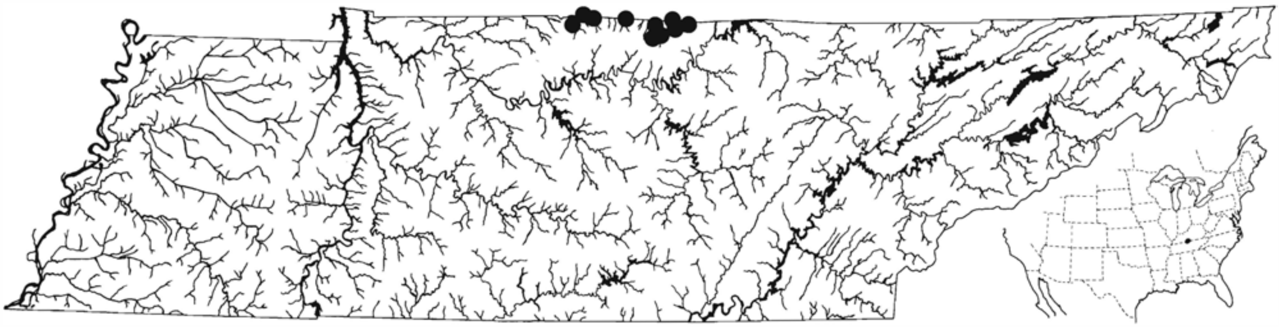
Splendid darter

Plate 214a. *Etheostoma barrenense*, splendid darter, female, 43 mm SL, Barren R. system, TN.

Plate 214b. *Etheostoma barrenense*, splendid darter, male, 53 mm SL, Barren R. system, TN.

Characters: Lateral line complete with 42–48 (41–50) scales. Dorsal fin with 11–12 (10–12) spines and 11–12 (10–13) soft rays. Anal fin with 2 spines and 7–8 (6–8) soft rays. Pectoral fin rays 13–15. Principal caudal fin rays 15–17 (14–18). Gill rakers 8–10, longest rakers about 3.5 times their basal width. Vertebrae 38–40. Branchiostegal rays 5. Gill membranes broadly joined. A narrow frenum consistently present. Nape, prepectoral area, belly, and opercles scaled. Cheeks usually scaled, breast usually naked. Supratemporal and infraorbital canals complete. Dorsum marked with eight (seven to nine) saddles. Midlateral area with 8–9 (7–10) round, square, or somewhat elongate blotches connected by a dark lateral band. A characteristic dark line extends the length of the body above the lateral-line canal and is dark brown and about 1/2 scale row deep anteriad, grading to orange and about 1 1/2 scale rows deep posteriad. Above this is a pale band extending from the eye to the caudal fin base that separates the lateral pigment features from the dorsal saddles. Nuptial males with bluegreen on snout, lower gill cover, lower portion of head, anal fin, and dorsal and ventral bases of caudal fin. Breast and lower sides bright orange. Spinous dorsal fin with bright red spot on distal half of first interradial membrane; brick red on distal half (anterior) to entire interradial membrane (posterior) on remainder of fin. Below this a narrow clear area, a somewhat broader dark band, and a clear basal band that are restricted to the anterior three-fourths of the fin. Soft dorsal fin with elongate ovals of brick red pigment in membranes increasing in length posteriad; this pigment separated by a clear area from a dark basal band that decreases in width from the first through the third to fifth interradial membrane. Pelvic fins black. Caudal and pectoral fins mottled.

Biology: The splendid darter occupies typical *Ulocentra* habitats of pools to gentle riffles and edges of riffles with rocky substrates in small to moderate streams.



Range Map 206. *Etheostoma barrenense*, splendid darter.

Winn (1958a,b) found spawning to occur from early April through mid May. As in other *Ulocentra*, spawning substrates were boulders in flowing pools or gentle riffles, and eggs were laid singly, with the annual production of each female estimated to be about 800 eggs. Position of the spawning embrace varied from horizontal to slightly inverted, with nearly vertical positions most frequent. Males were found to defend a single spawning boulder and a small adjacent area. Kuehne and Barbour (1983) reported that most breeding females were 2 years old and these produced about 800 ova; males were also sexually mature at age 2, but the larger 3-year-old males fertilized most of the eggs. Normal life span for both sexes was 3 years. Maximum length 53 mm SL (= 63 mm TL, or 2.5 in).

Distribution and Status: Endemic in Barren River portion of upper Green River system (Ohio River drainage) of Kentucky and Tennessee, where it is common. Like other endemics of that system (blackfin sucker, teardrop darter, orangefin darter), it is included on Tennessee's list of Rare Vertebrates because of its very restricted distribution (Starnes and Etnier, 1980).

Similar Sympatric Species: This is the only *Ulocentra* within its range. The combination of a very blunt snout, broadly connected gill membranes, and eight or more dorsal saddles is not shared by any other darters in the Barren River system.

Systematics: Subgenus *Ulocentra*, and a member of *E. simoterum* species group (Bailey and Etnier, 1988).

Etymology: *barrenense* = of the Barren.

Etheostoma bellum Zorach.

Orangefin darter

Characters: Lateral line complete with 51–60 (48–63) scales. Dorsal fin with 11–13 (10–13) spines and 11–13 (10–13) soft rays. Anal fin with 2 spines and 7–9 (6–9) soft rays. Pectoral fin rays 13–15 (12–15). Principal caudal fin rays modally 17 (16–17). Gill rakers 12–14 (12–15), length of longest rakers about 6 times their basal width. Vertebrae 37–38 (37–39). Branchiostegal rays 6. Gill membranes separate to narrowly joined. Frenum present. Scales absent from cheeks, breast, prepectoral area, and most of nape; opercles scaled. Sexes similar, but males more vividly colored. Body background color yellowish brown and marked with about ten dark horizontal lines on each side that extend from under the middle of the spinous dorsal fin to the caudal fin base. In some individuals these lines extend nearly to the head. Soft dorsal, caudal, and anal fins with dark marginal band, pale submarginal band, and an orange band proximal to that. These three bands are all about the same width and occupy the distal third of each fin; bases of these fins are brown to orange. Caudal fin with two large pale areas basally. Spinous dorsal fin with very narrow dark marginal band and pale submarginal band best developed posteriad: Adult males maintain bright colors throughout the year but are most colorful during the breeding season, when bases of all fins except the dorsal portion of the pectorals are bright orange, the belly is orange, orange spots occur on the sides, the gill cover is pale brown, and the breast is dark brown. The head is conspicuously larger than in other species of *Nothonotus*, and the prominent, dark suborbital bar is present in both sexes.

Biology: The orangefin darter occurs in swift gravel riffles from creeks to small rivers, and is the only

Nothonotus besides *E. juliae* and *E. rufilineatum* that is tolerant of small streams. Zorach (1968) suggested that spawning took place in late June or early July, which coincides with the midsummer reproductive period of other *Nothonotus*. Young available in our collection were 23–32 mm TL by mid November of their first year, and 33–42 mm TL by the following May. Specimens apparently representing 2-year-olds were 46–53 mm TL in May. Specimens up to 74 mm in these collections indicate the presence of at least one, and possibly two additional age groups.

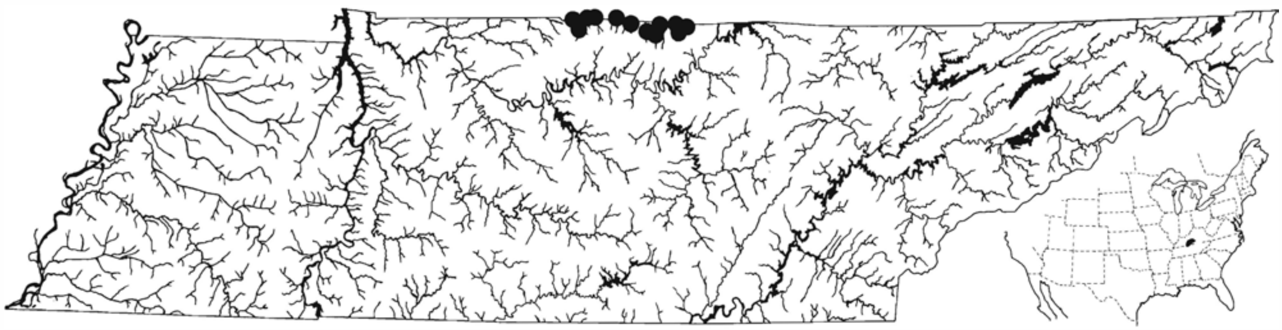
Fisher (1990) has provided very recent additional life history information, primarily from a population from South Fork Green River, Kentucky. Spawning occurred from late April through June at water temperatures of 20–25 C (68–77 F). Males were sexually mature at age 1, but most females did not mature until age 2. Males aggressively defended territories near or under a slab rock. During the spawning season their orange colors intensified, and two or three black bars developed on the nape region. Courtship by the male involved parallel positioning both head to head and head to tail with the female, nudging the female with his snout, and erecting of the median fins. The female selected the egg deposition site and dived head first into the gravel, burying so that her entire dorsum or only her head and caudal fin were exposed. The male assumed a head-to-head position directly above her, flexing his body into an S-shaped curve during spawning. After spawning, the abandoned eggs remained in the gravel as a loose cluster. Average mature eggs per female (probably representing average clutch size rather than fecundity) was 41. Eggs hatched in 7–9 days at water temperatures of 23 C (73 F), and larvae were 6.1 mm TL at hatching. Growth was similar to that estimated from Tennessee specimens, with both males and females averaging 30 mm SL (36 mm TL) at age 1. Males were 48 and 60 mm TL at ages 2 and 3, respectively, while females were slightly smaller (47 and 55 mm TL) at these ages. Maximum life span was 3 years. Food was dominated by dipteran larvae (midges and blackflies) plus baetid mayfly nymphs and water mites (Hydracarina). Maximum length (Page, 1983a) 75 mm SL (= 86 mm TL, or 3.4 in).

Plate 215a. *Etheostoma bellum*, orangefin darter, female, 55 mm SL, Barren R. system, TN.

Distribution and Status: Confined to the Barren and Green river systems (Ohio River drainage) above their confluence, where it is common. Like the other three fishes endemic to this area (blackfin sucker, teardrop darter, splendid darter), it appears on Tennessee's list of Rare Vertebrates because of its restricted distribution rather than because of any immediate threats to its survival (Starnes and Etnier, 1980).

Similar Sympatric Species: *Etheostoma maculatum* is the only sympatric *Nothonotus*. It occurs with *E. bellum* in the Kentucky portion of the two river systems but has not yet been recorded from headwaters of the Barren River in Tennessee, which may be too small to accommodate *maculatum*. It differs from *E. bellum* in having greater sexual dimorphism, in having chromatic colors

Plate 215b. *Etheostoma bellum*, orangefin darter, male, 70 mm SL, Barren R. system, TN.



Range Map 207. *Etheostoma bellum*, orangefin darter.

bright red and virtually restricted to the body rather than orange and on body and fins, in its more pointed snout, and in lacking both dark marginal and pale submarginal bands on the median fins.

Systematics: Subgenus *Nothonotus*. Presumed to be most closely related to *E. camurum* and *E. chlorobranchium* by Etnier and Williams (1989).

Etymology: *bellum* = pretty or beautiful.

Etheostoma blennioides Rafinesque.

Greenside darter

Characters: Lateral line complete, counts variable for the four nominal subspecies as follows: *E. b. blennioides* 59–72 (56–78); *E. b. newmani* 65–80 (59–86); *E. b. gutselli* 53–60 (50–63); *E. b. pholidotum* 54–65 (51–71). Dorsal fin with 12–14 (11–16) spines and 12–14 (11–16) soft rays. Anal fin with 2 spines and 7–9 (6–10) soft rays. Pectoral fin rays 14–16 (13–16). Principal caudal fin rays modally 17 (16–18). Gill rakers 8–12, length of longest rakers twice their basal width. Vertebrae 37–44. Branchiostegal rays 6. Gill membranes broadly connected. Frenum present, but often deep within groove between upper lip and snout. Scales present on cheeks, but variable between subspecies on opercles, prepectoral area, nape, and anterior belly; breast naked. Fleshy covering of snout continuous (no groove) over all but a small, free posterior portion of the maxillaries, a character unique among darters. Supratemporal and infraorbital canals complete. Background color tan to greenish brown. Dorsum with six to

Plate 216a. *Etheostoma blennioides*, greenside darter, 69 mm SL, Red R., TN.

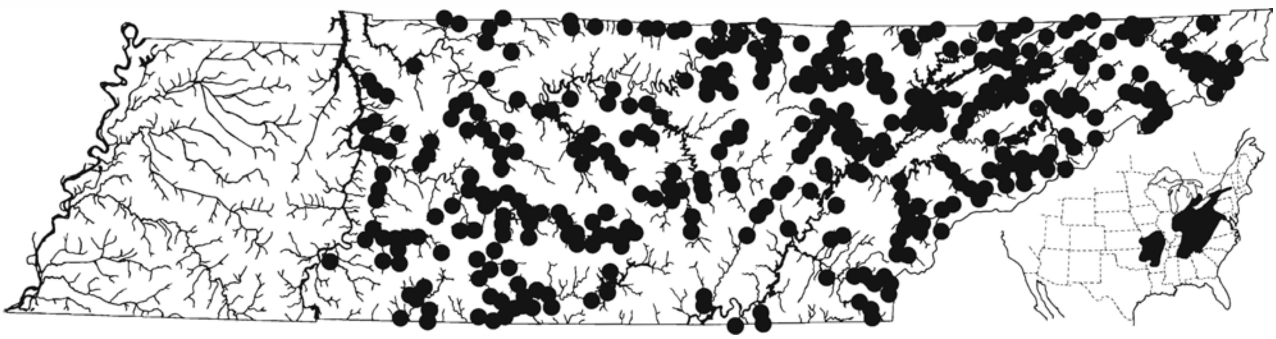
Plate 216c. *Etheostoma blennioides gutselli*, greenside darter, male, 84 mm SL, Little Tennessee R. system, NC.

Plate 216b. *Etheostoma blennioides*, greenside darter, male, 80 mm SL, Little R., TN.

seven saddles, sides with six to seven dark marks that are typically U-shaped. Throughout much of the year, males and females are rather similar in appearance, with orange to red spots on the body above the lateral line, red basal and dark marginal bands on the spinous dorsal fin, alternating dark and clear areas on rays of the soft dorsal, caudal, and pectoral fins, and clear anal and pelvic fins. Nuptial males intensely green to blue-green on lower sides and head, anal fin, and pelvic fins. Bright green also develops on the distal two-thirds of the spinous dorsal fin, as a broad median band in the soft dorsal fin, on much of the caudal fin, and on lower portions of the pectoral fins. Yellow marginal bands may occur on the soft dorsal and caudal fins, the red band in the spinous dorsal fin intensifies, and a basal red band is present in the soft dorsal fin. The normally U-shaped blotches on the sides become green vertical bars. Nuptial tubercles may develop on males as single, thickened projections on ventral scales from the mid-belly region posteriad to the caudal fin base, but are rarely evident. Tips of pelvic spines and pelvic, pectoral, and anal fin rays become thickened on both sexes during the breeding season.

Biology: Adult greenside darters are typically inhabitants of swift riffle areas with boulder or coarse rubble substrates in small to moderate rivers. During cooler months they often retreat to deep pool areas. Juveniles inhabit shallow pool areas adjacent to riffles. Adults are often associated with attached aquatic vegetation, and McCormick and Aspinwall (1983) found that they were definitely attracted to natural aquatic vegetation by olfactory stimuli while visual cues associated with artificial vegetation provided no measurable attraction (perhaps any such attraction was masked by avoidance of odors of artificial plants). In glacial regions the greenside darter is occasionally found along the edges of clear, cool lakes. The following life history information is summarized from Fahy (1954), Lachner et al. (1950), Winn (1958a,b), R. V. Miller (1968), Scott and Crossman (1973), Wolfe et al. (1978), Wynes and Wissing (1982), Hlohowskyj and White (1983), and our observations. Food of juveniles consists of midge larvae and microcrustacea; adults eat midge larvae, blackfly larvae, and other aquatic insect immatures, primarily mayflies and caddisflies. In the Little River, Tennessee, adults consumed large numbers of snails of the genus *Leptoxis* (= *Anculosa*). Feeding intensity is very low in winter and peaks in May and June. Spawning occurs in early spring at water temperatures of about 50–53 F. Males grow to larger sizes than females and become very darkened during the breeding season. Spawning occurs on a variety of substrates, from attached vegetation to boulders or sandy areas in riffles. In several studies the males have been found to be territorial, but this has not been consistently noted. Spawning is apparently initiated by the female approaching and often nudging the male. Then the male follows the female, who apparently selects the spawning substrate. Actual release of eggs occurs during a typical darter spawning embrace, in which the male assumes a position on top of and slightly to the side of the female. The female's position varies from horizontal to nearly vertical. Fecundity varies from about 500 to 2,000 eggs per season, and females presumably spawn repeatedly during a single season. Growth is rapid, with lengths of about 50–55 mm attained at age 1. Sexual maturity is attained after 1 (Fahy, 1954), or more normally 2, years' growth, and longevity appears to be at least 5 years. This is the largest species in the genus *Etheostoma*. Maximum total length 166 mm (6.5 in).

Distribution and Status: Widespread and often abundant in upland streams from Tennessee drainage north through Ohio drainage and in southern tributaries to the eastern Great Lakes. Absent from the Mississippi River Embayment, but widespread west of the Mississippi River from southern tributaries to the Missouri River south through the Ouachita River system. In Atlantic slope drainages, populations in the upper Susquehanna River, Pennsylvania, may be from human introduction or headwater piracy (Denoncourt et al., 1977), while those in the Potomac River drainage are believed to be the result of headwater piracy (Schwartz, 1965). The distinctive Blue Ridge upland subspecies, *E. b. gutselli*, is known from Tennessee based on a single recent specimen from Slick Rock Creek, tributary to Little Tennessee River, along the North Carolina border, and should be added to Tennessee's list of Endangered Fishes. It presumably occurred in Pigeon River from Newport upstream before industrial pollution from the Champion paper mill in Canton, North Carolina, eliminated much of the fish fauna of that river. It persists in the Pigeon River in North Carolina in an area where the river's flow has been diverted for hydropower and water in the old river bed is from seepage and small streams. It could eventually repopulate lower Pigeon River from that area if water quality continues to improve. Chances of locating additional populations of *gutselli* in Tennessee are remote, as the Little Tennessee River system from Abrams Creek downstream contains the widespread and abundant *E. b. newmani*. The population of *newmani* in Abrams Creek was extirpated along with the Endangered smoky madtom and several additional



Range Map 208. *Etheostoma blennioides*, greenside darter.

fish species, during a 1957 rotenone "reclamation" project.

Similar Sympatric Species: The distinctive head shape of *blennioides* is not shared by any other darters. Juveniles might be confused with members of the subgenus *Ulocentra*, all of which have eight to nine dorsal saddles with the most anterior saddle in contact with the occiput (versus six or seven saddles with anterior saddle separated from occiput); or *zonale* and *histrio*, which have 24 or fewer dorsal fin elements (versus 26 or more), and vertical bars rather than U-shaped blotches on the sides.

Systematics: Type species of the subgenus *Etheostoma*. R. V. Miller (1968) studied this species throughout its range and recognized four subspecies. The nominate subspecies occurs throughout the Ohio River drainage except for the Wabash River system (*E. b. pholidotum*) and the Barren-Green River system (*E. b. blennioides* x *E. b. newmani* intergrades); it is also the subspecies in the Potomac River drainage. The entire Cumberland and most of the Tennessee drainage are occupied by *E. b. newmani* (Agassiz), which also is widespread west of the Mississippi River. The upper Little Tennessee and Pigeon rivers (Tennessee drainage) are occupied by a geographically restricted subspecies formerly accorded species status, *E. b. gutselli* (Hildebrand). Supposed intergrades between that subspecies and *E. b. newmani* occur in the Hiwassee River system. The fourth subspecies, *E. b. pholidotum* (Miller), occurs disjunctly in the Wabash River system and Great Lakes tributaries east of the Mississippi River, and in southern tributaries to the Missouri River (Gasconade River system has intergrades with *E. b. newmani*). The more widespread *E. b. newmani* differs from *E. b. gutselli* in coloration (green rather than the mottled dark brown with blue-green nuptial colors in *gutselli*), squamation (*gutselli* has naked opercles and large naked areas on the belly), snout shape (*gutselli* lacks the median projection on the upper lip of *newmani*), and has the frenum well developed and continuous with the snout (present but partially buried in groove between snout and upper lip, not visible in side view, in *newmani*), and scale counts (lateral-line scales 53–63 in *gutselli*, 59–86 in *newmani*). Intergrades from the Hiwassee River system usually have scaled opercles, a small, broadly rounded projection on the upper lip, a buried frenum, and intermediate (56–71) lateral-line scale counts. The remaining subspecies differ from *newmani* primarily in extent of development of the projection on the upper lip (usually absent in *pholidotum*, shorter than width of upper lip in *b. blennioides*).

Etheostoma blenniodes is hypothesized to be the sister species to *E. lynceum* plus *E. zonale* by Bailey and Etnier (1988).

Etymology: *blennioides* = blenny-like.

Etheostoma blennius Gilbert and Swain.

Blenny darter

Plate 217. *Etheostoma blennius*, blenny darter, 64 mm SL, Buffalo R., TN.

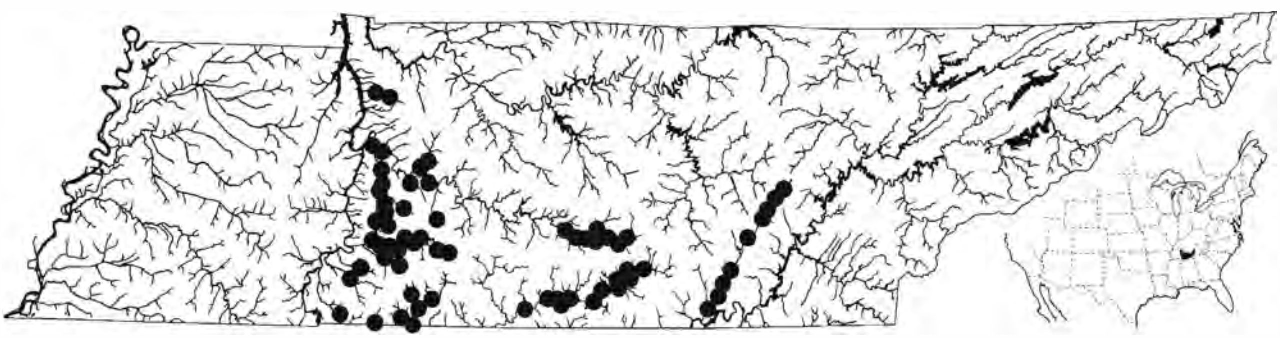
Characters: Lateral line complete with 41–48 (40–51) scales. Dorsal fin with 11–13 (10–14) spines and 11–12 (11–13) soft rays. Anal fin with 2 spines and 7–8 (7–9) soft rays. Pectoral fin rays 15–16 (15–17). Principal caudal fin rays modally 16 or 17 (14–18). Gill rakers 9–11, longest rakers about 4 times their basal width. Vertebrae 40–41 (40–42). Frenum present. Branchiostegal rays 6. Gill membranes broadly joined. Nape and belly fully scaled. Opercle usually naked, but often with a few large scales in Sequatchie River subspecies. Cheek, breast, and prepectoral area naked. The four prominent, dark brown dorsal saddles that angle anteriad make this one of our most distinctively marked darters. Background coloration is pale brown. The sides are marked with continuations of the dorsal saddles, between which are often additional dark blotches along the lateral line. Spinous dorsal fin with narrow, orange submarginal band. Both dorsal fins with brick-red membranes. Other fins clear to mottled. Nuptial males develop bright red spots on body scales, dark blue to green coloration on the lower head and breast, and blue-green caudal, pelvic, anal, and pectoral fins. The first interradial membrane of the spinous dorsal fin is often darkened. Tubercles in the form of low, rounded swellings develop on nuptial males on ventral and lower lateral scales from the anterior belly to the caudal fin base (Burr, 1979). Tips of the anal, pelvic, and lower pectoral fin elements develop thickened pads.

Biology: Preferred habitats of the blenny darter are swift gravel riffles in streams from only 3–4 m wide to medium sized rivers. Burr (1979) indicated a March-through-April spawning period, a life span of 3 years, and a diet of midge, blackfly, mayfly, and caddisfly larvae, in that order of importance. His analysis indicates that mean lengths of 43 mm SL (females) and 44 mm SL (males) are reached at age 1, and these fish are sexually mature; at age 2, males averaged 62 mm SL, while females were only 52 mm. Mature ova were 2–2.2 mm in diameter, and numbered 19–120 (mean = 56) per female. Maximum size 69 mm SL (= 82 mm TL, or 3.25 in).

Distribution and Status: Confined to the Tennessee River drainage of Tennessee and Alabama, and locally common. Its distribution shows a remarkable fidelity to Highland Rim habitats, presumably due to the unique chert gravel riffles so common in streams of that physiographic region. In the Duck River system, *E. blennius* is one of several fish species present in eastern Highland Rim habitats near the headwaters, absent from the middle portion of the system (Nashville Basin), and again present in the lower portion of the system (western Highland Rim). Although its status appears to be secure in Tennessee, it is included on Alabama's list of Fishes of Special Concern due to its limited distribution in that state (Ramsey, 1976).

Similar Sympatric Species: The blenny darter is sympatric with two other darters with a similar dorsal saddle pattern, *Percina tanasi* and *P. vigil*. The former occurs in the lower Sequatchie River with the blenny darter, and the latter occurs with the blenny darter in the lower Duck and Buffalo rivers. Both of these species differ from *E. blennius* in having separate to narrowly joined gill membranes, along with other characters available in the species accounts.

Systematics: Subgenus *Etheostoma*. The blenny darter has often been considered to have its closest relatives within the *E. variatum* species group (e.g. Hubbs and Black, 1940b), all of which have a similar dorsal saddle pattern. Wiley and Mayden (1985) and Mayden (1987) considered it the most primitive member of that group. Thompson (1973), Burr (1979), and Bailey and Etnier (1988) presented evidence that its true phylogenetic affinities are with *E. swannanoa* and its allies. Burr (1979) recognized the population occurring in the Sequatchie River as a distinct subspecies, *E. b. sequatchiense*. It differs from the nominate subspecies in having fewer lateral-line scales (usually 43 or fewer vs. usually 44 or more), slightly lower counts of dorsal fin



Range Map 209. *Etheostoma blennius*, blenny darter.

elements, and having interspaces between dorsal saddles with dark marks on scale edges forming dark horizontal lines. It also has a few large, exposed ctenoid scales on the dorsal portion of the operculum in about half the specimens.

Etymology: *blennius* = blenny-like.

Etheostoma boschungi Wall and Williams.

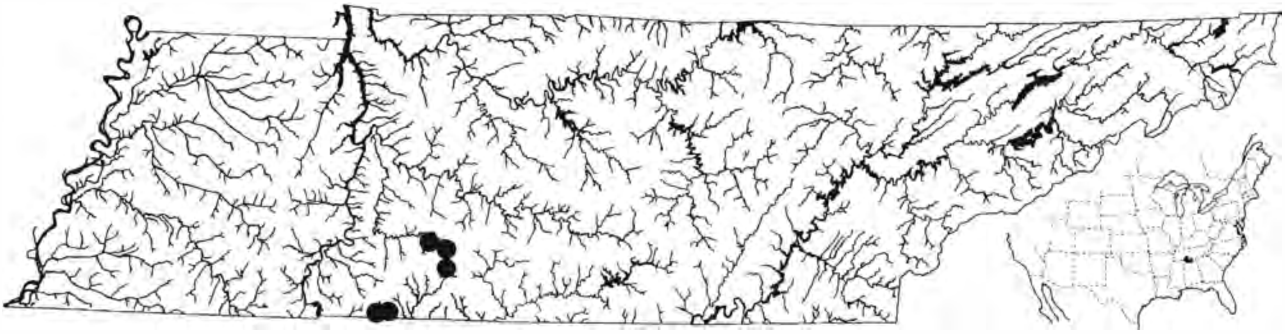
Slackwater darter

Plate 218a. *Etheostoma boschungi*, slackwater darter, female, 43 mm SL, Cypress Cr. system, TN.

Plate 218b. *Etheostoma boschungi*, slackwater darter, breeding male, 50 mm SL, Cypress Cr. system, AL.

Characters: Lateral line incomplete with 30–40 (24–44) pored scales and 43–53 (42–58) scales in lateral series. Dorsal fin with 9–11 (9–12) spines and 11–12 (10–13) soft rays. Anal fin with 2 spines and 7–9 (6–10) soft rays. Pectoral fin rays 12–13 (12–14). Principal caudal fin rays modally 16 or 17 (14–19). Gill rakers 8–12, length of longest rakers about twice their basal width. Vertebrae modally 36 (35–37). Branchiostegal rays 6. Gill membranes separate. Frenum well developed. Breast, prepectoral area, and cheeks naked. Opercles naked to having 1–6 embedded scales below the opercular spine. Nape usually fully scaled, but scales may be embedded; occasionally with naked areas anteriad. Supratemporal canal broadly interrupted. Infraorbital canal complete with 7 pores. The dorsum is brownish with three characteristic dark saddles, located anterior to the spinous dorsal fin, between the dorsal fins, and at the posterior end of the soft dorsal fin. Lateral blotches are variable, ranging from discrete to contiguous. A well-developed suborbital bar is present. The lips, lower head, and ventral portion of the body are pale yellow and heavily stippled with large melanophores. Rays of all fins except the spinous dorsal are speckled. The spinous dorsal fin has a narrow, dusky marginal band that widens posteriad, a broad, median, yellow to orange submarginal band, and a dark basal band. Nuptial males are brilliant orange on the lower half of the body, gill cover, lower jaw, and lateral portions of the upper jaw. The submarginal band in the spinous dorsal fin becomes bright orange, and the basal band darkens to iridescent blue or green. Orange also develops on the anal fin spines and their interradial membrane. Males develop nuptial tubercles on rays of the anal and pelvic fins, and on posterior belly scales.

Biology: Wall and Williams (1974), Boschung (1976), Williams and Robison (1980), and Boschung and Nieland (1986) have discussed various aspects of the slackwater darter's biology. It inhabits sluggish portions of small to medium-sized woodland streams that range from 3 to 10 m wide. It is often associated with pools containing leaf litter and detritus. Less commonly it is taken from more current-swept areas with cleaner substrates. In the upper Buffalo River we have found it associated with dense growths of filamentous algae. Reproductive habits are markedly different from those of darters in other subgenera. During late winter, slackwater darters migrate considerable distances (up to 4 km) up small tributaries to seepage areas in open fields which they enter during flooded periods. Spawning occurs primarily during late February and March (water temperature about 14 C). Breeding sites are among the stems of rushes (*Juncus*) in very shallow water. Eggs are laid singly or in groups of two or three on the *Juncus* stems. Females produce an average of over 300 mature eggs per year. Males defend nest sites vigorously during spawning and through early development of the eggs. Adults and larvae apparently exit the fields during April and return downstream to resident habitat areas. It is speculative as to what perpetuated the open areas used for slackwater darter reproduction prior to the advent of agriculture, but areas frequented by large mammals, such as bison wallows, may have been important. The diet consists of aquatic isopods, amphipods (*Hyalella*), mayfly nymphs (*Stenonema*, *Leptophlebia*), midge larvae, and limpets. Young slackwater darters attain lengths of 20–25 mm by June and are 35–40 mm long at age 1; 2-year-olds average 45–55 mm TL. Sexual maturity occurs at age 2, and maximum life span is about 3 years. The overall biology of *E. boschungi* is very similar to that reported for *E. trisella* (Ryon, 1981). None of the original 89 type specimens was larger than 52 mm SL, but Page (1983a) reported a maximum size of 65 mm SL (= 78 mm TL, or 3.1 in).



Range Map 210. *Etheostoma boschungi*, slackwater darter.

Distribution and Status: The slackwater darter occurs in widely separated localities in the southwestern Highland Rim region in Tennessee and northern Alabama. In spite of targeted survey efforts (Boschung, 1976), only about ten populations are known. Tennessee populations occur in the headwaters of the Buffalo River and Shoal Creek in Lawrence County, and in Cypress Creek, Wayne County. Alabama populations occur in lower portions of the latter two systems and in the Flint River system to the east. Because of its highly specialized breeding habitat, it is likely that this darter has been extirpated from a number of systems due to drainage of fields, other agricultural practices, and perhaps instream barriers. In 1992 we located a probably very important breeding site in a seepage area in a field in the Cypress Creek and Dulin Branch confluence area a few hundred meters west of Cypress Inn, Wayne Couty. The cypress darter is listed as a Threatened Species by the U.S. Fish and Wildlife Service Office of Endangered Species.

Similar Sympatric Species: *Etheostoma caeruleum* and *E. spectabile* (subgenus *Oligocephalus*) have much wider dark marginal bands on the spinous dorsal fin, have red on the soft dorsal fin (males), lack the large, dark chromatophores on the lower face, and have a moderate to faint suborbital bar. Members of the *E. squamiceps* complex (subgenus *Catonotus*) share the dark markings on the lower face but have fewer dorsal spines and lack orange or red colors.

Systematics: Subgenus *Ozarka* (Williams and Robison, 1980). Hypothesized to be most closely related to a group comprised by Ozarkian species *punctulatum*, *cragini*, and *pallididorsum* (Mayden, 1985). Variation has been treated by Wall and Williams (1974).

Etymology: *boschungi* is a patronym for H. T. Boschung, ichthyologist at the University of Alabama.

Etheostoma caeruleum Storer.

Rainbow darter

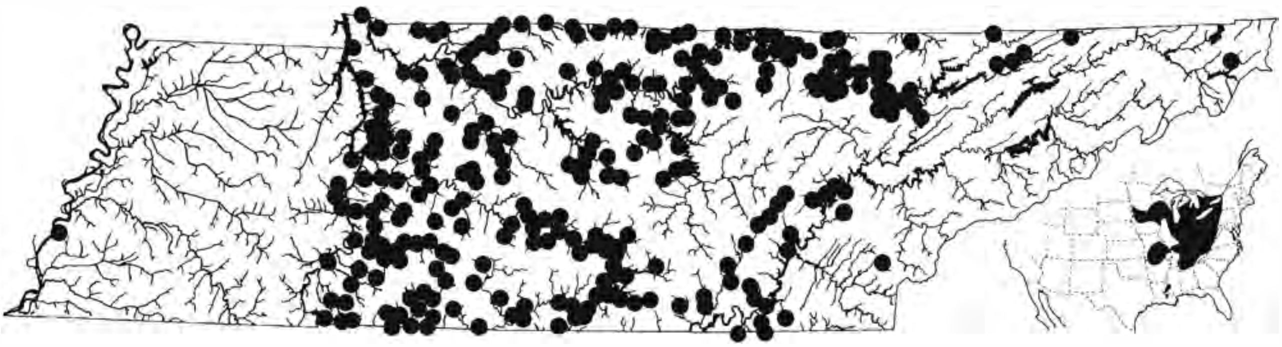
Plate 219a. *Etheostoma caeruleum*, rainbow darter, female, 44 mm SL, Cumberland R. system, TN.

Plate 219b. *Etheostoma caeruleum*, rainbow darter, male, 51 mm SL, Barren R. system, TN.

Characters: Lateral line incomplete with 22–34 (14–35) pored scales and 40–51 (36–57) scales in lateral series. Dorsal fin with 9–11 (8–13) spines and 12–14 (10–15) soft rays. Anal fin with 2 spines and 6–8 (5–9) soft rays. Pectoral fin rays modally 13 (10–15). Principal caudal fin rays modally 17, often 16 (14–17). Gill rakers 9–12, length of longest rakers 3–4 times their basal width. Vertebrae 36–37 (35–38). Branchiostegal rays 6. Gill membranes separate to narrowly joined. Frenum present. Breast and prepectoral area naked. Opercles and belly scaled. Nape varying from covered with embedded scales to partially naked. Cheeks naked or with a few scales behind eye. Mature males and females differ greatly in coloration. Dark markings in both sexes consist of about eight–ten dorsal saddles, with saddles two (posterior nape), three (between dorsal fins), and five (posterior end of soft dorsal fin) usually much darker. There are about ten midlateral dark blotches, the posterior five–seven of which (starting at anal fin origin) form oblique bars that are often continuous across the venter. Three fused basicaudal spots form a trident shape, and a suborbital bar is usually present. Nuptial males are brilliantly colored, and large males retain considerable color throughout the year. The cheeks and breast are blue-green, and blue and red bars alternate on the posterior half of the body. The branchiostegals (throat) are reddish orange. The spinous dorsal fin is basically red on its basal half and blue-green on its distal half, with a narrow pale marginal band. Additional narrow or interrupted dark, clear, or red bands are often present. The soft dorsal fin is mostly reddish orange with a narrow blue marginal and narrow clear submarginal band. The anal fin becomes almost entirely blue-green in the highest males, but usually retains at least some orange or red pigment near the middle of the fin. Pelvic fins are dusky to blue-black. Rays of the soft dorsal and anal fins are speckled in females and juveniles, with adult females usually having a narrow red band in the spinous dorsal fin and some red in the soft dorsal and anal fins. Nuptial males develop tubercles in the form of thickenings on scales on the posterior belly and lower caudal peduncle.

Biology: The rainbow darter is an inhabitant of upland streams ranging from small creeks to medium-sized rivers. Adults frequent fast-flowing riffles while younger individuals may be found in slower areas near the margins or in runs or pools. It is most common in areas with fine gravel substrates. Studies on breeding behavior have been conducted by Reeves (1907), Lachner et al. (1950), Winn (1958a,b), and J. Howell (1968). The reproductive season is late March to May or June, at water temperature of 15 C or higher. Spawning occurs in shallow gravel riffle areas. Brightly colored dominant males defend nonstationary territories. Females stage in pools below and swim up into the riffles where they are pursued by males. A female selects a site, burrows into the gravel enough to implant the lower half of her body, and is mounted by a male; thus the eggs are left buried in the gravel until hatching. Females spawn with several males over the course of a season. Though sexually mature at 1 year, 2-year-old males appeared to be dominant in spawning activities. Distler (1968) believed that frequent hybridization occurred with the closely related *E. spectabile* at certain localities; however, this was not supported by the results of electrophoretic investigations made by Martin and Richmond (1973). A hybrid with the unrelated *E. rufilineatum* is known (Mayden and Burr, 1980). According to Winn (1958b), females may lay 500–1,500 eggs over a season. J. Howell (1968) reported only up to 120 mature ova in females studied by him. Early development of *E. caeruleum* has been described by Cooper (1979) and growth by J. Howell (1968). Hatching of eggs requires about 10–12 days at water temperatures of 17–18 C. The larval stage is completed about 45–50 days after hatching, at which time the juveniles are about 15 mm TL. Based on Howell's data and our own collections, 1-year-olds are sexually mature and about 40–45 mm TL, and at age 2 lengths are about 50–55 mm. Larger individuals are assumed to be 3- to 4-year-olds. Rainbow darters feed on a variety of items, including midge larvae, hydropsychid and hydroptilid caddisfly larvae, mayfly nymphs, and fish eggs (Turner, 1921; J. Howell, 1968; Adamson and Wissing, 1977; Wynes and Wissing, 1982; Hlohowskyj and White, 1983; Vogt and Coon, 1990). Young feed principally on copepods and midge larvae. Feeding intensity is low during winter and peaks in May and June. On a daily basis, feeding is highest mornings and late afternoons, with a roving search pattern which is most pronounced in pools and constrained in riffles. Vogt and Coon (1990) found surprisingly little difference in feeding habits of rainbow darters and *E. spectabile*, a similar species, which is often syntopic. Maximum total length 80 mm (3.1 in).

Distribution and Status: The rainbow darter is widely distributed in the uplands of the Mississippi River basin through much of eastern and central United States. It occurs in Great Lakes tributaries (except Lake Superior) and in the upper Potomac drainage of the Atlantic slope. It is typically abundant, and is often the dominant darter where it occurs. In Tennessee, it is abundant throughout the chert gravel streams of the Highland Rim, and occurs locally in suitable gravel habitats in the Nashville Basin. It is much less common in east Tennessee, occurring sporadically in the Ridge and Valley from the Chattanooga area upstream. In the upper Tennessee drainage, it is known from only a few localities in the Ridge and Valley in the Clinch-Powell and upper Holston river systems. Why this typically very successful species cannot realize its potential in that region is an intriguing question; two additional darters that are widespread and abundant throughout their broad ranges (*E. nigrum* and *E. flabellare*) also have very spotty distributions in Ridge and Valley streams. The rainbow darter is common throughout much of the Cumberland Plateau, and occurs above Cumberland Falls in Kentucky but is extremely rare in the Tennessee portion of



Range Map 211. *Etheostoma caeruleum*, rainbow darter.

that system above Cumberland Falls. An isolated population occurs in Bear Creek, a Mississippi River tributary in Tipton County.

Similar Sympatric Species: Very similar in appearance to the orangethroat darter, *E. spectabile*, with which it is syntopic in the western Highland Rim, portions of the Cumberland Plateau, the Midwest, and much of Missouri and Arkansas. Rainbow darters have modally 13 (vs. 12 or fewer) pectoral fin rays, modally 17 (versus 16 or fewer) principal caudal fin rays, a complete infraorbital canal (interrupted in *spectabile*), and red in the anal fin of adults (blue or clear in *spectabile*). With a bit of practice, differences can be detected between the dorsolateral pigment patterns of the two species, with *spectabile* typically having rows of faint but fairly continuous horizontal brown lines while *caeruleum* lacks such lines or the lines are formed from discrete spots on scale centers. Also occurs occasionally with *E. luteovinctum*, which has well scaled cheeks, among other differences.

Systematics: Subgenus *Oligocephalus*. The systematics of *E. caeruleum* were studied by Knapp (1964), who regarded Tennessee populations as belonging to the subspecies *E. c. caeruleum*. He recognized two other subspecies, awaiting formal description, in the White River system of the Ozarks, and on the Coastal Plain in western Mississippi. The former differs in having horizontal rows of red spots on the sides, while the latter has low meristic counts and differs in shape and dorsal fin pigmentation from typical *caeruleum*. McCormick (1988) found morphological variation consistent with Knapp's, but some discordance in biochemical variation. He recognized populations from Crowleys Ridge and the Little Red system in Arkansas as new species and populations from southwestern Mississippi (Homochitto R., etc.) and White River system of Missouri as new subspecies. Other relevant studies were conducted by Trautman (1930), Martin and Richmond (1973), and Ross (1973). Schleuter and Thomerson (1971) made the interesting observation that variation in caudal fin structure in this darter was perhaps due to its reduced function in benthic fishes.

Etymology: *caeruleum* = blue.

Etheostoma camurum (Cope).

Bluebreast darter

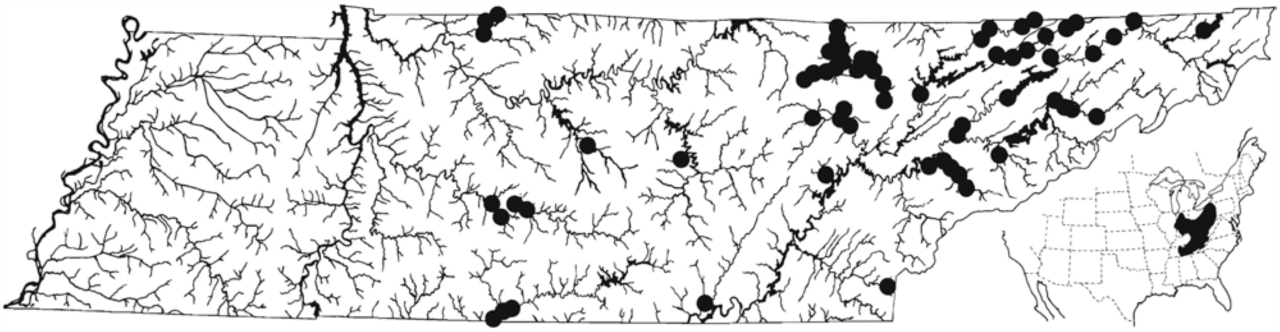
Plate 220a. *Etheostoma camurum*, bluebreast darter, female, 52 mm SL, Red R., TN.

Plate 220b. *Etheostoma camurum*, bluebreast darter, male, 59 mm SL, Little South Fork R., KY.

Characters: Lateral line complete with 50–65 (47–70) scales. Dorsal fin with 10–13 (9–15) spines and 11–13 (10–14) soft rays. Anal fin with 2 spines and 7–9 (6–9) soft rays. Pectoral fin rays 13–15. Principal caudal fin rays modally 17 (16–17). Gill rakers 11–13 (10–14), length of longest rakers about 3–4 times their basal width. Vertebrae 37–40. Branchiostegal rays 6. Gill membranes separate. Frenum well developed. Scales absent from cheeks, nape, breast, and prepectoral area. Head canals complete. Juveniles with about ten poorly developed dorsal saddles, with only the two on the nape persistent in adults. Sides marked with about ten small, W-shaped midlateral blotches in juveniles and females. All stages with sides marked with dark horizontal lines between scale edges on posterior two-thirds of body. Both males and females with dark marginal and cream-colored submarginal bands on median fins, and dark membranes on anterior portion of spinous dorsal fin. Sexes similarly patterned, but adult males are much brighter, and nuptial colors persist throughout the year. In peak breeding color they have bright blue to green breasts, rows of bright red spots on the sides, and reddish brown coloration on median and pelvic fins, with reds more prominent on the anal and pelvic fins. Specimens from the Red River, tributary to the Cumberland, are uncharacteristically bright orange on the belly and pectoral, pelvic and anal fins, similar to coloration seen in *E. bellum*. Seven to ten narrow, oblique, dark bars often appear on the sides, and are most pronounced from the anal fin origin posteriad, where they extend from the dorsum to the venter.

Biology: Bluebreast darters occur in areas with moderate to swift currents, depths of .5–1.5 m, and coarse, silt-free substrates of boulders, gravel, and bedrock in moderate to large rivers. They do not occur in small streams. Reproductive behavior has been reported by Mount (1959) and Stiles (1972). In our area, spawning may occur from late May through early August. Females partially bury themselves in sand or fine gravel substrates in areas protected from torrential currents by large boulders. Eggs are apparently released and fertilized while the female is partially buried. Males may protect the spawning site for several hours after spawning, but Stiles never observed a male protecting the same site on successive days. Hybrids with *E. tippecanoe* and *E. rufilineatum*, which spawn in similar fashion, are known (Mayden and Burr, 1980; our data). Age, growth, and fecundity data have not been reported, but are likely similar to those of other members of the subgenus. Stiles (1972) and Bryant (1979) found the diet of adults in Tennessee to consist primarily of midge larvae and small mayfly nymphs. Mayfly nymphs (Baetidae and Ephemerellidae) were utilized to a greater degree by this species than by its syntopic consubgeners, *E. vulneratum* and *E. rufilineatum*. Jordan and Copeland (in Jordan and Evermann, 1896, p. 1076) were very impressed with this beautiful species, and after unsuccessfully attempting to maintain specimens in aquaria, commented that "they died where other darters lived, and that before they died all other fishes seemed cheap and common beside them." Maximum total length 89 mm (3.5 in) from North Fork Holston River.

Distribution and Status: Widespread but generally uncommon and with a spotty distribution throughout much of the Ohio, Cumberland, and Tennessee drainages. Because it is an obligate inhabitant of moderate to large rivers, many populations have been extirpated by impoundments, with remaining populations isolated by these structures. It shows little if any tolerance for tailwaters and reservoirs, and is apparently adversely affected by siltation, as populations in agricultural areas of Illinois, Indiana, and Ohio are either extirpated or jeopardized. In Tennessee this beautiful fish continues to be fairly common in the Tennessee drainage, occurring in portions of the Clinch, Holston, French Broad, Sequatchie, and Little rivers in east Tennessee, and the Duck and Elk rivers in middle Tennessee. We recently collected a juvenile in Ft. Loudon Reservoir near a gravel island just above the mouth of George's Creek, several river miles removed from the nearest known populations in Little River and the lower Holston River. In the middle Cumberland River drainage *E. camurum* continues to be common in the area below Cumberland Falls not affected by Lake Cumberland in Kentucky, and in the Big South Fork system in Tennessee. In the



Range Map 212. *Etheostoma camurum*, bluebreast darter.

lower Cumberland drainage *E. camurum* is known to persist only in the Red River in Robertson County, Tennessee.

Similar Sympatric Species: *Etheostoma rufilineatum*, *E. aquali*, *E. acuticeps*, *E. sanguifluum*, *E. vulneratum*, and *E. wapiti* are similar in general appearance, but these species have more sharply pointed snouts. In *rufilineatum* the cheeks and opercles are marked with several dark horizontal dashes and the lips are orange in life. In *camurum* the cheeks and opercles are uniformly gray except for a post-orbital dark spot and a vague suborbital bar, and the lips are never orange. Female *rufilineatum* have large, dark brown spots on the median fins, while in female *camurum* these fins have a dark marginal and pale submarginal band as in the males. Submarginal pale bands are lacking on median fins of *acuticeps*, *aquali*, *sanguifluum*, and *vulneratum*, but may be distinct in *wapiti* males. In addition, *acuticeps* does not develop bright colors and lacks scales on the operculum; and *aquali*, *sanguifluum*, and *vulneratum* females have spotted rather than banded median fins.

Systematics: Subgenus *Nothonotus*. Hypothesized to be most closely related to *E. bellum* and *E. chlorobranchium* by Etnier and Williams (1989). Zorach (1972) mentioned the existence or previous existence of at least two populations related to *E. camurum* that may represent distinct subspecies or even species. Fifteen of these were taken from the main channel of the Cumberland River 2.8 km below Wolf Creek Dam in Cumberland County, Kentucky, July 1956, by R. M. Bailey. According to Zorach, these specimens had several characters suggesting a close relationship with *E. bellum*. No additional specimens have been taken, and the population may be extirpated. Four additional specimens, from East Fork Stones River and Pine Creek, tributaries to the Cumberland River in middle Tennessee, have lateral-line scale counts of 61, 63, 64, and 67. Although counts this high are not unusual for specimens from the upper Tennessee, they are much higher than counts from farther up the Cumberland drainage (mean = 52.8, Zorach, 1972), the Red River (mean = 52.6 in 19 available specimens, range 50–56), and recently available specimens from the lower Tennessee River. Both the Duck River (31 specimens counted) and the Elk River (16 specimens counted) populations have a mean of about 55 lateral-line scales, with a range of 49–57 in the Duck and 50–61 in the Elk. Our specimens from the Red River are more orange on the body and fins than specimens from other areas, but otherwise appear to be typical *E. camurum*.

The taxonomic relationship between *E. camurum* and the very closely related but more upland species, *E. chlorobranchium*, continues to be puzzling. The two species are apparently not sympatric anywhere, although in several major tributaries to the upper Tennessee River *E. camurum* occurs in the lower elevations and *E. chlorobranchium* occurs at higher elevations in association with the Blue Ridge. The elevation at which the transition between species occurs is apparently extremely variable from river to river. Unfortunately, the portions of these rivers (Holston, French Broad, Nolichucky, Little Tennessee, Hiwassee) where the species are potentially sympatric have been altered by impoundments or tailwater habitats in which neither species typically occurs. The Hiwassee and Nolichucky river populations might eventually provide sufficient specimens to allow a more definitive analysis of the taxonomic status of *E. chlorobranchium*. Our largest specimens, from North Fork Holston River, approach *E. chlorobranchium* in size, and have lateral-line scale counts (58, 59, 62, 64) intermediate between Tennessee River *camurum* and Watauga River (Holston system) *chlorobranchium*. Three available specimens from the lower Holston River, Knoxville, have similar scale counts (58, 58, 59), and are typical *camurum* in head shape and coloration. We have not seen North Fork Holston specimens in color, but Zorach examined 15 specimens from the upper North Fork in Virginia and was content with their identification as *camurum*. Our four North Fork specimens appear to have head shapes and submarginal band widths more like *chlorobranchium*, and remaining coloration, noted when they arrived in our laboratory three months after capture, consisted of considerable green on the caudal fin, an additional *chlorobranchium* character. Additional specimens from that area, accompanied by color notes or photos, would also be helpful.

Perhaps there is an unstudied mechanism of natural selection, "altitudinal melanism," operating on these and other fish species (*E. vulneratum*, *E. rufilineatum*, *E. b. blennioides* vs. *E. b. gutselli*) in which selective regimens cause replacement or masking of red and yellow pigments with darker blues, greens, and browns. Similar color shifts in other aquatic organisms with wide altitudinal ranges should be available if these sorts of differences in selective pressures, perhaps related to different solar radiation spectra, exist.

Etymology: *camurus* = blunt headed.

Etheostoma chlorobranchium Zorach.

Greenfin darter

Characters: Lateral line complete with 55–70 (52–72) scales. Dorsal fin with 11–12 (10–14) spines and 12–13 (11–14) soft rays. Anal fin with 2 spines and 8–9 (7–10) soft rays. Pectoral fin rays 13–15. Principal caudal fin rays 17 (16–18). Gill rakers 11–14, length of longest rakers about 4 times their basal width. Vertebrae 38–40. Branchiostegal rays 6. Gill membranes separate. Frenum present. Cheeks, nape, breast, and prepectoral area naked. Head canals complete. Both males and females with dark marginal and cream-colored submarginal bands on median fins. Pigmentation of females and juveniles as described for *E. camurum*. Nuptial males are characterized by having bases of median fins bright green. Green pigment develops on the body, often obscuring the brownish red spots on the sides, and the orange to pink flush on the belly. In extremely dark specimens, the dark horizontal lines between the scale rows are not visible.

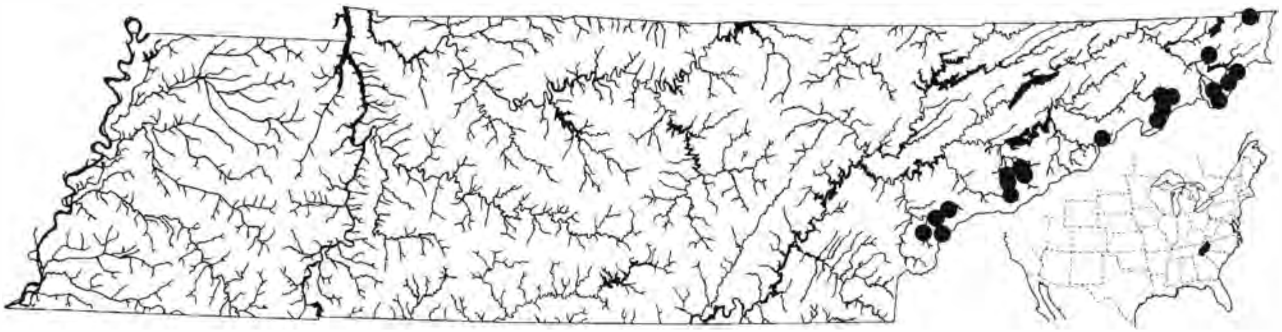
Biology: The greenfin darter is the largest species in the subgenus *Nothonotus* and is an inhabitant of cool to cold high-elevation creeks and rivers where it is associated with swift currents over bedrock, boulder, or coarse rubble substrates. Its spawning behavior is presumably similar to that described for *E. camurum*. Richard T. Bryant (pers. comm.) indicated that food of this species is far more varied than that of other *Nothonotus* studied, with contents of single digestive tracts often containing 10–15 different taxa of aquatic arthropods—mostly immature insects. Length-frequency data available from several large series in our collection indicate that growth is rapid, with lengths of about 45 mm attained at age 1, assuming a midsummer spawning period as is typical for the subgenus. Mean length of fish slightly over 2 years old (7 August) was 62 mm. Summer specimens larger than 75 mm appear to represent individuals 3 years old, with extremely large specimens probably 4 or perhaps 5 years old. Our two largest specimens are 110 mm long (94 mm SL, 4 in TL).

Plate 221a. *Etheostoma chlorobranchium*, greenfin darter, female, 71 mm SL, Nolichucky R. system, TN.

Distribution and Status: Restricted to the upper Tennessee River drainage, and mostly confined to Blue Ridge habitats, but penetrating into the upper Ridge and Valley in cooler rivers. Range extends from the upper Holston River system (but according to Zorach, 1972, not in the North Fork) south through the French Broad and Little Tennessee rivers. It is absent from Little River. Our collection contains three specimens from the Hiwassee River that have been tentatively identified as *E. camurum*, but all are juveniles; they may actually represent *E. chlorobranchium*. The greenfin darter is often abundant, but its habitats are not easy to collect with seines.

Similar Sympatric Species: Other *Nothonotus* with which it occurs include *vulneratum*, *rufilineatum*, and

Plate 221b. *Etheostoma chlorobranchium*, greenfin darter, breeding male, 83 mm SL, Little Pigeon R. system, TN.



Range Map 213. *Etheostoma chlorobranchium*, greenfin darter.

acuticeps. It differs in the same characters that differentiate *E. camurum* from these species.

Systematics: Subgenus *Nothonotus*, intimately related to *E. camurum*. Zorach (1972) treated systematics. There remains a possibility that this is merely a high-altitude morph of *E. camurum*. It differs from that species in having higher vertebral and scale counts, a slightly more pointed snout, and slightly narrower pale submarginal bands on the median fins. The most striking difference between the two species is the development of dark green coloration on the fins and body of *chlorobranchium*; *camurum* has these areas red, orangish, or brown. The enhanced development of dark green coloration in high-elevation populations also occurs in *E. vulneratum*, *E. rufilineatum*, and *E. blennioides*, and could reflect the end result of different selective pressures acting in these habitats. See additional comments under *E. camurum*.

Etymology: *chloro* = green, *branchium* = fin.

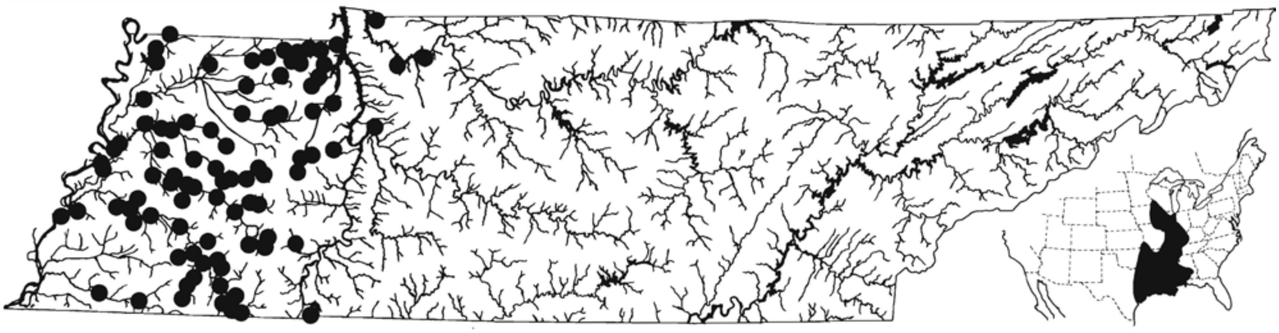
Etheostoma chlorosoma (Hay).

Bluntnose darter

Plate 222. *Etheostoma chlorosoma,* bluntnose darter, female, 41 mm SL, Obion R. system, TN.

Characters: Lateral line incomplete with 0–42 pored scales and 51–60 (47–64) scales in lateral series. Dorsal fin with 8–10 (7–12) spines and 10–11 (8–13) soft rays. Anal fin with 1 spine and 7–9 (6–11) soft rays. Pectoral fin rays 12–14 (12–15). Principal caudal fin rays 15 (13–17). In characters listed above, nonparenthetical values include 90% or more of counts of Mississippi River drainage specimens, while parenthetical extremes include entire range of the species. Many counts were provided by H. L. Bart, Jr. and R. C. Cashner (in Litt.). Gill rakers 5–7 (4–9), all but 3–4 vestigial, longest rakers about as long as wide. Vertebrae 38–40. Branchiostegal rays 5 (4–6). Gill membranes slightly connected to separate. Frenum lacking. Nape partially naked. Cheeks, opercles, belly, breast, prepectoral area, and temporal regions of head fully covered with exposed scales in Tennessee specimens, but portions of breast and belly may be naked in specimens from elsewhere. Preoperculomandibular canal usually complete. Infraorbital canal widely interrupted, with 2–4 anterior pores and 0–1 posterior pores. Supratemporal canal usually interrupted. Ground color pallid to straw yellow with brown markings. There are six often poorly defined, hourglass-shaped dorsal saddles and eight to ten irregular W-shaped midlateral blotches. A suborbital bar is typically present, and the preorbital bars of each side are continuous around the snout (Fig. 140). Dorsal and caudal fin rays are speckled, and a median dusky band may be evident in the spinous dorsal fin. Males darken on the belly, dorsal fin, and pelvic fins during the breeding season and develop sharp tubercles on pelvic (upper and lower surfaces) and anal fin soft rays. Spines associated with these two fins have hardened thickenings in nuptial males. Bright colors are absent.

Biology: The bluntnose darter is an inhabitant of low-gradient streams typified by sluggish to moderate current and sand and scattered detritus substrates. It also occurs in oxbows and overflow pools where substrates are reasonably firm. Its biology is poorly known. Tuberculate specimens from Tennessee are from March and



Range Map 214. *Etheostoma chlorosoma,* bluntnose darter.

April collections. Page et al. (1982) collected nuptial specimens on 30 April in Kaskaskia River, Illinois, at water temperatures 22 C. These spawned in an aquarium the next day, with males courting females in a sandy area, and the females subsequently selecting egg deposition sites (twigs, algae, dead leaves) where 1–3 eggs were attached per spawning act. Stomachs examined from specimens in our collection contained hydropsychid caddisfly, dytiscid beetle, and midge larvae. In collections examined by us, young-of-year were about 30 mm TL in mid August. Based on length classes and scale annuli, other age groups in a large August collection were 37–41 mm, and 46–50 mm TL. Maximum length 50 mm SL (= about 61 mm TL, or 2.4 in).

Distribution and Status: Gulf Coastal Plain from Colorado River drainage, Texas, east through Mobile Basin, and extending north in lowlands of Mississippi River basin to southeastern Minnesota. The bluntnose darter is common in Coastal Plain habitats in west Tennessee.

Similar Sympatric Species: Very similar in appearance to the johnny darter, *E. nigrum*, in which the preorbital bars are not continuous around the snout. Tennessee johnny darters have naked cheeks and often have the breast naked or with embedded scales. Also sympatric with the speckled darter, *E. stigmaeum*, which has 2 anal spines, a naked breast, and develops blue and red nuptial colors.

Systematics: Subgenus *Vaillantia*, along with *E. davisoni* of southeastern Alabama and western Florida. Systematics have been discussed by Cole (1967), W. M. Howell (1968), and Bart and Cashner (1986). Variation is slight within the Mississippi River basin, but Bart and Cashner (1986) noted considerable variation in scale counts and squamation in drainages both east and west of the Mississippi River. No subspecies are recognized.

Etymology: *chloro* = green, *soma* = body, not a very apt name, but under some conditions greenish tinges might be imagined on the basically yellowish body.

Etheostoma cinereum Storer.

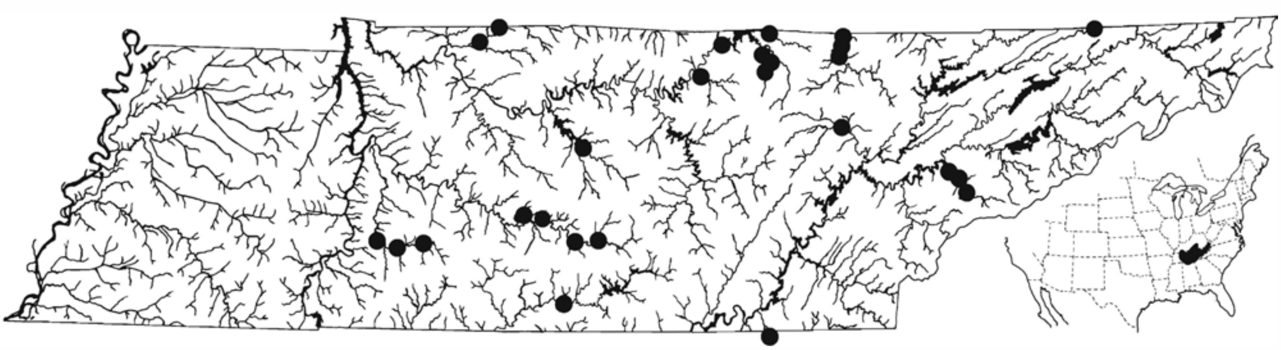
Ashy darter

Plate 223. *Etheostoma cinereum*, ashy darter, male, 79 mm SL, Little R., TN (preserved several hours before photo).

Characters: Lateral line complete with 53–60 (50–63) scales. Dorsal fin with 11–13 (9–14) spines and 12–13 (11–14) soft rays. Anal fin with 2 spines and 8–9 (7–9) soft rays. Pectoral fin rays modally 15 (14–16). Principal caudal fin rays 17 (16–18). Gill rakers not developed. Vertebrae 41–43 (39–44). Branchiostegal rays 6 (6–7). Gill membranes separate. Frenum well developed. Head canals complete. Belly and opercles with exposed scales. Cheek scales small and embedded. Breast, prepectoral area, and most of nape naked. Characteristically, the dorsolateral area is marked with numerous wavy horizontal brick-red lines. About 11–12 small midlateral blotches are present, below which are oblique dusky streaks. A suborbital bar is lacking. The spinous dorsal fin has a narrow red marginal band, and numerous brick-red spots occur on the membranes. The soft dorsal fin, which is greatly expanded in mature males, has red interradial membranes breaking up into spots basally. The caudal fin is speckled with red, and the pectoral, pelvic, and anal fins are clear. Pelvic and anal fins become brilliant electric blue in breeding males, and a similar blue spot appears in the anterior membranes of the spinous dorsal fin. Blue also appears on the chin, isthmus, breast, belly, lower caudal peduncle, and lower operculum. In the Cumberland drainage the lips are red, but this has not been noted for Tennessee drainage specimens. Nuptial tubercles were noted on anal fin soft rays and on ventral surfaces of the second and third pelvic fin soft rays on a single Rockcastle River specimen collected on 5 March (Shepard and Burr, 1984).

Biology: The ashy darter is an inhabitant of small to medium upland rivers, where it occurs locally in areas of bedrock or gravel substrate with boulders, water willow, and other cover with minimal silt deposits. Depths in these areas are .5–2 m, and currents are sluggish. Snorkeling observations reveal that these fishes spend much of the time beneath or in proximity to slab-rock boulders. Biological information is available from our studies and Shepard and Burr (1984). Breeding season peaks in March, and may extend from late January through early April. Females produce 50–250 ova per year. Burkhead (pers. comm.) found eggs deposited on the filter tubes in an unwitnessed aquarium spawning, suggesting that the sides of boulders or water willow stems are used as egg deposition sites. Young reached lengths of 40–75 mm at age 1, and age-1 males over 60 mm and females over 65 mm were mature. Lengths at ages 2 and 3 were 50–94, and 70–99 mm, respectively, with growth slowest in the Cumberland drainage and fastest in the Duck River system. Diet is dominated by midge larvae, with the burrowing mayfly, *Ephemera*, a significant food item in the Cumberland drainage. We noted a considerable amount of incidental detritus and sand grains in several digestive tracts examined. Life span is 3 to 4 years, with maximum size 100 mm SL (= about 115 mm TL or 4.5 in).

Distribution and Status: Ashy darters occur sporadically in the Highland Rim and Ridge and Valley portions of the Tennessee and Cumberland river drainages and in the lower reaches of some Cumberland Plateau rivers of those drainages. The water quality necessary to maintain silt-free pool areas is now rare in these regions, and it is likely that populations have been extirpated before discovery. Prior range probably included preimpoundment main-channel areas of both the Cumberland and Tennessee rivers. Shepard and Burr (1984) reported that only five river systems are currently known to have viable populations, with ashy darters presumably extirpated or not taken in recent years from the remaining ten localities of historical occurrence. *Etheostoma cinereum* was described from near Florence, Alabama (Storer, 1845), but has not been recorded from that state since, and was not collected again in the Tennessee drainage until 1965. It is a difficult species to collect, and the ashy darter's status may not be quite as gloomy as indicated above. The healthiest known population is in Little River, Blount County, Tennessee, from the Melrose Mill Dam downstream to the Tennessee Highway 33 bridge in Rockford. We were consistently able to collect specimens in a long pool area on the east side of the river below the riffle immediately below the U.S. 411 bridge by using four to six people and a small seine. We start the seine parallel to the shore, about 1.5 m deep, and slowly move toward the shore with two or three people stooped over and hand-fitting the lead line over boulders and snags while the two brail tenders keep pace. In this area we typically could collect 5–15 specimens per hour, and the technique is also effective for *Percina aurantiaca* juveniles and *P. macrocephala*. Several mark-and-recapture population estimates made in this area have yielded estimates of about 30–60 individuals in an area of about 2,000 square meters. The total ashy darter



Range Map 215. *Etheostoma cinereum*, ashy darter.

population in the pool area between the riffle below the bridge and the next riffle downstream, based on relative habitat quality and total area of the pool relative to that sampled, was probably about 300 individuals. Although success of collecting for rare riverine fishes is typically erratic, of late we have noted a disturbing overall downward trend in Little River. The ashy darter is considered a Threatened Species in Tennessee (Starnes and Etnier, 1980), is extirpated from both Alabama and Georgia, is extremely rare in Virginia, and persists in Kentucky in the Little South Fork and Rockcastle rivers.

Similar Sympatric Species: With its distinctive color pattern and snout shape, the ashy darter bears little resemblance to any other darters.

Systematics: *Etheostoma cinereum* is the only species in the subgenus *Allohistium*, and relationships with other darter groups are unknown. It is generally conceded to represent a very primitive member of the genus *Etheostoma* (Page and Whitt, 1973a; Page, 1977; Collette and Banarescu, 1977; Bailey and Etnier, 1988). We note that Shepard and Burr (1984) are in error in reporting a modal count of 16 principal caudal fin rays. Of 70 UT specimens counted, counts are 16(1), 17(62), 18(7), and most of these specimens were utilized in the above study. Also, we noted the presence of 7 branchiostegal rays in 17 of 155 counts (both sides counted). These data, both indicating retention of primitive characters, reinforce its basal position within *Etheostoma*.

Etymology: *cinereum* = ashy.

Etheostoma coosae (Fowler).

Coosa darter

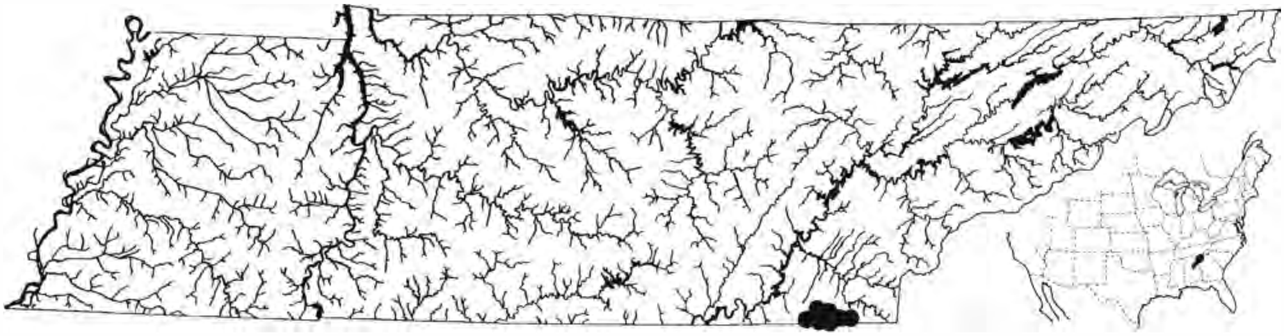
Characters: Lateral line complete with 46–53 (42–59) scales. Dorsal fin with 9–11 (8–12) spines and 11–12 (10–13) soft rays. Anal fin with 2 spines and 6–8 soft rays. Pectoral fin rays 13–14 (12–15). Principal caudal fin rays 15–17. Gill rakers 9–10 (8–11), length of longest rakers about twice their basal width. Vertebrae 37–39. Differs from other *Ulocentra* in consistently having 6 rather than 5 branchiostegal rays. Gill membranes broadly joined. Frenum absent. Cheeks, opercles, nape, belly, and prepectoral area scaled. Breast usually naked. Head canals complete. Dorsum with eight dark saddles. Mid sides marked with about eight to ten blotches. Adult males with lower head, breast, and gular area green; pelvic and anal fins dark with green tints;

Plate 224a. *Etheostoma coosae*, Coosa darter, female, 41 mm SL, Coosa R. system, AL.

Plate 224b. *Etheostoma coosae*, Coosa darter, male, 53 mm SL, Conasauga R. system, TN.

spinous dorsal fin with blue-green marginal band, clear submarginal band, median band of bright red spots, submedian clear band and basal dark band; soft dorsal fin with brick-red membranes; sides with about six blue to blue-green, vertically elongate, rectangular blotches on posterior portion of body. Adult females may have a red spot in the anterior and posterior interradial membranes of the spinous dorsal fin, and the anterior red spot is often, in characteristic *Ulocentra* fashion, larger and brighter than the more posterior spots.

Biology: The Coosa darter occurs in small to large streams in gentle riffle areas and over clean gravel substrates in pools and along stream margins. O'Neil (1981) provided biological information. Spawning occurs from March through May and peaks in April. Courtship consists of dorsal fin displays and contact (nudging and bumping with the snout) initiated by males and occasionally by females. During the spawning embrace, eggs are deposited singly on the sides or undersurfaces of boulders and are immediately fertilized by the male. As in *E. simoterum*, the spawning pair may assume a vertical to inverted position to conform with the spawning surface chosen. Females produce about 300–500 eggs per year. Food is dominated by midge and blackfly larvae (78%), supplemented with cladocera, copepods, mayfly nymphs, and caddisfly larvae. Sexual maturity may occur after 1 year's growth, and life span is 3 years. Maximum length (Page, 1983a) 60 mm SL (71 mm TL, or 2.75 in).



Range Map 216. *Etheostoma coosae*, Coosa darter.

Distribution and Status: Restricted to the Coosa River system (Mobile Basin) above the Fall Line in Tennessee, Georgia, and Alabama. The Coosa darter is typically a very common species in suitable habitats.

Similar Sympatric Species: The much less common holiday darter, *E. brevirostrum*, has a blunter snout, narrow vertical lime-green bands that encircle the caudal peduncle, a median red band in the soft dorsal fin (virtually entire fin red in *coosae*), red in the anal fin, modally 11 vs. 10 dorsal spines, and 5 (vs. 6) branchiostegal rays. Differs from the similarly colored (females and juveniles) *E. stigmaeum* in having eight to nine vs. six dorsal saddles.

Systematics: Subgenus *Ulocentra*. Bailey and Etnier (1988) included it in the *E. duryi* species group, and indicated a possible close relationship between *coosae* and *zonistium* based on coloration of the spinous dorsal fin.

Etymology: Named after the Coosa River.

Etheostoma crossopterum Braasch and Mayden.

Fringed darter

Characters: Lateral line incomplete with 7–44 pored scales and 47–55 (38–64) scales in lateral series. Dorsal fin with 8–9 (7–10) spines and 12–14 (11–15) soft rays. Anal fin with 2 spines and 7–8 (6–9) soft rays. Pectoral fin rays 11–12 (10–13). Principal caudal fin rays 16–19, modally 17. Gill rakers 8–11, length of longest rakers 1–2.5 times their basal width. Branchiostegal rays 6. Gill membranes slightly joined. Frenum present. Scales present on cheeks, opercles, nape, belly, breast, and prepectoral area, but may be embedded and difficult to see. Females and non-nuptial males drab olivaceous to darkly patterned, essentially identical to *E. neopterum*, *E. nigripinne*, and *E. squamiceps*. Dorsal saddles (eight to nine) and 10–12 midlateral blotches may be evident, or sides may be mottled. Three basicaudal dark spots, a dark humeral spot above the pectoral fin base, and a suborbital bar are usually present; additional dark mottling typically present on cheeks. Spinous dorsal fin with marginal and basal dusky bands. Rays of soft dorsal, caudal, and pectoral fins speckled or banded. Nuptial males darker, especially on the head, and the spinous dorsal, anal, and pelvic fins blacken except at their margins. Soft dorsal fin black with a pale marginal band (extreme tips of rays may be dark) and rows of thin, pale dashes. The head of breeding males becomes swollen, tips of dorsal spines develop small knobs, and the soft dorsal fin rays extend well past the membranes and have tiny swellings at their tips. Nuptial tubercles are not formed.

Biology: Page (1974b) was in part treating *E. crossopterum* in his study of the biology of *E. squamiceps*. Preferred habitats are gently flowing pool areas or riffles with slab-rock rubble substrates in small streams. Spawning occurs from late March into May with eggs deposited in a single layer on the underside of stones and tended by the males. Males court females by erecting fins, intensifying their color, and tail wagging, and probably mimicking eggs with swollen tips of dorsal fin rays (see Bart and Page, 1989). When a female enters a nest, she assumes a belly-up position. The male joins, pressing alongside, and spawning occurs; two to five eggs are deposited during each encounter. Up to 1,500 ova may eventually be deposited in the nest of a single male by several females. Fecundity of females ranges from 30 to 350 ova depending on her size (age). Males guard and maintain the nest by sweeping away silt and debris with their dorsal fins or picking by mouth. Eggs probably hatch in about 2 weeks at normal spawning temperatures of 14–19 C; hatchlings are 6.5 mm TL. Lengths are about 35–50, 60–70, and 74–80 mm TL at ages 1, 2, and 3, with males averaging larger. Three-year-old females were not found in Page's study. The diet consists of aquatic insect immatures, including midge and caddisfly larvae and mayfly nymphs, and crustaceans, such as isopods, amphipods, and small crayfishes. Juveniles feed on microcrustaceans and midge larvae. Maximum total length 110 mm (4.3 in), females about 75 mm (3 in).

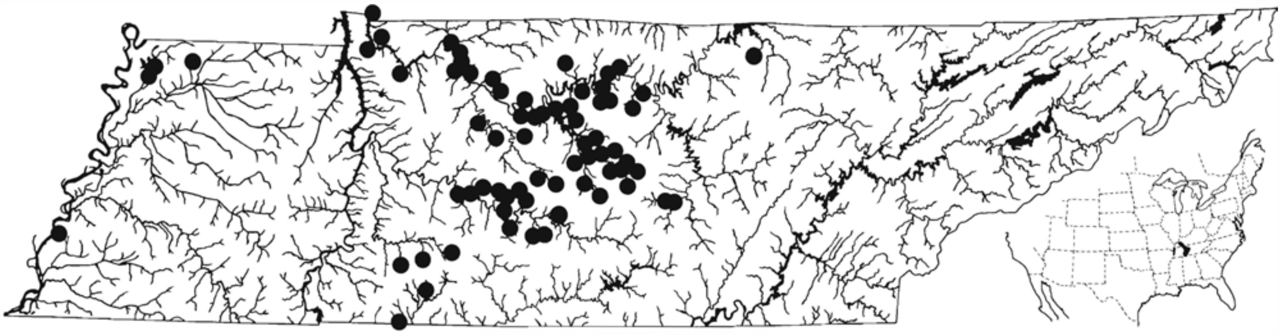
Distribution and Status: Common in portions of the Highland Rim and Nashville Basin in tributaries to the middle and lower Cumberland River into Kentucky, and Shoal Creek, southern tributaries to upper Buffalo River, and middle Duck River system of the Tennessee River drainages. Disjunct populations perhaps representing this species occur in the lower Barren Fork system of the Cumberland drainage in Warren County (one specimen), and on the Coastal Plain in tributaries draining bluffs east of Reelfoot Lake in Obion County and in Bear Creek in Tipton County (Mississippi River drainage).

Similar Sympatric Species: Occurs with other subgenus *Catonotus* species *flabellare* and uncommonly *kennicotti*, both of which lack scales on the breast, prepectoral area, nape, and opercle. *Etheostoma crossopterum* lacks the broadly connected gill membranes of *flabellare* and lacks the multiple horizontal rows of dark lines on the sides that occur on sympatric *flabellare*; in *kennicotti* the dark upper half and clear lower half of the spinous dorsal fin is diagnostic. Occurs with "bar-cheek" members of *Catonotus* (*smithi*, *striatulum*, *virgatum*), which have the characteristic pale, oblique cheek bar which is lacking in *crossopterum*. Reportedly sympatric (but perhaps not syntopic?) in Shoal Creek and Duck River system with the very closely related *E. nigripinne* (Braasch and Mayden, 1985; Page et al., 1992); if so, they may be distinguished only by comparison of nuptial males, chiefly the soft dorsal fin, which in *crossopterum* has the posterior (third) branch of each ray much longer than the middle branch (middle and posterior branches subequal in *nigripinne*), and has a marginal pale band (black margin in *nigripinne*). Although not diagnostic, comparisons of counts of lateral scale series, dorsal spines, pectoral, anal, and soft dorsal fin rays, and maximum size with data given in Braasch and Mayden (1985) may allow reasonably accurate identification in the absence of nuptial males if large series are available. Sympatric with the very similar *E. neopterum* group in lower Duck River and in the Shoal Creek system. Nuptial males of *neopterum* differ markedly from *crossopterum* in having large, spherical swellings on tips of the elongate soft dorsal fin rays (Pl. 240). When nuptial males are not available, modal soft dorsal ray counts (11–12 in *neopterum*, 12–14 in *crossopterum*), infraorbital canals (often complete in *neopterum*), and branching pattern of soft dorsal fin rays (branches adnate and only two per ray in *neopterum*, divergent and separated by membrane in *crossopterum*, and typically with three branches per ray in adults) are useful but not completely diagnostic for identification.

Plate 225a. *Etheostoma crossopterum*, fringed darter, female, 53 mm SL, Duck R. system, TN.

Systematics: Subgenus *Catonotus*; a member of the *E. squamiceps* complex recently accorded species status by Braasch and Mayden (1985), hypothesized to be sister species to *E. nigripinne*. See further comments under *E. squamiceps*. Page et al. (1992) offer a more recent interpretation of its taxonomy and distribution.

Plate 225b. *Etheostoma crossopterum*, fringed darter, breeding male, 78 mm SL, Duck R. system, TN.



Range Map 217. *Etheostoma crossopterum*, fringed darter.

Etymology: *crosso* = fringed, *pteron* = fin, in reference to the fringed soft dorsal fin of nuptial males.

Etheostoma ditrema Ramsey and Suttkus.

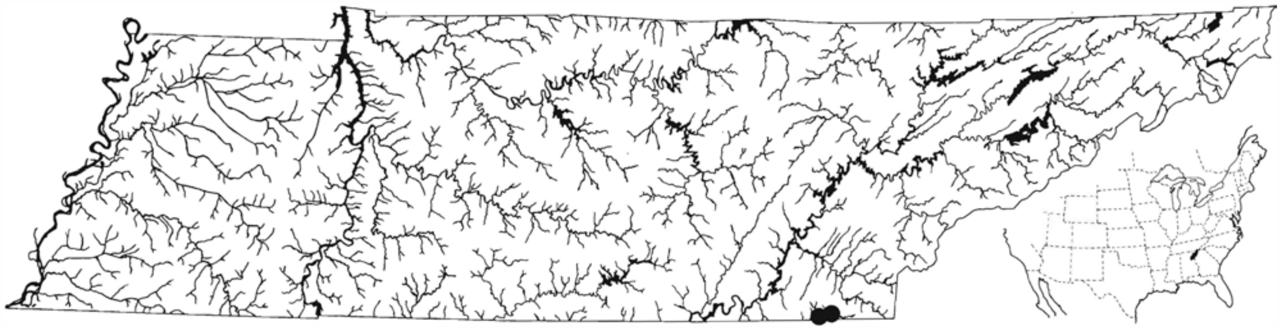
Coldwater darter

Plate 226a. *Etheostoma ditrema*, coldwater darter, female, 43 mm SL, Conasauga R. system, GA.

Plate 226b. *Etheostoma ditrema*, coldwater darter, male, 43 mm SL, Conasauga R. system, GA.

Characters: Lateral line incomplete, with 23–33 (19–38) pored scales and 43–50 (41–54) scales in lateral series. Dorsal fin with 9–11 (8–12) spines and 10–11 (9–12) soft rays. Anal fin with 2 spines and 6–7 (6–8) soft rays. Pectoral fin rays 12–13 (11–13). Caudal fin rounded, with 15–16 (14–16) principal rays. Gill rakers 8–11 including vestiges on lower limb, length of longest rakers about 1.5 times their basal width. Vertebrae 36–37 (35–37). Branchiostegal rays 6. Gill membranes separate. Frenum well developed. Scales, usually exposed, present on cheeks, opercles, breast, prepectoral area, and belly. Nape often with naked areas. Infraorbital canal usually complete, with 8 (5–9) pores. Preoperculomandibular canal with 9–10 (8–11) pores. Supratemporal canal often interrupted. The coronal canal is often interrupted, resulting in two pores rather than the usual single coronal pore. Dorsum mottled dark brown with about nine variously developed saddles. Sides irregularly mottled with brown, some specimens with darker scale centers resulting in a pattern of longitudinal lines. Three vertically arranged basicaudal spots are present, and a suborbital bar is usually evident. Dark speckles are present on the rays of the dorsal and caudal fins and are variously developed on the rays of the remaining fins. In males, the belly becomes scarlet and reddish spots are usually present on the sides. The spinous dorsal fin has bluish marginal and median bands and red submarginal and basal bands. The soft dorsal fin is clear to slightly bluish with a row of reddish spots centrally and basally. The anal fin is bluish with a dusting of melanophores and reddish spots basally. Red and blue coloration intensifies on nuptial males. So far as known, breeding tubercles are lacking.

Biology: The coldwater darter is strictly an inhabitant of spring-fed runs or pools. Maximum abundance is reached in vegetation-filled spring ponds with growths of aquatic mosses (*Fontinalis*), watercress, and milfoil. Individuals are often encountered among this vegetation and apparently perch within it well above the substrate. Seesock (1979) has studied its biology. The coldwater darter has an extended spawning season from March to September with peak activity during April to June. Females contain an average of only about 50 mature ova with larger females containing more eggs and spawning earlier. Based on aquarium observations, spawning occurs in vegetation. Males court females by fin erection and nudging the head region. If receptive, the female bends her head and tail towards the male and then swims with him to a vertical perching position in the vegetation above. After mounting by the male, the pair progress upward extruding and fertilizing small num-



Range Map 218. *Etheostoma ditrema*, coldwater darter.

bers of eggs which are apparently left unattended. Males are only weakly territorial prior to spawning. Seesock believed the coldwater darter to be short-lived with a life span of only 2 years. Sexual maturity is reached at age 1. Because of continuous recruitment over the extended reproductive season, growth was difficult to ascertain. It would appear that a length of 35–40 mm is average for the first year. The diet of the coldwater darter is composed of typical spring-dwelling invertebrates with amphipods being predominant. Other important constituents are midge larvae, isopods, and copepods. Maximum total length 65 mm (2.5 in).

Distribution and Status: The coldwater darter is confined to a few spring habitats in the Ridge and Valley portion of the Coosa River system above the Fall Line in Alabama, Georgia, and extreme southern Tennessee. Only about a dozen populations are presently known; several have doubtless been eliminated by habitat alterations. In Tennessee, it is known in the Conasauga system from the headwaters of the Sugar Creek system in Bradley County and from a small spring branch along the main river in Polk County about 3 km east of the Bradley County line but has not been taken from spring habitats farther up river. It is abundant in a spring tributary to the Conasauga River 3 km south of the Tennessee line along Georgia Highway 225 (Murray County) and at Cohutta Springs a few kilometers to the west. It is considered threatened throughout its range (Ramsey, 1976; Helfman and Freeman, 1979; Starnes and Etnier, 1980).

Similar Sympatric Species: None.

Systematics: Member of subgenus *Oligocephalus*. Hypothesized by Ramsey and Suttkus (1965) to be a spring-adapted upland relative of *E. swaini*, which occurs on the Gulf Coastal Plain. Aberrant, possibly intermediate, populations from near the Fall Line in Shelby County, Alabama, have been under study (Utter and Ramsey, 1981).

Etymology: *ditrema* = two holes, in reference to the twin coronal pores.

Etheostoma duryi Henshall.

Black darter

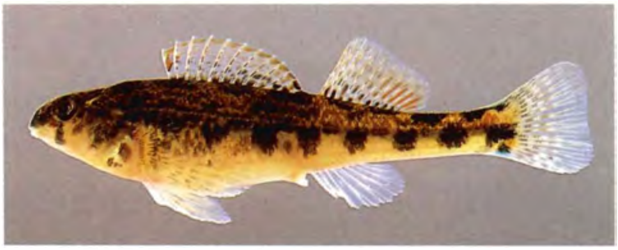


Plate 227a. *Etheostoma duryi*, black darter, female, 49 mm SL, Elk R. system, TN.

Plate 227b. *Etheostoma duryi*, black darter, male, 48 mm SL, Elk R. system, TN.

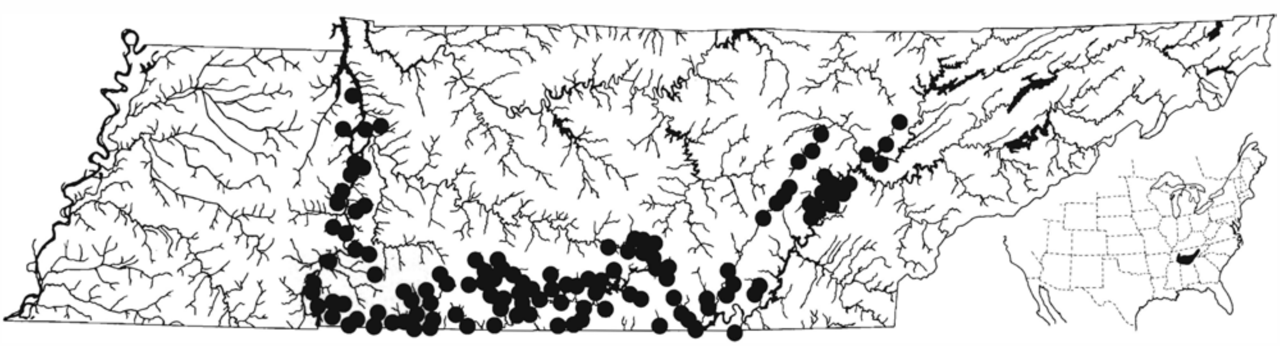
Characters: Lateral line complete with 42–51 (39–57) scales. Dorsal fin with 10–12 (9–13) spines and 11–13 (10–14) soft rays. Anal fin with 2 spines and 6–8 (5–9) soft rays. Pectoral fin rays 13–15 (12–16). Principal caudal fin rays modally 17 (15–18). Gill rakers 7–10, length of longest rakers about twice their basal width. Vertebrae 37–40, modally 38. Branchiostegal rays 5.

Gill membranes broadly connected. Frenum absent. Head canals complete. Nape, cheeks, opercles, belly, and prepectoral area scaled. Breast naked to fully scaled. Dorsum with eight or nine dark saddles. Sides with about nine dark blotches which are often fused to form a continuous lateral stripe, especially in females. Nuptial males with green on lower face and throat, breast dirty orange, an orange streak on lower sides from anterior belly to base of caudal fin, some orange marks on dorsolateral area, lateral and ventral scales often edged with dark pigment, pelvic fins dark, anal fin dark but often with orange at posterior base, caudal fin mottled, with orange at base, soft dorsal fin with brick-red membranes. Spinous dorsal fin variable, typically with dark basal band anteriad, brick red marginal band, and central portion composed of three to six horizontal rows of brick red vermiculations or spots. Both dorsal fins elongate in adult males. Orange ocellus typically present on first interradial membrane of spinous dorsal fin in both males and females, but often obscured in nuptial males. Breeding tubercles absent.

Biology: The black darter occurs in typical *Ulocentra* habitats of pools and gentle riffles with firm substrates, in areas ranging from small creeks to small rivers. Where sympatric with *E. simoterum*, *duryi* tends to inhabit pool and shoreline areas while *simoterum* occurs in swifter currents. Page et al. (1982) reported breeding behavior to be essentially identical with that of *E. simoterum*. Breeding season peaks in April (March through early May). Males show considerable aggression towards each other, with lateral displays accompanied by erection of dorsal fins, and chasing frequently observed. Females select egg deposition sites, typically on the sides of boulders, and eggs are deposited singly and immediately fertilized by the accompanying male, who assumes an S-shaped position while embracing the female. Sexual maturity typically occurs after 1 year's growth at 28–35 mm SL, and after 2 year's growth standard lengths are 40–48 mm; specimens larger than 50 mm SL may represent 3-year-olds. Males are slightly larger than females in all age groups. Other aspects of its biology are unstudied. Maximum size 70 mm (2.75 in) TL.

Distribution and Status: Confined to the Tennessee River drainage where it is ubiquitous in streams of the lower bend of the river in Alabama. In Tennessee it is widespread in the Chattanooga area, and of sporadic occurrence upstream to portions of the lower Clinch River system. In middle Tennessee, it is associated with Highland Rim habitats, occurring in Little Duck River and Crumpton Creek (Duck River system) in Coffee County, the Elk River system, eastern tributaries to the lower Tennessee River downstream to the mouth of the Duck River, and in the several Highland Rim areas on the west side of the Tennessee River. It is replaced by the saffron darter in the Buffalo River system, most of the Duck River system, the Indian Creek system of Wayne and Hardin counties except near its mouth, and eastern tributaries to the Tennessee River below the mouth of Duck River and Trace Creek. It is typically a common species where it occurs.

Similar Sympatric Species: Often confused with *E. simoterum*, which has a distinct but narrow frenum and a noticeably more blunt snout. We have had little difficulty in separating these species using these characters. In juveniles, the two basicaudal dark spots are fused in *duryi*, but separate in *simoterum*. In addition, adult males of *duryi* have greatly elevated dorsal fins and brick red, horizontal rows of vermiculations or spots in the spinous dorsal fin; in *simoterum* these fins are less elevated and the spinous dorsal fin either has brick-red vertical streaks (*E. s. simoterum*) or a median row of bright orange ocelli (*E. s. atripinne*) in the membranes. The very similar saffron darter (*E. flavum*) is occasionally sympatric with *duryi*. Adult males differ from male



Range Map 219. *Etheostoma duryi*, black darter.

duryi in having orange lips, yellow rather than green on the side of the head, the entire area below the lateral stripe yellow (orange ventral band in *duryi*), and in pigmentation of the spinous dorsal fin (*flavum* typically lacks an orange ocellus in the first interradial membrane, has uniformly brown or brown streaked obliquely with darker brown membranes versus three to six horizontal rows of brick red vermiculations or spots in *duryi*, and has a brown marginal band that widens posteriad and has a pale border versus the brick red band of rather uniform intensity and width in *duryi*). Males, females, and juveniles of *duryi* have an orange spot above and/or below the basicaudal dark spot; these are absent in *flavum*. Where geographical contact has occurred between these two species, *flavum* dominates over orange to yellow substrates of Fort Payne Chert origin, while *duryi* is more typical of darker limestone substrates and spring habitats (Etnier and Bailey, 1989).

Systematics: Subgenus *Ulocentra*. Relationships between *duryi* and the saffron darter, *E. flavum*, are very complex, with several apparent cases of introgressive hybridization and competitive exclusion noted in areas of contact (Etnier and Bailey, 1989). In the upper Duck River system, *duryi* has apparently invaded Little Duck River and Crumpton Creek, Coffee County, from the adjacent headwaters of the Elk River. It also occurs in a limited portion of the main channel of Duck River between the headwaters of Normandy Reservoir and several natural and human-made falls and dams extending from Old Stone Fort a short distance upstream. Normandy Reservoir may be significant in preventing downstream movement of *duryi* in the Duck River system, but it seems more likely that the habitats from Normandy downstream favor *flavum*. Norman Branch, a tributary to Normandy Reservoir in Bedford County, produced a single adult male of *duryi* along with many *flavum* when sampled on 29 March 1985, suggesting that *duryi* has had access to this area prior to construction of Normandy Reservoir. The series of barriers to upstream movement in the Duck River, starting at Old Stone Fort, have apparently been effective in preventing *duryi* from entering the upper Duck River proper, as only *flavum* has been taken in that area. Saffron darters apparently gained access to upper Indian Creek, Wayne County, via headwater piracy from the Buffalo River. In Indian Creek, *flavum* has apparently replaced *duryi* except from at least one lower tributary, Alexander Branch, where a 1985 sample produced many *duryi* and a single adult male *flavum*. In areas where recent contact has occurred between these very similar species, characters suggest that introgressive hybridization has been a prelude to eventual elimination, presumably by competitive exclusion, of either *duryi* or *flavum*.

Etymology: Named after the collector of the original types, Mr. Charles Dury.

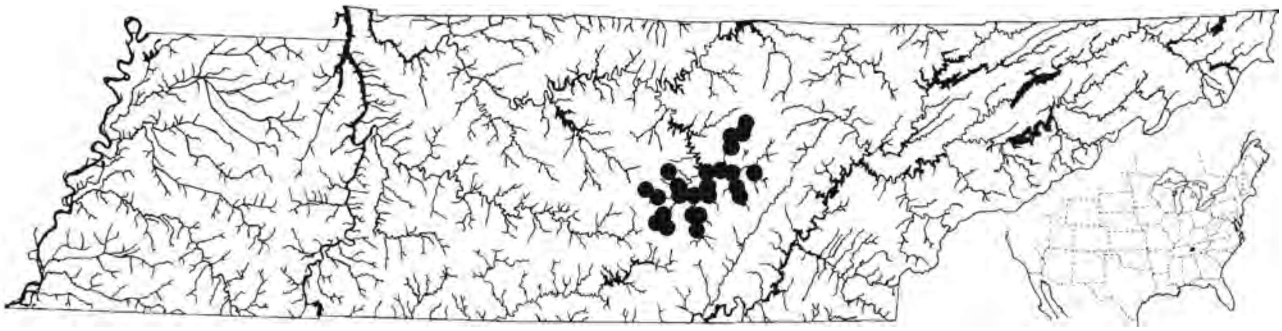
Etheostoma etnieri Bouchard.

Cherry darter

Plate 228a. *Etheostoma etnieri*, cherry darter, female, 46 mm SL, Barren Fork R., TN.

Plate 228b. *Etheostoma etnieri*, cherry darter, male, 52 mm SL, Barren Fork R., TN.

Characters: Lateral line complete with 45–52 (44–57) scales. Dorsal fin with 10–11 (9–12) spines and 11 (10–12) soft rays. Anal fin with 2 spines and 7 (6–8) soft rays. Pectoral fin rays 14–15. Principal caudal fin rays modally 17 (16–18). Gill rakers 7–9, length of longest rakers about twice their basal width. Vertebrae 38–39. Branchiostegal rays 5. Gill membranes broadly connected. Frenum narrow if present. Scales present on nape, belly, cheeks, opercles, and prepectoral area. Breast usually scaled on posterior half. Dark suborbital bar present. Head canals complete. Dorsum with about eight or nine dark saddles. Sides with about eight dark, midlateral blotches. Both sexes with lateral line depigmented and dorsolateral scales with pale centers and darker edges, resulting in about three or four alternating dark and pale horizontal lines above the lateral line; lateral-line area overlaid with dark red stripe about five scale rows wide. Adult males with gray to dark green on breast, pale green on snout and sides of head, pelvic fins dark distally with red membranes basad, base of anal fin and lower sides bright red, spinous dorsal fin



Range Map 220. *Etheostoma etnieri*, cherry darter.

with bright red ocellus in first interradial membrane, remaining membranes with dark brown reticulations, soft dorsal and caudal fin with bright red membranes, bases of caudal fin often green.

Biology: The cherry darter is a large and robust *Ulocentra* that occurs over gravel shoal areas of cool, medium-sized creeks to large rivers, but avoids the tiny creeks often occupied by other members of its subgenus. Its biology is unstudied but presumably similar to that of other *Ulocentra*. Length distribution of specimens in our collection indicates that average lengths are about 42, 52, and 62 mm at ages 1, 2, and 3; sexual maturity is apparently not until age 2. Maximum total length 76 mm (3 in).

Distribution and Status: Restricted to the upper Caney Fork River system of the Cumberland River drainage in the eastern Highland Rim, where it is common in large, cool streams. Although it has a very restricted distribution, it is apparently under no current threats.

Similar Sympatric Species: None known. Lower portions of the Caney Fork River system (below Center Hill Reservoir) are occupied by *E. simoterum atripinne*, but the two species are not known to occur together. *Etheostoma simoterum atripinne* has a distinct frenum, a row of bright orange spots in the spinous dorsal fin, orange rather than cherry red coloration elsewhere on the body and fins, and lacks the faint horizontal dark lines above the lateral line. Records of *E. etnieri* from the lower Caney Fork system (Platania, 1980) that appear in the Atlas of North American Freshwater Fishes are in error.

Systematics: Subgenus *Ulocentra*. Bouchard (1977) felt that *E. etnieri* was closely related to *E. duryi*. Bailey and Etnier (1988) placed it in the *E. duryi* species group.

Etymology: *etnieri* is a patronym for David A. Etnier, co-author of this book.

Etheostoma flabellare Rafinesque.

Fantail darter

Plate 229a. *Etheostoma flabellare*, fantail darter, 40 mm SL, lower Tennessee R. system, TN.

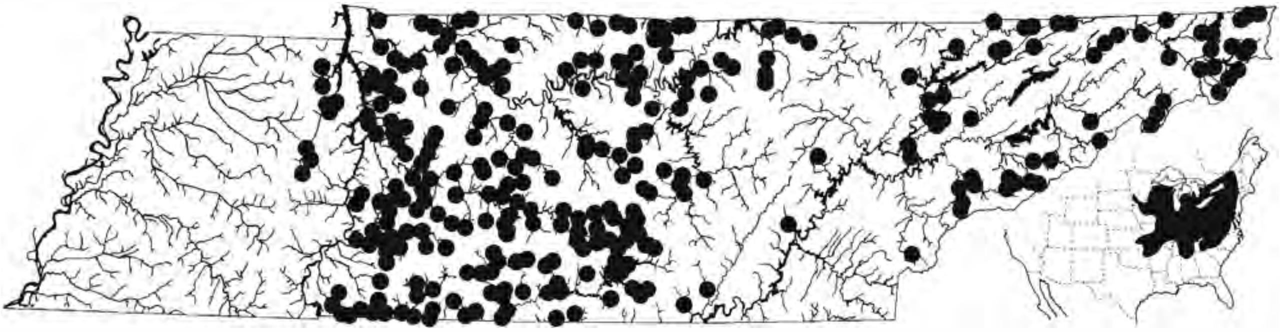
Plate 229b. *Etheostoma flabellare*, fantail darter, breeding male, 56 mm SL, Little Duck R., TN.

Plate 229c. *Etheostoma flabellare*, fantail darter, upper Tennessee R. form, 53 mm SL, Little R. system, TN.

Characters: Lateral line incomplete with 17–59 (mean = 26–42) pored scales and 38–62 (mean = 45–53) scales in lateral series throughout its range. Dorsal fin with modally 7–8 (range 5–10) spines and modally 12–14 (range 11–16) soft rays. Anal fin with 2 spines and 7–9 (7–10) soft rays. Pectoral fin rays 12–14 (11–14). Principal caudal fin rays modally 16–17 (range 15–19). Gill rakers 7–12, length of longest rakers about 3 times their basal width. Vertebrae 32–37. Gill membranes broadly joined. Branchiostegal rays usually 6. Frenum present. Cheeks, nape, opercles, and breast naked. Prepectoral area usually naked. Belly squamation variable, but typically consistent within populations. In most populations in eastern and northern portions of range the belly is typically naked anteriad, often with a row or two of scales along the ventral midline. Many populations from the Tennessee and Cumberland river drainages, the Barren River system, and the Ozarks, have bellies completely covered with exposed scales. Infraorbital canal interrupted, typically with 4 anterior and 2 posterior pores. Supratemporal canal variable within many populations, complete or interrupted. Preoperculomandibular canal with 10 pores. Pigmentation varies geographically. Background color may be gray, olivaceous, tan, or gold. Most Mississippi and Great Lakes drainage forms have gray to olive background colors; but specimens from the Atlantic Coastal drainages, and to a lesser extent the upper Tennessee and New rivers, are often tan to golden. Northeastern and eastern populations are conspicuously marked with 6 to 12 elongate vertical blotches on the sides that more or less continue across the dorsum. In specimens from more western portions of the range, the less conspicuous lateral blotches more or less alternate with the eight or so dorsal saddles, and dark marks on scale centers above the lateral line produce horizontal stripes in specimens from many of the populations. A pair of dark basicaudal spots is often present just posterior to the pale areas at the upper and lower base of the caudal fin. In all forms the low spinous dorsal fin has an orange to yellow border, the soft dorsal fin is speckled or banded, and the caudal fin is vertically banded with dark pigment. A linear postorbital spot is present, and the preorbital dark mark continues forward on the snout, but a suborbital bar is absent. Nuptial males darken overall, especially on the head. Nuptial tubercles do not develop, but in males the tips of the dorsal spines become swollen, forming fleshy knobs, and epithelial tissues of the belly, breast, and head become thickened and rugose.

Biology: The fantail darter is a common inhabitant of clear, small to medium upland streams, and less commonly occurs in large rivers. It frequents rocky riffle areas with moderate to fast current, often in very shallow water. Spawning occurs during April and May. Reproductive behavior has been detailed by Lake (1936) and Winn (1958a,b). Nuptial males select spawning sites beneath flat stones and prepare a clean nest by sweeping it free of silt and debris. Females entering the nests to spawn assume an inverted position and spawn in a head-to-tail position with the male, depositing adhesive eggs in a monolayer on the underside of the flat rock. After up to several hours of spawning, the female is ejected by the male, who cares for the eggs by sweeping away silt with the soft-tipped dorsal fins and warding off potential predators. The bright yellow to orange knobs on tips of the dorsal spines may function as egg simulators (Page and Swofford, 1984; Knapp and Sargent, 1989; Bart and Page, 1991), as females are attracted to nests already containing eggs (or "fake eggs"). Females contain 130–425 mature ova and usually deposit fewer than 50 in a given male's nest. Many females may spawn in a single nest, which may contain up to 500 or more eggs. Hatching requires 14–35 days at water temperatures of 17–23 C (Lake, 1936). Larvae are about 7 mm long at hatching; they disperse from the nest site soon after hatching, settling among crevices in the substrate. Early development was described in detail by Cooper (1979), and Simon (1985a). Based on studies in New York and Iowa (Lake, 1936; Karr, 1964), fantail darters grow to 25–30 mm TL the first year and to about 45 mm at age 2; however, Small (1975), based on studies in Kentucky, reported year classes averaging 47, 64, and 72 mm TL; comparable lengths were reported by Lotrich (1973) and Baker (1978) in additional Kentucky studies; life span was estimated at 2.5 years for males and 2 years for females (Baker, 1978). The diet of fantail darters consists of midge, blackfly, and caddisfly larvae, mayfly nymphs, isopods, and amphipods (Turner, 1921; Lotrich, 1973; Small, 1975; Baker, 1978; Adamson and Wissing, 1977). Morning and late-afternoon feeding peaks were observed by Adamson and Wissing. Maximum length about 95 mm (3.3. in) (= 78.5 mm SL) in the New River and upper Tennessee River subspecies, with other subspecies usually considerably smaller.

Distribution and Status: Widely distributed from the Santee River drainage of the Carolinas northward to Great Lakes tributaries from New York to Minnesota; south in Mississippi River basin to Ozarks and northern Alabama. In Tennessee, the fantail darter occurs disjunctly in the Cumberland Plateau, Highland Rim, and Nashville Basin (*E. f. flabellare*), and an undescribed subspecies occurs widely in the lower Blue Ridge in the Tennessee drainage and is rare in Ridge and Valley



Range Map 221. *Etheostoma flabellare*, fantail darter.

streams above the Chattanooga area, where we have records from the Holston system in Hawkins County, the Clinch and Powell river systems, Crooked Creek near Maryville in Blount County, Whites Creek in Cumberland County, Tellico River in Monroe County, and Richland Creek in Rhea County. The rarity in that area of this and two other very successful darters (*E. caeruleum* and *E. nigrum*) was discussed under *E. caeruleum*. Otherwise, the fantail is typically a very common species where it occurs.

Similar Sympatric Species: Occurs with several other species of the subgenus *Catonotus* in various parts of range. All of these have separate to narrowly joined gill membranes, which join to form an acute angle (obtuse angle in *flabellare*). Most similar to *E. kennicotti* which has a prominent black submarginal band in the spinous dorsal fin, and to the duskytail darter, which has the lower head profusely speckled with large melanophores and usually occurs in streams larger than those occupied by Tennessee and Cumberland drainage *E. flabellare*. Both of these species typically have 12 or fewer dorsal fin soft rays, while *E. flabellare* has 13 or more in over 95% of specimens from the Tennessee and Cumberland drainages.

Systematics: Type species of the subgenus *Catonotus*. Variation in muscle proteins was analyzed by Wolfe et al. (1979) who noted that Cumberland River drainage populations in the vicinity of the Rockcastle system, Kentucky, were distinctive. McGeehan (1985) provided a badly needed study of variation throughout the fantail's range. He concluded that the nominal subspecies *E. f. lineolatum* (Agassiz), the striped fantail, should be reduced to a synonym of *E. f. flabellare* based on the erratic geographical distribution of striped and nonstriped forms. McGeehan recognized four subspecies, with *E. f. flabellare* occurring in the Cumberland, Great Lakes, Ozarkian, and upper Mississippi drainages, the upper Hudson and Susquehanna drainages of the Atlantic slope, the lower Tennessee River drainage below Chattanooga, and the Ohio River drainage except for the New River system. It is characterized by having a projecting lower jaw, and in nuptial males anal and pelvic fins are clear (lower jaw not protruding, anal and pelvic fins black in other subspecies). Except for the middle and upper Ohio drainage, most populations have rows of horizontal dark lines along the upper sides (this character of sporadic occurrence in other subspecies). McGeehan suggested that a distinctly pigmented form, possibly warranting subspecies status, occurs in the lower Tennessee drainage and the White River system of the Ozarks. Our examination of nearly 300 specimens from the lower Tennessee drainage indicates considerable between-population differences in modal counts of dorsal and anal fin elements, but no consistent differences in counts or pigmentation between these and adjacent populations in the Cumberland and lower Ohio drainages. Additional subspecies recognized by McGeehan include *E. f. brevispina* (Coker) of the Santee and Pee Dee drainages of the Carolinas, distinguished by having only 11–13 soft dorsal fin rays and 7 or fewer midlateral bars, and in having 77% or more of scales in lateral series pored. *Etheostoma f. humerale* (Girard) occurs from the lower Susquehanna drainage south along the Atlantic slope through the Potomac, James, and Roanoke drainages (limited material from the Neuse, Tar, and Cape Fear drainages were included here, but these are sufficiently different from more northerly *E. f. humerale* to warrant further study). It differs from *E. f. brevispina* in having 13–15 soft dorsal fin rays and fewer than 70% of scales in lateral series pored, and from the New and upper Tennessee river subspecies in its smaller size, vertically less produced lateral bars, and coarser scales (mean of fewer than 50 scales in lateral series except in Potomac drainage). An undescribed subspecies occurs in the New River system of the upper Ohio drainage and in the upper Tennessee drainage downstream to the Chattanooga area. It is characterized by its large size (often over 55 mm SL), eight or more vertically elongate lateral bars, and small scales (mean of more than 50 scales in lateral series). *Etheostoma flabellare* is hypothesized to be most closely related to *E. kennicotti* (Braasch and Mayden, 1985).

Etymology: *flabellare* = fan tail; *brevispina* = short spine; *humerale* is in reference to the large, darkened humeral scale typical of *flabellare* and many related species.

Etheostoma flavum Etnier and Bailey.

Saffron darter

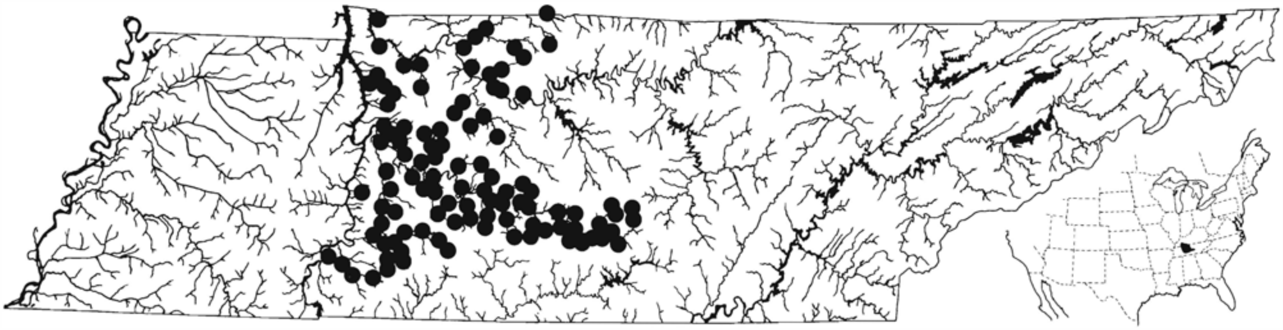
Characters: Lateral line complete with 45–53 (42–59) scales. Dorsal fin with 10–12 (9–12) spines and 10–12 (9–13) soft rays. Anal fin with 2 spines and 6–8 soft rays. Pectoral fin rays 14–15 (13–16). Principal caudal fin rays usually 17 (16–18). Gill rakers 8–10, length of longest rakers about twice their basal width. Vertebrae 38–39 (37–40). Frenum absent. Gill membranes broadly joined.

Plate 230a. *Etheostoma flavum*, saffron darter, female, 41 mm SL, Duck R. system, TN.

Branchiostegal rays 5. Scales present on nape, belly, cheeks, opercles, and prepectoral area. Breast usually naked. Head canals complete. Suborbital bar present. Dorsum with about eight saddles. Sides with about eight midlateral blotches. Characteristically, saddle five (under origin of soft dorsal fin) angles down and back to connect with the fifth lateral blotch, while saddle seven (just behind soft dorsal fin) angles down and forward, connecting with the sixth lateral blotch—leaving saddle six (under middle of soft dorsal fin) isolated and not connected with any lateral blotches. Both sexes with orange lips in life, yellow lower sides, brown upper sides, and a pale marginal and narrow, brown submarginal band on the spinous dorsal fin that is best developed posteriad. Nuptial males with lower half of head and body uniformly golden yellow except for the orange lips. Upper half of body brown between darker saddles and lateral blotches, lacking red or orange spots. Bases of caudal fin distinctly blue-green. Spinous dorsal fin with membranes uniformly golden to brown, or with oblique gold or brown streaks; orange ocellus in first interradial membrane usually lacking. Soft dorsal fin with brick-red membranes. Both dorsal fins elongate in adult males. Anal fin of nuptial males with dark margin and yellow base. Pelvic fins dusky to black.

Biology: The saffron darter inhabits areas with coarse substrates in small to medium-sized streams, usually in slack water to areas of gentle current. Juveniles less than 20 mm long from early June and seasonality of peak breeding colors suggest that the reproductive season is initiated in March or early April. Spawning may extend over several months, since 1-year-olds from a late March sample from a very cool stream ranged from 27 to 44 mm. The largest of these were sexually mature. Samples from warmer streams indicated that in

Plate 230b. *Etheostoma flavum*, saffron darter, male, 53 mm SL, Duck R. system, TN.



Range Map 222. *Etheostoma flavum*, saffron darter.

females sexual maturity and lengths of about 30–45 mm (24–35 mm SL) are reached at age 1, with apparent 2-year-olds averaging about 54 mm. Males average about 3–5 mm longer than females, and the largest males (65 mm or larger) may represent 3-year-olds. Keevin et al. (1989) studied spawning behavior under both field and aquarium conditions. Courtship involved fin displays by both males and females, and the male rubbing the nape of the female with his chin. Males were aggressive toward conspecific males during the breeding season, but the area defended was not stationary. Additional aspects of its biology are unstudied. The maximum total length of 71 mm (2.8 in) from a late October collection suggests that few individuals live more than 3.5 years.

Distribution and Status: Occurs in the Cumberland River drainage from Whites Creek, Davidson County, downstream and the Tennessee River drainage in the Buffalo River, Duck River system except for Little Duck River and Crumpton Creek, eastern tributaries to the Tennessee River downstream from the mouth of Duck River (except Trace Creek, Humphreys County), and Indian Creek in Wayne and Hardin counties. It is typically a common species, with several series in our collection containing well over 50 specimens.

Similar Sympatric Species: Sympatric with *E. simoterum* throughout much of its range, and differing from that species in lacking a frenum, having a less blunt snout, and lacking bright orange fin and body pigmentation in adults. Juveniles of the two species differ in that the two small dark spots at the base of the caudal fin are separate in *E. simoterum* but are fused into a single median spot in the saffron darter. Very similar to and occasionally sympatric with *E. duryi*. See account for *E. duryi* for differentiating characters.

Systematics: Subgenus *Ulocentra*. Referred to as the "golden snubnose darter" in Page (1983a) and Kuehne and Barbour (1983). Systematics discussed in account for *E. duryi*.

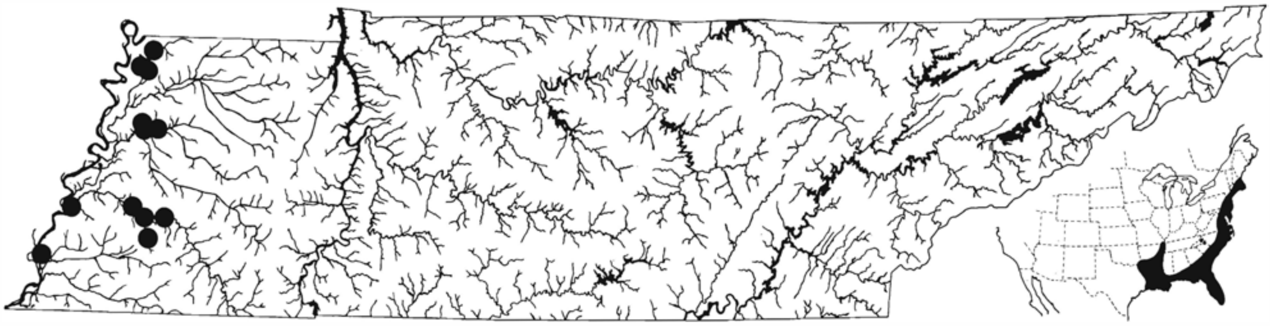
Etymology: *flavum* = golden.

Etheostoma fusiforme (Girard).

Swamp darter

Plate 231. *Etheostoma fusiforme*, swamp darter, 40 mm SL, Isom L., TN.

Characters: Lateral line incomplete with 8–31 (0–37) pored scales and 45–58 (42–63) scales in lateral series. Dorsal fin with 9–11 (8–12) spines and 10–12 (8–13) soft rays. Anal fin with 2 spines and 7–9 (5–10) soft rays. Pectoral fin rays modally 13 (12–15). Vertebrae 38–39 (37–40). (Above data for *E. f. barratti* from Collette, 1962). Principal caudal fin rays modally 14 (13–15) in *E. f. barratti*, often modally 12–13 in *E. f. fusiforme*. Gill rakers 7–12, lengths of longest rakers about 3 times their basal width in Tennessee specimens; *E. f. barratti* have more (10–12) and longer gill rakers than *E. f. fusiforme* (7–8). Branchiostegal rays 6. Gill membranes slightly connected. Frenum present. Infraorbital canal interrupted, supratemporal canal usually complete. Extensively scaled, with exposed scales covering the cheeks, opercles, nape, breast, belly, prepectoral area, and extending forward on top of head to anterior rim of eye. The preoperculum has a moderately serrate border. Ground color pale greenish to yellow;



Range Map 223. *Etheostoma fusiforme*, swamp darter.

dark pigment is variable and consists of dorsolateral mottling and speckling, about 12 (sometimes indistinct) dorsal saddles, 10–12 midlateral blotches, three black basicaudal spots, and a weak suborbital bar. The fin rays are speckled, and the spinous dorsal fin of males typically has a dark basal and submarginal band. Breeding males darken and develop tubercles on soft rays of the pelvic and anal fins, the pelvic spine, and often on the second anal spine.

Biology: Like the slough darter (*E. gracile*), the swamp darter is an inhabitant of sluggish or lentic waters such as ditches and oxbow lakes typical of the Coastal Plain lowlands. It appears to prefer areas with clearer water and more vegetation than those frequented by *gracile*. In spite of its abundance in some portions of its range, the biology of the swamp darter has not been thoroughly studied. Spawning behavior was reported on by Smith (1907), Fletcher (1957), and Collette (1962) and is similar to that related herein for *gracile* except that courtship did not involve head bobbing or tactile stimulation of the female's head. Territoriality was not noted. Nuptial specimens have been collected from late March through May in the southern portion of its range, and spawning is likely about one month later in our area. Eggs hatch in 8–10 days. In our largest collection, taken in late summer, specimens over 40 mm TL had a well-defined annulus on the scales, and apparent young-of-year specimens were 24–31 mm TL. Collette (1962) reported a maximum longevity of 1 year for some populations. McLane (1950) examined the diet of a Florida population and found it to include mosquito larvae, microcrustaceans, and midge larvae. Northeastern populations studied by Schmidt and Whitworth (1979) matured at 32–46 mm TL, rarely lived to spawn twice (2 years), and fed on midge larvae, microcrustacea, and amphipods. Maximum total length 56 mm (2.25 in) with females slightly larger than males.

Distribution and Status: Mostly on the Coastal Plain from Maine to eastern Texas and Oklahoma where it is often common in its preferred habitats. Isolated populations are known from the upper French Broad River system (see Systematics below) of North Carolina (Collette, 1962) and upper Savannah River drainage of northeast Georgia (Tallulah River, Rabun County, UT collection). Suitable vegetated, clear water habitats are rare in the Mississippi River drainage, and the swamp darter is correspondingly uncommon. It has probably been extirpated from many habitats by alteration related to agricultural activity (swamp drainage, channelization, siltation). In Tennessee it occurs only in a few better-quality vegetated habitats such as Reelfoot and Isom lakes and adjacent ditches, and swamps and oxbow lakes in the Forked Deer and Hatchie river systems.

Similar Sympatric Species: The cypress darter, *E. proeliare*, consistently has a midlateral row of linear dark dashes (poorly defined blotches in *fusiforme*), is less elongate, and lacks scales on the breast, nape, and top of the head.

Systematics: Subgenus *Hololepis* (the swamp darters) of many authors (e.g. Hubbs and Cannon, 1935; Collette, 1962; Bailey and Etnier, 1988), was combined with subgenus *Microperca* and *E. exile* by Page (1981) into the more inclusive subgenus *Boleichthys*. The subspecies *E. f. barratti* (Holbrook) occurs in the Mississippi River Embayment and along the Gulf and southern Atlantic coasts to the Pee Dee drainage of the Carolinas, and is replaced northward by *E. f. fusiforme*. J. Bailey (1950) reported an isolated new subspecies from a pond in the French Broad system of the upper Tennessee drainage in North Carolina, but Bailey et al. (1954) and Collette (1962) attributed the existence of this population to an introduction of *E. f. barratti*.

Etymology: *fusiform* = tapering at each end, spindle shaped.

Etheostoma gracile (Girard).

Slough darter

Plate 232a. *Etheostoma gracile*, slough darter, 39 mm SL, lower Tennessee R. system, TN.

Plate 232b. *Etheostoma gracile*, slough darter, breeding male, 44 mm SL, Tennessee R. system, TN.

Characters: Lateral line incomplete with 16–24 (13–29) pored scales and 43–53 (40–55) scales in lateral series. Dorsal fin with 9–10 (7–12) spines and 10–12 (9–14) soft rays. Anal fin with 2 spines and 6–7 (5–9) soft rays. Pectoral fin rays 13 (12–14). Principal caudal fin rays 15–17, modally 16. Vertebrae usually 37–38 (36–39). Gill rakers 9–12 (8–13), length of longest rakers about 3 times their basal width. Branchiostegal rays 6. Gill membranes slightly connected. Frenum present. Infraorbital and supratemporal canals complete. Cheeks, opercles, and prepectoral area scaled, nape and belly often with naked areas anteriad, breast naked. Ground color is pallid to straw yellow. Dark pigment consists of dorsal mottling and about ten lateral blotches may be present. A faint suborbital bar and three basicaudal spots may be present. Rays of the soft dorsal and caudal fins are speckled. Males have black to blue-black marginal and basal bands and a bright red median band on the spinous dorsal fin, and a series of about ten vertical green bars on the sides that may continue across the back. Breeding tubercles form on the rami of the lower jaw, distally on the anal and pelvic fin rays, and on the pelvic spine.

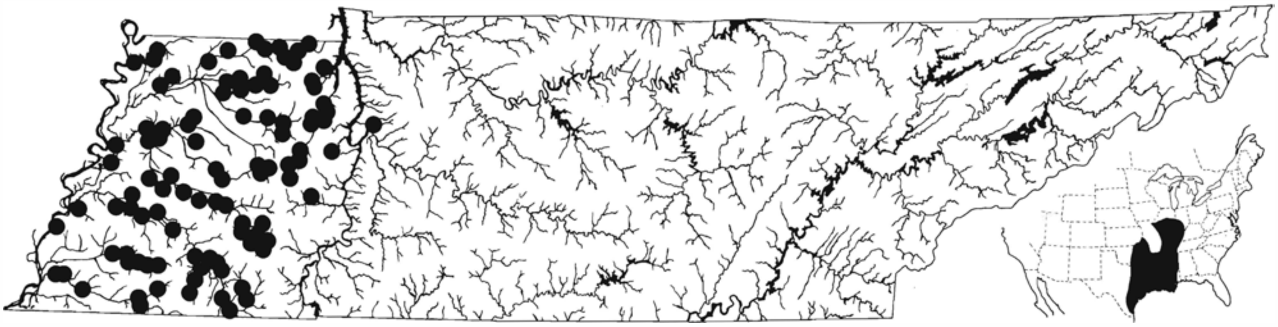
Biology: The slough darter, as the name implies, is a denizen of sluggish lowland streams, occurring both in smaller creeks and in backwaters of larger rivers. Favored habitats are slackwater areas up to a meter in depth with soft substrates of silt and detritus. Rooted aquatic vegetation is typically sparse to absent, and waters with high turbidity are tolerated. The biology of *E. gracile* has been studied by Collette (1962) and Braasch and Smith (1967). Spawning occurs primarily during May, although peak breeding colors appear earlier, presumably associated with establishment of territories by males. Within the territory, females select the spawning sites, which usually consist of twigs or leaf stems. Based on aquarium observations, males pursue females and courtship consists of mounting the female while straddling with the pelvic fins and stroking with the pectorals; tactile stimulation of the female's head is achieved by the male opening his mouth and bobbing his head, bringing the chin tubercles into play. Eggs are laid singly; the female may return to a site several times until a row of eggs has been deposited. Females produce 30–50 eggs per year. Hatching requires 4–5 days at water temperature of 23 C, and hatchlings are about 3 mm long. Young reach total lengths of about 20 mm by midsummer, and are sexually mature and average 35 mm at age 1. Life span may be 3 or 4 years. Food is primarily midge larvae, mayfly nymphs, and microcrustacea. Maximum total length 61 mm (2.4 in).

Distribution and Status: Occurring mostly on the Gulf Coastal Plain from the Pascagoula River system in Mississippi westward through Texas and northward throughout the Mississippi River Embayment and adjacent areas above the Fall Line. In Tennessee, *E. gracile* is moderately common throughout the Coastal Plain.

Similar Sympatric Species: Occasionally syntopic with another member of its subgenus, *E. fusiforme*, which has scales covering the breast and top of the head and lacks red coloration. Similar in appearance to young of *E. asprigene* and *E. swaini*, which do not have the lateral line arched upward anteriad, and to *E. proeliare* which has only 4–5 pored lateral-line scales.

Systematics: Subgenus *Hololepis* (but see comments in introduction to genus and under *E. fusiforme* for subgeneric placement). Infraspecific variation was studied by Collette (1962). Highly similar to and presumably sister species of *E. zonifer* of the Black Belt province of the Mobile Basin.

Etymology: *gracile* = slender.



Range Map 224. *Etheostoma gracile*, slough darter.

Etheostoma histrio Jordan and Gilbert.

Harlequin darter

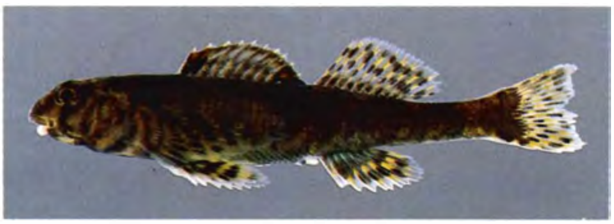
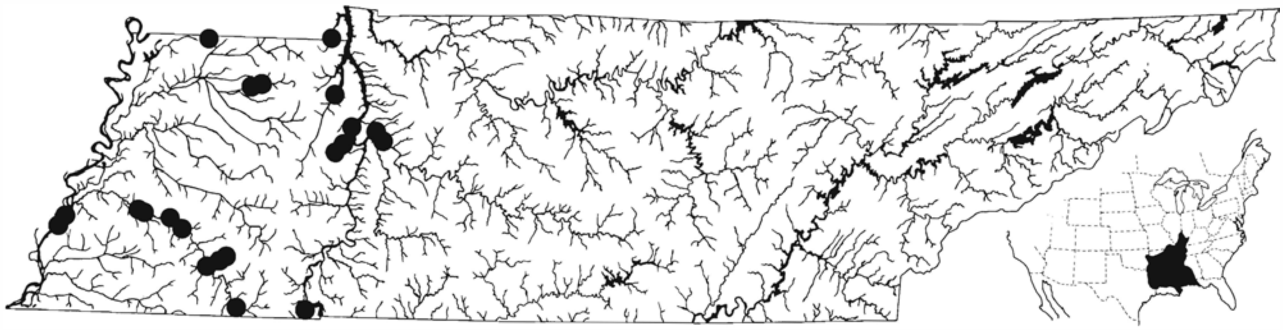


Plate 233. *Etheostoma histrio*, harlequin darter, male, 44 mm SL, lower Tennessee R. system, TN.

Characters: Lateral line complete with 48–55 (45–58) scales. Dorsal fin with 9–10 (9–11) spines and 14–15 (13–16) soft rays. Anal fin with 2 spines and 6–8 soft rays. Pectoral fin rays 14–15 (13–16). Principal caudal fin rays modally 16 (14–17). Gill rakers 8–11, length of longest rakers 2–3 times their basal width. Vertebrae 37–39. Branchiostegal rays 6. Gill membranes broadly joined. Frenum present. Breast, much of prepectoral area, and belly naked. Cheeks usually with a few scales behind eye. Nape usually well scaled. Opercles varying from naked to covered with exposed ctenoid scales, but usually naked. Infraorbital and supratemporal canals complete. A boldly patterned darter with six regularly spaced dorsal saddles, eight or nine dark midlateral blotches that alternate with the saddles, and a pair of fused dark blotches at the caudal base that completely cover that area. A dark suborbital bar is present, and dark blotches are scattered over the lower head and breast. The spinous dorsal fin has a rusty marginal band, dusky middle area, and dark base. Other fins have alternating dark blotches on the rays, with pigment often continuing across the membranes. Sexes are similar in coloration except during the winter and early spring months when males develop bright green colors on the sides. Nuptial tubercles are absent.

Biology: The harlequin darter occurs primarily below the Fall Line and is typically encountered in areas with moderate to swift current and firm substrates. It is often associated with submerged snags, logs, brush, leaf packs, or detritus (Hubbs and Pigg, 1972; Starnes, 1973; Sisk and Webb, 1976; Warren, 1982). It avoids small streams and is one of the few darters we have taken regularly in the main channel of the Mississippi River. Kuhajda and Warren (1989) indicated a February–March spawning season and reported that harlequin darters disappeared from their usual habitats at this time but gave no indication of spawning habitat. We have a number of mid-May collections containing young-of-year specimens that range from 14–27 mm TL, also indicating an early spring spawning period. However, a female collected 24 April from the Tombigbee River, Mississippi, was still full of mature eggs and apparently on the verge of spawning. It would appear that considerable seasonal movement occurs in this species, perhaps into big rivers and reservoirs during colder months from smaller tributaries occupied from late spring through fall. We have had difficulty collecting adults during colder months from streams where they were abundant in samples from May through October and have often been unable to collect adults from big rivers in May where young-of-year were common. Kuhajda and Warren (1989) found that sexual maturity in females apparently occurs at age 1 (at total lengths of 40–50 mm based on our collections) and fecundity ranged from about 90–450 ova depending on age; a maximum lifespan of 4+ years was indicated. The diet consists mainly of midge, blackfly, and caddisfly larvae, and mayfly nymphs. Maximum size 64 mm SL (Page, 1983a) = about 76 mm TL, or 3 in.

Distribution and Status: Widespread in lower Mississippi River basin from lower Wabash and Green river systems of Illinois, Indiana, and Kentucky south, and in Gulf drainages east through Escambia River and west



Range Map 225. *Etheostoma histrio*, harlequin darter.

through the Neches River drainage of Texas. In Tennessee *E. histrio* occurs in direct tributaries to the Mississippi River, western tributaries to the lower Tennessee River, and in the lower Duck River system. It is uncommon in collections, but probably more abundant than records would indicate due to its preference for large rivers and habitats that are difficult to collect.

Similar Sympatric Species: Both *zonale* and *lynceum* are very similar in appearance, but have a red band near the base of the spinous dorsal fin (marginal rusty band in *histrio*). In *lynceum* the cheeks, opercles, and prepectoral area are scaled, and 95% of specimens have 44 or fewer lateral-line scales. Sympatric *zonale* have at least a few scales on the breast and/or prepectoral area, and the belly is fully scaled or has a small naked area just behind the pelvic fin base. Differs from members of the subgenus *Ulocentra* in having six rather than eight or nine dorsal saddles.

Systematics: Subgenus *Etheostoma*. Tsai (1966, 1968a) found little variation in characters throughout its range. Tennessee River drainage specimens (only two were available to Tsai) are not separable from those of other areas. Hypothesized to be sister species to *E. rupestre* of the Mobile Basin by Bailey and Etnier (1988) which, together, form the sister group to *E. blenniodes* plus *E. lynceum* and *E. zonale*.

Etymology: *histrio* = a harlequin, in reference to the mask-like facial pigmentation.

Etheostoma jordani Gilbert.

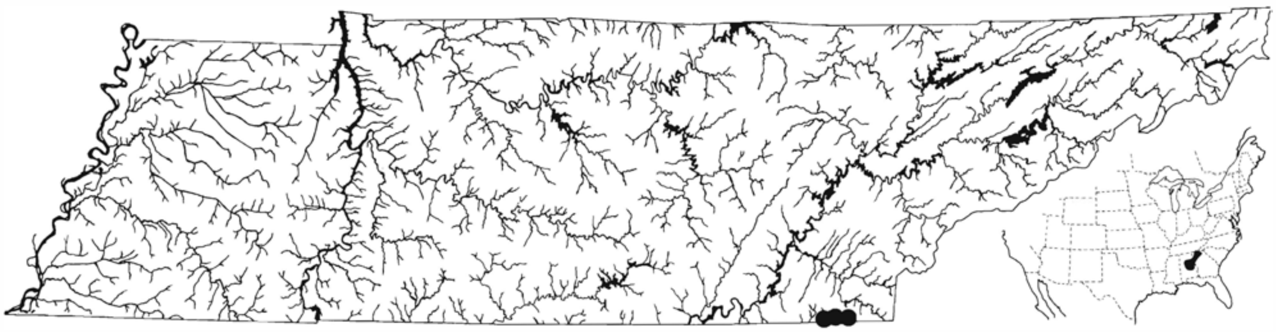
Greenbreast darter

Characters: Lateral line complete with 46–53 (43–56) scales. Dorsal fin with 10–11 (7–12) spines and 11–12 (10–13) soft rays. Anal fin with 2 spines and 7–8 (6–9)

Plate 234a. *Etheostoma jordani*, greenbreast darter, female, 43 mm SL, Conasauga R., TN.

Plate 234b. *Etheostoma jordani*, greenbreast darter, male, 43 mm SL, Conasauga R., TN.

soft rays. Pectoral fin rays 12–13 (12–14). Principal caudal fin rays modally 17 (16–17). Gill rakers 11–14 (9–14), with length of longest rakers about 3 times their basal width. Vertebrae modally 37 (34–38). Frenum present. Gill membranes separate. Branchiostegal rays 6. Scales absent from cheeks, breast, anterior portion of nape, and prepectoral area; opercles typically scaled except in Black Warrior River system. A dusky suborbital bar and dark humeral spot are typically present. Background color brownish with eight to nine irregular dorsal saddles and 8–11 lateral blotches most evident posterior to anal fin origin where they tend to form vertical bars. Caudal fin base pale and with a vertical row of four discrete dark spots. Females and juveniles with median fins speckled with brown and paired fins immaculate; soft dorsal, caudal, and anal fins often with dark border and pale submarginal band. Both sexes lack the lateral rows of horizontal dark lines typical of most *Nothonotus*. Males retain bright colors throughout the



Range Map 226. *Etheostoma jordani*, greenbreast darter.

year, but colors intensify during the breeding season. The spinous dorsal fin has a narrow pale margin, a bright red submarginal band, another pale area below this, and the basal two-thirds of the fin is black on the first two membranes and dusky elsewhere. Soft dorsal and caudal fins with dark margin, clear submarginal band, broad red median band, and dusky base. Anal fin, paired fins, and breast blue-green in nuptial males. Sides of body with scattered red spots. Breeding tubercles absent.

Biology: Greenbreast darters occur in shallow, swift riffles in medium to large streams. Orr and Ramsey (1990) studied reproductive behavior in both Piedmont and Coastal Plain populations in Alabama. Spawning occurred from early April through late May, earlier than for other *Nothonotus*. Individuals in the Piedmont population reached larger sizes than those on the Coastal Plain, but in both populations most females were sexually mature during their second summer (age 1+) at sizes as small as 23 mm SL; life span was 3 years for both sexes. Spawning occurred in sand and gravel riffles 10–30 cm deep with current velocity 55 cm/sec at water temperatures 21–24 C (70–75 F). The female selected the spawning site, buried herself with only head and caudal fin exposed, and was mounted by a male positioned directly above her, head to head. Ovaries of females collected on 22 April contained a mean of 159 (range 113–232) eggs (Coastal Plain) and a mean of 255 (104–448) in the Piedmont population. The largest ovarian eggs on this date were 1.52 mm in diameter in both populations. O'Neil (1980) also reported a 3-year life span in a northern Alabama population, where females were sexually mature at 35–40 mm SL at age 1+, spawning continued through June, and annual egg production was estimated at 100–300 per female. Presence of specimens 20–23 mm SL in our May collections from the upper Coosa River system suggest that sexual maturity is delayed until age 2+ for at least a portion of females from these populations. Stomachs examined by O'Neil contained 58% midge and other dipteran larvae, 24% mayfly nymphs, and smaller quantities of water mites and caddisfly larvae. Feeding behavior was analyzed in detail by Orr (1989). Maximum total length 77 mm (3 in).

Distribution and Status: Confined to the upper Mobile Basin (but not present in the Tombigbee River drainage), primarily above the Fall Line, and often a very common species in suitable habitats.

Similar Sympatric Species: This is the only *Nothonotus* in the Mobile Basin drainage. Similar in shape and coloration to *E.* (*Oligocephalus*) *whipplii,* which does not occur in the Tennessee portion of that drainage, and differs in lacking four discrete basicaudal spots and in having an incomplete lateral line and scaled cheeks and nape.

Systematics: Subgenus *Nothonotus*. Systematics studied by Zorach (1969). Etnier and Williams (1989) considered *rufilineatum* and the *E. maculatum* species group to be closest relatives. Studies by R. M. Wood and R. L. Mayden (in litt.) indicate that *jordani* may be polytypic among river systems in the Mobile Basin; if so, the Conasauga (Coosa) form represents "typical" *jordani*.

Etymology: *jordani* is a patronym for the eminent ichthyologist, David Starr Jordan.

Etheostoma kennicotti (Putnam).

Stripetail darter

Characters: Lateral line incomplete with 14–29 (6–37) pored scales and 39–50 (38–53) scales in lateral series. Dorsal fin with 7–8 (6–9) spines and 11–12 (10–13)

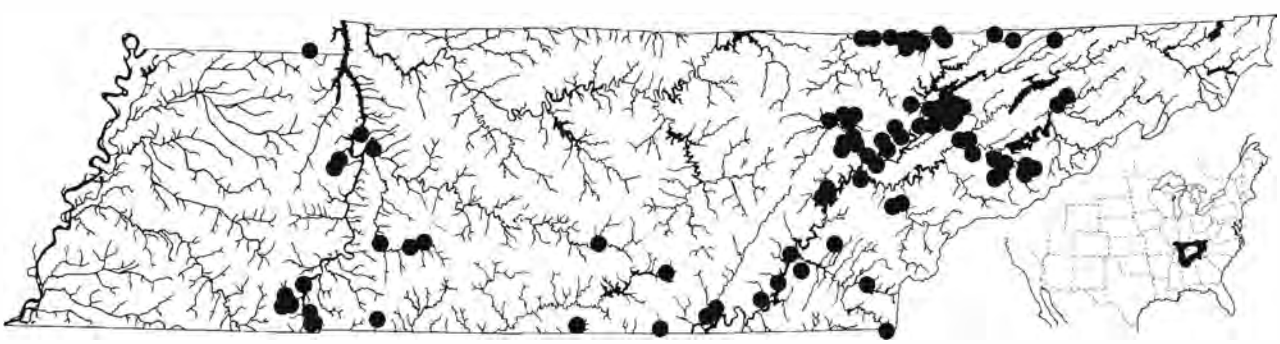
Plate 235a. *Etheostoma kennicotti*, stripetail darter, 40 mm SL, Holston R. system, TN.

Plate 235b. *Etheostoma kennicotti*, stripetail darter, breeding male, 48 mm SL, upper Cumberland R. system, TN.

soft rays. Anal fin with 2 spines and 7–8 (6–9) soft rays. Pectoral fin rays 12–13 (11–14). Principal caudal fin rays modally 17, often 16 (14–18). Gill rakers 6–8 (5–9), with length of longest rakers about 1–1.5 times their basal width. Vertebrae modally 34 (32–35). Branchiostegal rays 6. Gill membranes narrowly joined. Frenum present. Cephalic sensory system incomplete, with interrupted infraorbital and supratemporal canals. Scales absent from cheeks, opercles, nape, breast, and prepectoral area; belly often naked anteriad. Females, juveniles, and non-breeding males are tan with darker brown mottling in the form of six to seven dorsal saddles and 9–12 vertically elongate lateral blotches. A dark humeral spot is consistently present, and a faint subocular bar may occur. The spinous dorsal fin has a clear basal band and dark brown submarginal band. Pectoral fins are often mottled on their dorsal half, and the soft dorsal and caudal fins are conspicuously banded, the caudal with 6–11 vertical stripes which are extremely well developed in upper Cumberland populations. Anal and pelvic fins are clear. Nuptial males have swollen, darkened heads, yellow-orange knobs on dorsal spine tips, lack dorsal and lateral mottling, and develop a pinkish to golden-orange coloration on the sides. Breeding tubercles are absent. Above data from Page and Smith, 1976, and our collection.

Biology: The following account is summarized from Page (1975a) and Page and Schemske (1978). Preferred habitat of the stripetail darter is pool areas in small headwater streams where slabrocks are abundant. As is typical for the subgenus, the spawning site is the underside of a slabrock that is cleaned of silt and defended by a single male. In southern Illinois, territories were established as early as 20 March, with peak spawning occurring in April and May at water temperatures of 14–20 C. Males are suspected to entice females to spawn by mimicking eggs with the swollen tips of their dorsal fin spines (Bart and Page, 1991). Several females may contribute to each nest, but only one female is tolerated at a given time. Annual egg production per female averaged about 50 (24–130). Males vigorously defend the nest site against intruders, and remain with the nest until the eggs hatch. Larvae are about 4.3–4.7 mm TL at hatching and transform to juveniles at between 12–20 mm (Simon, 1985a). Sexual maturity occurs at age 1, and life span is about 2.5 years. Food of both juveniles and adults consisted of midge larvae, mayfly and stonefly nymphs, and crustaceans. Stonefly nymphs were significant food items only in December and January. Crustacea eaten by juveniles were mainly copepods and ostracods, while larger adults shifted to amphipods and isopods. Maximum total length 85 mm (3.3 in).

Distribution and Status: This is one of several species of small stream fishes that avoids the Nashville Basin physiographic province but occurs in a complete circle in the higher elevation areas around the Basin. Occurs



Range Map 227. *Etheostoma kennicotti*, stripetail darter.

throughout much of the Tennessee River drainage, in the Cumberland drainage above and slightly below Cumberland Falls, the Green River system of the Ohio drainage, and in tributaries to the lower Ohio River. It is common only in the upper Cumberland and lower Ohio river portions of its range, perhaps in response to the paucity of other darter species and absence of other *Catonotus* in these areas; it also reaches larger maximum size in these areas (Page and Smith, 1976). It apparently has excellent dispersal capabilities, since small numbers of juveniles often occur in collections from large rivers and in TVA cove rotenone samples from Tennessee River reservoirs.

Similar Sympatric Species: Potentially sympatric with all other *Catonotus* except *olivaceum*, *striatulum*, and *virgatum*. Differs from other *Catonotus* in having a clear basal and dark submarginal band on the spinous dorsal fin. Most similar to and often sympatric with *E. flabellare*, which has pigment in the base of the spinous dorsal fin and broadly connected gill membranes. Thus far not known to occur with the similar duskytail darter, an undescribed *Catonotus* typical of large creeks and rivers, and broadly sympatric with *kennicotti*. The duskytail darter has a less prominently banded caudal fin and some dark pigment in basal membranes of the spinous dorsal fin.

Systematics: Hypothesized to be most closely related to *E. flabellare* (Braasch and Mayden, 1985). Page and Smith (1976) studied variation and noted lower scale counts in the Ohio and lower Tennessee drainages and fewer caudal fin bars in the Cumberland drainage. Variation was clinal, and they did not recognize the validity of the distinctive nominal subspecies, *E. k. cumberlandicum* Jordan and Swain, of the upper Cumberland drainage.

Etymology: *kennicotti* is a patronym for the collector of the type specimens, Robert Kennicott.

Etheostoma luteovinctum Gilbert and Swain.

Redband darter

Characters: Lateral line incomplete with 32–40 (28–47) pored scales and 50–56 (46–61) scales in lateral series. Dorsal fin with 9–11 (8–11) spines and 12–14 (12–15) soft rays. Anal fin with 2 spines and 7–8 (6–8) soft rays. Pectoral fin rays 12–13 (12–14). Principal caudal fin rays modally 15 (14–16). Gill rakers 9–11, length of longest rakers 1–2 times their basal width. Above data from 50 upper Duck and 43 upper Caney Fork specimens, plus extreme values from Page (1983a). Vertebrae modally 37 (36–38). Branchiostegal rays 6. Gill membranes narrowly joined. Frenum present. Scales present on nape, cheeks, opercles, belly, and prepectoral area; breast fully scaled to scaled on posterior half. Infraorbital canal interrupted under eye. Supratemporal canal complete in adults, but often interrupted in juveniles. Body color brown, with seven (six to eight) bold dorsal saddles and eight to nine lateral blotches. The suborbital bar is prominent, and a dusky basicaudal spot may be present. Adult females have dark margins on both dorsal fins; a dark basal band and some red spots in posterior membranes may develop in the spinous dorsal. The soft dorsal fin has about three rows of dark spots on the rays, and membranes are clear to dusky, occasionally with some reddish brown spots. Caudal fin with dark marks on rays forming four to five vertical bands. Other fins usually unmarked. Lower sides with some bright red or orange spots in larger females. Males are brightly colored throughout the year and have gaudy nuptial colors. The spinous dorsal fin is blue on its distal half and red on its basal half. Soft dorsal fin with blue margin, clear submarginal band, red band covering middle half of fin, and blue basal band. Caudal and pectoral fins with black to dark blue on rays, membranes clear. Anal fin blue. Pelvic fins and lower body black to dark blue or blue-green. Seven or eight bright red oblique bars occur on the sides, primarily below the lateral line anterior to the soft dorsal fin, and extending to upper sides posteriad. Males develop breeding tubercles on the spines and rays of the anal fin, on the dorsal surface of the pelvic fin rays, and occasionally on the lower caudal fin rays and on scales of the posterior half of the belly and lower caudal peduncle.

Biology: The biology of the geographically restricted redband darter has not been studied. It inhabits pools and sluggish runs in small streams and springs which are usually of moderate gradient and have limestone bedrock, rubble, gravel, and silt substrates. Such streams are very productive and usually have growths of aquatic mosses, filamentous algae, and/or watercress. Spawning occurs during March and April based on nuptial specimens. During this time, individuals are common in gravel riffles, which may be the spawning area. Based on size distributions in several large samples of redband darters, total lengths of 25–30 mm are reached by mid June, they are 45–50 mm TL by late July, and they are sexually mature at about 50–55 mm at age 1. Age 2 specimens are about 60–70 mm TL, and it seems doubtful that many individuals live to be much more than 2 years old. Digestive tracts examined contained only midge larvae, but other spring-associated organisms, such as isopods and amphipods, may also be consumed. Maximum total length 76 mm (3.0 in).

Distribution and Status: The redband darter is restricted to limestone streams of the Nashville Basin and the cherty areas of the adjacent Barrens Plateau (Highland Rim). It is fairly widespread in the Duck River system, and in the Cumberland River drainage is common in headwaters of the Caney Fork system and localized in the Stones River system. The type locality is given as "Stones River near Nashville" (Gilbert, 1887), and it persists in the lower Stones River system in Stones Creek, Davidson County. It is a locally common species and in spite of its restricted range is under no immediate threat.

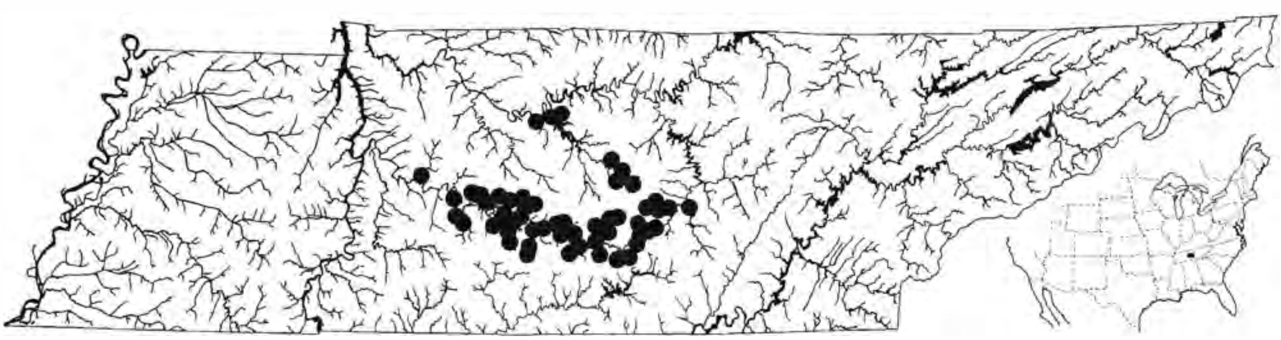
Plate 236a. *Etheostoma luteovinctum*, redband darter, female, 44 mm SL, Duck R. system, TN.

Similar Sympatric Species: Most similar to *caeruleum* and *spectabile* but differing from both in lacking orange branchiostegal membranes, in having more extensively scaled cheek and breast regions, and in usually having 50 or more scales in lateral series. Further differing from *caeruleum* in having an interrupted infraorbital canal and in lacking red on the anal fin. We have not taken *luteovinctum* and *spectabile* together, but they are potentially sympatric in the upper Caney Fork and upper Stones river systems. In *luteovinctum* the dorsal saddles and suborbital bar are much more pronounced than in *spectabile*, and there are no horizontal brown lines on the upper sides.

Systematics: Subgenus *Oligocephalus*.

Etymology: *luteo* = yellow, *vinctum* = banded.

Plate 236b. *Etheostoma luteovinctum*, redband darter, breeding male, 54 mm SL, Duck R. system, TN.



Range Map 228. *Etheostoma luteovinctum*, redband darter.

Etheostoma lynceum Hay.

Brighteye darter

Characters: Lateral line complete with 38–44 (36–47) scales. Dorsal fin with modally 10 (7–12) spines and 11–12 (9–13) soft rays. Anal fin with 2 spines and 7–9 (7–10) soft rays. Pectoral fin rays 13–15 (12–16). Principal caudal fin rays modally 15 or 16 (13–17). Gill rakers 8–9 (7–11), length of longest rakers 2–3 times their basal width. Vertebrae 36–38. Branchiostegal rays 5 or 6. Gill membranes broadly joined. Frenum present. Supratemporal and infraorbital canals complete. Breast and anterior part of belly naked; nape, cheeks, opercles, and prepectoral area scaled. Background color dark gray, dorsum with six dark saddles, sides with about nine vertical bars. A suborbital bar is present, and the caudal fin base has one or two median and two marginal dark spots. Dark marks are often present on the lower head. In females the spinous dorsal fin has a narrow clear margin, a dark basal band, and is gray elsewhere; other fins have dark marks on the rays which may align to form banding patterns. Adult males have dark red basal bands on both dorsal fins, and distal portions of these fins are mostly bright green during the breeding season. Bright green also develops on the dorsal and ventral margins of the caudal fin, over much of the anal, pectoral, and pelvic fins, on the lower head, and on the vertical dark bars. Nuptial tubercles are absent.

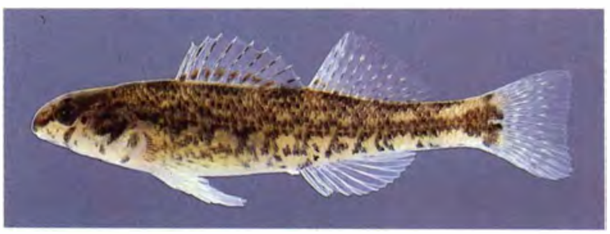


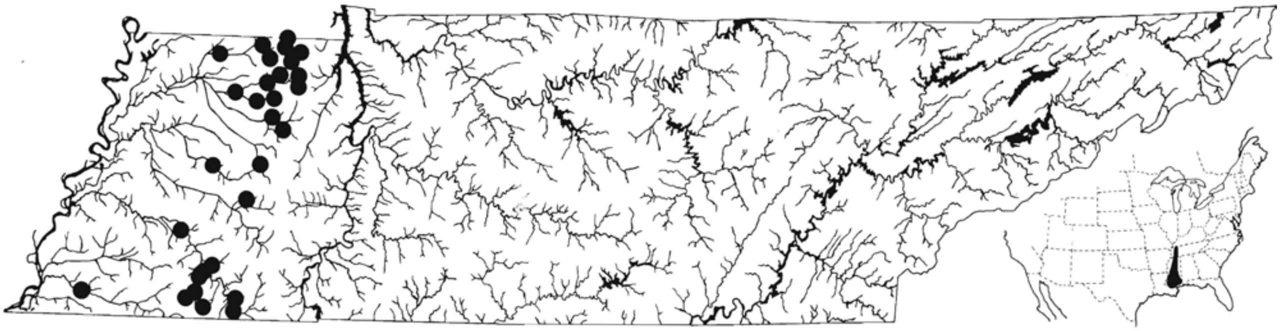
Plate 237a. *Etheostoma lynceum*, brighteye darter, 38 mm SL, Hatchie R. system, TN.

Biology: *Etheostoma lynceum* inhabits swifter Coastal Plain streams, often with considerable spring flow, and typically occurs over gravel riffles or in detrital aggregations in second to fourth order streams. Rooted aquatic vegetation is often present, but not necessary for their presence. The breeding season is during April and May. Young reach lengths of 30–45 mm at age 1, and larger yearlings are sexually mature and presumably spawn. What appear to be 2-year-olds average about 50 mm long, and specimens of 60–70 mm probably represent a third age class. These observations were generally corroborated in a recent study by Bell and Timmons (1991) who also noted that males were larger than females at similar ages, maximum fecundity of about 200 ova in larger females, and a diet dominated by midge and blackfly larvae and mayfly nymphs. Maximum total length 72 mm (2.8 in).

Distribution and Status: Restricted primarily to the upper Coastal Plain east of the Mississippi River from the Obion River system in Tennessee and Kentucky south and east through the Pascagoula River drainage of Mississippi and western Alabama. Although stream rechanneling projects have undoubtedly eliminated many populations, the brighteye darter continues to be a common species in better quality streams within its range.

Similar Sympatric Species: Sympatric members of the subgenus *Ulocentra* have eight or nine rather than six dorsal saddles. *Etheostoma stigmaeum*, *E. chlorosoma,* and *E. nigrum* also have six dorsal saddles, but lack broadly connected gill membranes and have tan to brown coloration rather than the dark gray and green

Plate 237b. *Etheostoma lynceum*, brighteye darter, breeding male, 50 mm SL, Obion R. system, TN.



Range Map 229. *Etheostoma lynceum*, brighteye darter.

colors of *lynceum*. Most similar to *E. histrio*, which has a marginal rather than basal red or rusty band on the spinous dorsal fin, dark blotches on the breast as well as the lower head, a more extensive dark basicaudal blotch, and the naked area on the belly continues to the anus.

Systematics: Subgenus *Etheostoma* (Bailey and Etnier, 1988; but see alternate view presented by Page, 1981). Tsai and Raney (1974) presented a thorough account of the systematics of *E. zonale* and considered *lynceum* to be a subspecies of *zonale*. However, Etnier and Starnes (1986) examined additional specimens from the area of geographic proximity of the two taxa and concluded that the lack of intergrading populations plus the absence of any evidence of recent genetic exchange argued strongly that they are fulfilling Simpson's (1961) definition of species by each being a group of populations "evolving separately from others and with its own unitary evolutionary role and tendencies." *Etheostoma blenniodes* is considered the closest relative to *lynceum* and *zonale* by Bailey and Etnier (1988).

Etymology: *lynceum* is presumably derived from Lynceus, one of Jason's argonauts (Greek mythology), to whom was attributed remarkable vision. Brighteye darter conforms to the probable derivation of the species epithet.

Etheostoma microlepidum Raney and Zorach.

Smallscale darter

Characters: Lateral line complete with 60–68 (55–71) scales. Dorsal fin with 12–14 (11–15) spines and 11–12 (11–13) soft rays. Anal fin with 2 spines and 8–9 (7–9) soft rays. Pectoral fin rays 13–14 (12–15). Principal caudal fin rays modally 17 (16–18). Gill rakers 13–15, length of longest rakers 3–5 times their basal width. Vertebrae modally 39 (38–40). Branchiostegal rays 6. Gill membranes narrowly joined. Frenum present. Scales absent from nape, breast, and prepectoral area; opercles and belly scaled, cheeks with a few scales at postorbital spot. Supratemporal and infraorbital canals complete. Background color brown to dark olive. In all stages there is a dusky suborbital bar, a dark humeral spot, and horizontal dark lines (not noted on females by Raney and Zorach, 1967) between scale rows along the posterior sides. Four vertically aligned basicaudal spots are present (obscured in adult males), with the midlateral spots occasionally fused. Females have a mottled gray spinous dorsal fin, and red pigment is often present near the anterior margin. Other fins have brown spots centered on the rays, and pale yellow membranes. The soft dorsal, caudal, and posterior third of the anal fin have a dark marginal and clear submarginal band. Darker brown spots are scattered on the sides, and eight or nine dorsal saddles are occasionally apparent. Nuptial males darken on the body and have extensive areas of bright green on the median fins. Bright red spots are scattered on the sides. The spinous dorsal fin has a narrow orange margin and dark base, intensifying to black anteriad. Soft dorsal and caudal fins with black marginal and yellow to orange submarginal bands. In the caudal fin the terminal orange submarginal band continues forward along the dorsal and ventral margins of the fin and may connect with (or be separated by green pigment from) the pair of large basicaudal orange spots. Anal fin with dark marginal and clear submarginal band on posterior third. The breast and paired fins are dark gray. Several oblique dark bars often develop on the caudal peduncle.

Biology: The smallscale darter occurs in deep, swift riffles with boulder and coarse rubble substrates. In Red River, Robertson County, we found *microlepidum* only in the deepest, swiftest portion of a slabrock riffle that extended across the entire river. It was the only *Noth-*

onotus collected in that area, but *E. camurum*, *E. rufilineatum*, and *E. tippecanoe* occurred throughout the remainder of the riffle. Juveniles are often taken in gravel riffles. Page et al. (1982) located a nest in East Fork Stones River, Tennessee, on 6 May at water temperature of 21 C. The nest contained 346 eggs attached in a loose mass to the underside of a large rock, indicating reproductive behavior typical for the *E. maculatum* species group (see *E. vulneratum* account). Juveniles in our collection had grown to 32–40 mm TL at age 1. Other aspects of its biology have not been studied. Maximum total length 93 mm (3.6 in).

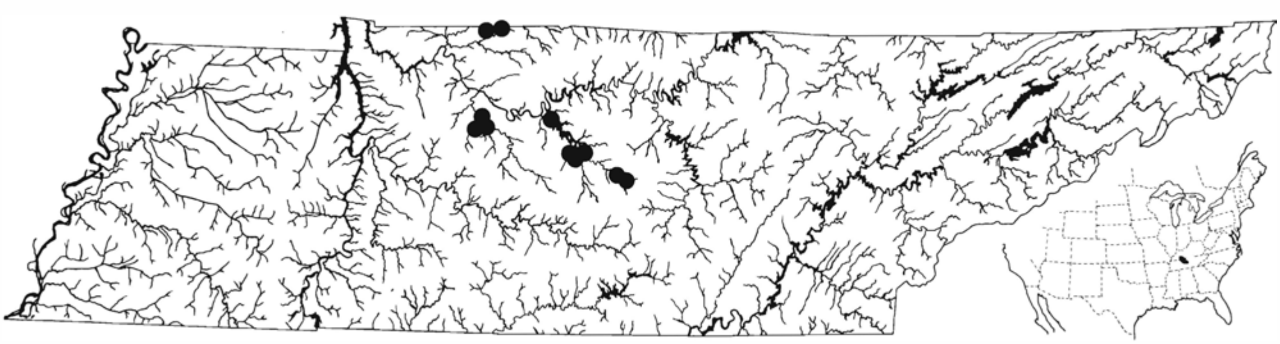
Plate 238a. *Etheostoma microlepidum*, smallscale darter, female, 66 mm SL; Red R., TN.

Distribution and Status: Confined to large streams and rivers in the Cumberland River drainage from Stones River downstream through Little River, Kentucky. All known sites are from the Stones, Harpeth, Red, and Little river systems. Percy Priest Reservoir on the lower Stones River has reduced available habitat in that system, and any additional losses of habitat could result in the finescale darter being considered for Protected status.

Similar Sympatric Species: Occurs with both *E. tippecanoe* and *E. rufilineatum*. Juveniles might be confused with the tiny *E. tippecanoe*, in which males are orange, the lateral line is incomplete, and there is a prominent dark basicaudal bar and nape saddle. In *E. rufilineatum* there are dark horizontal marks on the cheeks and opercles rather than a single suborbital bar, lips are orange in life, and the snout is much more sharply pointed. Members of the subgenus *Catonotus* are similar in shape, but have modally 9 or fewer dorsal fin spines and incomplete lateral lines.

Systematics: Subgenus *Nothonotus*. Believed most closely related to *aquali*, *maculatum*, *sanguifluum*, *vul-*

Plate 238b. *Etheostoma microlepidum*, smallscale darter, male, 64 m SL, Red R., TN.



Range Map 230. *Etheostoma microlepidum*, smallscale darter.

neratum, and *wapiti* (see Etnier and Williams, 1989). Its affinities were suggested to be with the Ozarkian *E. moorei* by Raney and Zorach (1967). Raney and Zorach (1967) mistakenly included Duck River in the range of *microlepidum* based on specimens of *E. aquali*.

Etymology: *micro* = tiny, *lepidum* = scale, referring to its relatively high scale counts.

Etheostoma microperca Jordan and Gilbert.

Least darter

Plate 239. *Etheostoma microperca*, least darter, 32 mm SL, Spring R., MO.

Characters: Lateral line incomplete with 0–1 (0–4) pored scales and 31–35 (30–36) scales in lateral series. Dorsal fin with 6–7 (5–8) spines and 9–10 (8–11) or 8–9 (7–10) soft rays in Ozarkian and Midwestern populations, respectively. Anal fin with 1 (22%) or 2 (88%) spines and 5–6 (4–7) soft rays. Pectoral fin rays modally 10 (9–12). Principal caudal fin rays modally 14 (13–15) in 50 UT specimens, but reported as usually 12–13 (11–14) in Burr (1978). Gill rakers 4–6, length of longest rakers 2–3 times their basal width. Vertebrae modally 33 (32–34). Gill membranes moderately joined. Branchiostegal rays 5 (5–6). Frenum present. Nape, cheeks, breast, and prepectoral area naked. Opercles and belly range from naked to well scaled. Cephalic sensory canals of head greatly reduced, with supratemporal canal interrupted, infraorbital canal lacking posterior branch and having 2–3 pores on anterior segment, and preoperculomandibular canal reduced and having only 6 (5–7) pores. Body and head heavily mottled with dark brown pigment on a tan background. The tan nape has a median dark line extending from the occiput to the spinous dorsal fin, and there is a midlateral row of about eight dark blotches. A dark suborbital bar is prominent. Spinous dorsal fin with gray marginal and basal bands. The soft dorsal and caudal fins have about five or six brown to gray bands extending across both rays and membranes. Anal fin rays, and occasionally adjacent membranes, have two or three rows of dark brown pigment. The pectoral fin rays are margined with dark brown, and pelvic fin rays have scattered dark blotches. Females may develop some orange in the spinous dorsal fin and yellow to pale orange in the anal and pelvic fins during the breeding season. Nuptial males have a median row of red spots in the spinous dorsal fin, red anal and pelvic fins, and green body coloration. Pelvic fins develop expansive fleshy flaps anterior to the spine, membranes between the first 3 or 4 pelvic fin elements widen, and the longest pelvic rays extend to the anal fin. Nuptial tubercles develop on ventral surfaces of the pelvic fin rays.

Biology: Least darters occur in a wide variety of habitats from tiny streams and springs to ponds, lakes, and large, sluggish rivers. The single common denominator is the presence of abundant aquatic vegetation. Burr and Page (1979) studied biology of an Illinois population and incorporated information from earlier studies by Petravicz (1936) and Winn (1958a,b). Males begin to develop secondary sexual characters in January and reach peak color and tuberculation in April. Breeding may occur from February (Oklahoma) through July (northern populations) at water temperatures of 12–20 C and might even occur throughout the year in springs with relatively constant temperature. Cichoki and Rendell (1982) reported spawning temperatures of 22–28 C in Ontario, agonistic behavior of nuptial males, and a female display that elicited mounting by males. Peak breeding in Illinois was during May. In larger waters males apparently move to the shallow spawning areas prior to the breeding season and remain there, while females inhabit deeper waters and move into the shallows only to breed. Courting males actively pursue females and display by assuming a vertical position in midwater and vibrating their fins. Females select the spawning site, typically a vertical strand of vegetation, and the pair, with the male clasping the female with his enlarged pelvic fins, assumes a typical darter embrace. Spawning position is usually vertical but may range from horizontal to inverted. Females shed 1 to 3 eggs per spawning act and quickly move to another site to continue spawning. Mature eggs per female ranged from 36–240, but fecundity may be greater than this if undeveloped ova mature during the breeding season. Eggs are 0.8–1.1 mm in diameter and have a prominent indentation typical of the subgenus *Microperca*. Hatching time ranges from 6–11 days at temperatures of 23–15.5 C, with hatchlings 3–3.5 mm long. At age 1 both sexes average 28 mm SL and all are sexually mature. Maximum life span is 2 years with few individuals living much more than 1 year. Food is primarily midge larvae, isopods, and microcrustacea, particularly copepods. Feeding peaks near mid-day (Cordes and Page, 1980). Maximum size 37 mm SL (= 47 mm TL, or 1.8 in).

Distribution and Status: The least darter occurs from the Hudson Bay drainage of northwestern Minnesota east through southern and eastern Great Lakes tributaries, and south to the Ohio River drainage of Illinois, Indiana, and Ohio. Disjunct populations occur in the Ozark region from Central Missouri through northeastern Arkansas and eastern Oklahoma. It is apparently extirpated from Iowa, and is known from Kentucky based on but two records, one of which is questionable (Burr, 1978). We include it, with some reservation, in the Tennessee fauna based on a single female collected in Richland Creek, Davidson County, on 18 April 1954 and housed at Oklahoma State University (Burr, 1978). This record may not be valid, but small streams in the Nashville Basin have not been thoroughly collected, least darters have very spotty and unpredictable distributions throughout much of their range, and the heavily vegetated streams of the Basin appear to offer suitable habitat. The presence of *Notropis rupestris*, a form closely related to *Notropis heterolepis*, in the Nashville Basin (see account for that species) indicates that at least one fish with much more northerly affinities and a preference for heavily vegetated habitats has persisted as a glacial relict in Tennessee. Hopefully, the above will stimulate a more thorough search for extant least darter populations in Tennessee.

Similar Sympatric Species: Least darters differ so markedly from other darters in the Nashville Basin in their reduced head canals and lateral-line pores and in the greatly modified pelvic fins of males, that it is unlikely they would be confused with other species. They differ from the occasionally sympatric and closely related *E. proeliare* in lacking a bilobed urogenital papilla in the females and in having fewer pored lateral-line scales, 6–7 (versus modally 8) dorsal fin spines, and naked cheeks and prepectoral areas.

Systematics: Subgenus *Microperca*. Burr (1978) reported on systematics of the three included species, and Buth et al. (1980) studied isozyme variability in the group (see comments under *E. proeliare*). Ozarkian *E. microperca* differ from northern populations in reaching larger sizes and having slightly higher scale and fin ray counts; in northeastern populations the infraorbital canal is further reduced to only 2 pores on the anterior canal segment (Burr, 1978). Page (1981) combined the subgenera *Microperca* and *Hololepis*, and *E. exile*, into the subgenus *Boleichthys*, a view not shared by Bailey and Etnier, 1988.

Etymology: *micro* = small, *perca* = perch.

Etheostoma neopterum Howell and Dingerkus.

Lollypop darter group

Characters: Lateral line incomplete with 25–38 (14–45) pored scales and 43–53 (41–58) scales in lateral series. Dorsal fin with 8–9 (8–11) spines and 11–13 (10–14) soft rays. Anal fin with 2 spines and 6–9 soft rays. Pectoral fin rays 11–12 (11–13). Principal caudal fin rays modally 16 (14–17). Gill rakers 8–10 (7–11), lengths of longest rakers 1–3 times their basal width. Branchiostegal rays 6. Gill membranes separate to narrowly joined. Frenum present. Infraorbital canal complete (northern populations) or interrupted, supratemporal canal interrupted. Scales present on cheeks, opercles, nape, breast, belly, and prepectoral area. Coloration of females and non-breeding males basically as in *crossopterum*, *nigripinne*, and *squamiceps*. Sides generally mottled, eight or nine dorsal saddles, three basicaudal spots, a humeral spot, a suborbital bar (absent in males of *pseudovulatum*, Duck River system), and additional dark mottling on cheek usually present. Breeding males darken overall and have swollen heads. Spinous dorsal fin black with pale, swollen spine tips, a row of tiny clear spots medially, and a clear band basally. Soft dorsal fin dark, with rays greatly produced past membranes and each tipped with a large, spherical, white knob; two to four rows of crescent shaped pale spots occur medially.

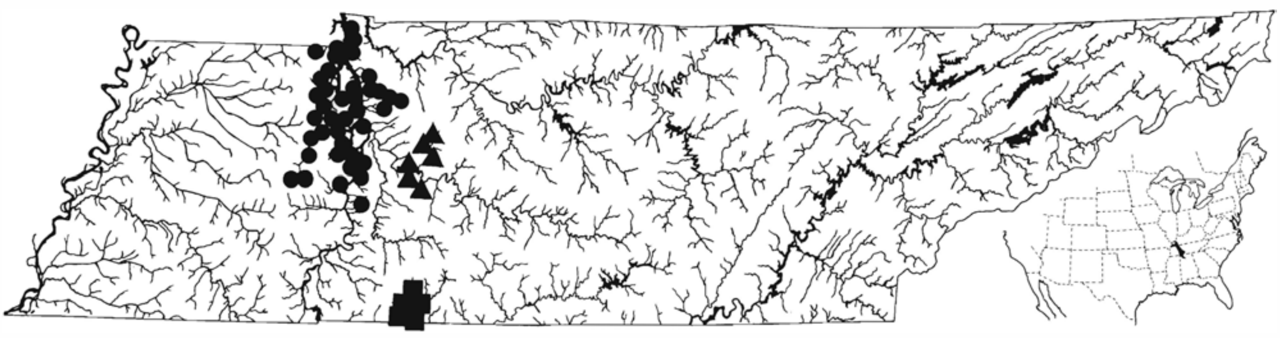
Biology: Members of the lollypop darter group inhabit small to medium gravelly streams and typically occur beneath overhanging banks in areas of low gradient. Preferred habitats have dense mats of exposed tree roots. On several occasions we have had difficulty collecting specimens with small seines in these habitats, but spot applications of ichthyocides indicated that lollypop darters were extremely common. Page and Mayden (1979, based on *E. oophylax*, see Systematics) reported on two nests that they found in mid April. The nests, each containing about 600 eggs attached to the underside of a flat rock, were found near the middle of the stream and were each guarded by a single male. Several females had probably contributed to each nest. Members of the subgenus *Catonotus* deposit their eggs in a single layer under slabrocks. They theorized that the occasional double layering in these nests, not observed elsewhere in the subgenus, reflected the paucity of suitable nesting habitat in this stream. In many areas where these species occur, slabrocks are virtually absent, and it is possible that additional suitable spawning sites are found under overhanging banks. Egg-mimicking by males, using the swollen tips of the dorsal fin rays, is probably very important in courtship behavior of these species (Page and Bart, 1989). Howell and Dingerkus (1978) reported predation by sculpins (*Cottus*) and mudpuppies (*Necturus*). Unknown aspects of its biology are inferred to be similar to that of the *E. squamiceps* (see *E. crossopterum* account) complex as reported by Page (1974b). Maximum total length 84 mm (3.25 in), with males reaching larger sizes than females.

Distribution and Status: The *neopterum* group occurs in Highland Rim and some adjacent Coastal Plain tributaries to the lower Tennessee River from Shoal Creek in Alabama downstream. A form also occurs in Bayou du Chien, tributary to the Mississippi River in western Kentucky (but see Systematics below).

Plate 240a. *Etheostoma oophylax*, guardian darter, female, 59 mm SL, Big Sandy R. system, TN.

Similar Sympatric Species: Most similar to other members of the *E. squamiceps* complex, *E. crossopterum* and *E. nigripinne*, which are occasionally sympatric (but never syntopic). Nuptial males of the *neopterum* group, available from April through May, are readily recognized by the unique bulbous tips of the soft dorsal fin rays. Females, juveniles, and non-nuptial males differ from *crossopterum* and *nigripinne* in having soft dorsal fin rays modally 11–12 (vs. 12–14), each with only 2 adnate branches (not separated by membrane); vs. 3 branches in adult males and often females, and always divergent and well separated by membranes. Infraorbital canals are consistently interrupted in both *crossopterum* and *nigripinne* but are often complete in the *neopterum* group, particularly in the northern portion of its range. Occasionally sympatric with *flabellare*, *kennicotti*, and *smithi* and separable

Plate 240b. *Etheostoma oophylax*, guardian darter, breeding male, 65 mm SL, Big Sandy R. system, TN.



Range Map 231. *Etheostoma neopterum* group (*E. neopterum*, lollypop darter, squares; *E. oophylax*, guardian darter, circles; *E. pseudovulatum*, egg-mimic darter, triangles).

from these using the same characters discussed in the account for *E. crossopterum.*

Systematics: A member of the *E. squamiceps* complex of the subgenus *Catonotus* which in earlier years was confounded with other members of the group (see Howell and Dingerkus, 1978; and Braasch and Mayden, 1985); hypothesized to be sister species of *E. squamiceps* by Braasch and Mayden. Page et al. (1992) now (while this book was in press) indicate that *E. neopterum* is a complex of four very similar species, with "true" *neopterum* confined to the Shoal Creek system of Tennessee and Alabama. The other three species recognized in the group are: (1) *E. oophylax* Ceas and Page, the guardian darter, in tributaries to the lower Tennessee River from Perry County, Tennessee, downstream into Kentucky; (2) *E. chienense* Page and Ceas, the relict darter, in Bayou de Chien, a Mississippi River tributary in western Kentucky; and (3) *E. pseudovulatum* Page and Ceas, the egg-mimic darter, in the lower Duck River system (Piney River, Little Piney Creek, Beaverdam Creek) of Hickman and Dickson counties, Tennessee. These species are distinguished on pigmentation of dorsal fins in breeding males and genetic attributes.

Etymology: *neo* = new, *pteron* = wing or fin, in reference to the uniquely modified soft dorsal fin of nuptial males; *oophylax* = egg-guarder; *chienense*, in reference to Bayou de Chien; *pseudovulatum* = provided with false eggs. We see no reason for emending the original lollypop (Howell and Dingerkus, 1978) to lollipop as done by Robins et al. (1980, 1991).

Etheostoma nigripinne Braasch and Mayden.

Blackfin darter group

Characters: Lateral line incomplete with 21–28 (10–45) pored scales and 43–51 (38–58) scales in lateral series. Dorsal fin with modally 8 (often 9, rarely 7 or 10) spines and modally 13 (often 14, range 11–15) soft rays. Anal fin with 2 spines and 7–8 (6–9) soft rays. Pectoral fin rays 11–12 (10–13), mode usually 11. Principal caudal fin rays 16–17 (15–18), mode usually 16. Gill rakers 7–9, mostly rudimentary, with length of longest rakers 1–1.5 times their basal width. Branchiostegal rays 6. Gill membranes separate to slightly joined. Frenum present. Cephalic sensory system incomplete, with interrupted infraorbital and supratemporal canals. Scales present on cheeks, opercles, nape, breast, belly, and prepectoral area. Coloration of females and non-breeding males usually tan with brown mottling, sometimes with about 12 poorly defined midlateral blotches. The dorsum may have about eight dark saddles and is often abruptly paler than the sides. Three basicaudal spots, a humeral spot, and a subocular bar are usually present; additional dark mottling typically present on cheek. Spinous dorsal fin with pale orange margin and dusky submarginal and basal bands. Soft dorsal, caudal, and pectoral fins speckled or banded. Nuptial males are dark gray to black overall, especially on the head. The dorsal spines have pale tips, there is a narrow orange margin, and the spinous dorsal fin membranes have clear windows in the membranes submarginally and basally. The soft dorsal fin is dark, has a black margin (yellow in *forbesi*), lacks a pale submarginal band, and rows of small pale spots may be evident. In breeding males, the head becomes swollen and knobs form on the dorsal spine tips but not on the tips of soft dorsal rays, which are scarcely produced past the membranes. Breeding tubercles are not developed.

Biology: Members of the blackfin darter group inhabit small upland creeks where they frequent gently flowing riffles or pools with slabrock rubble substrates. Their biology has not been studied in depth but is presumed to approximate closely that of *crossopterum* and *squamiceps*, which were studied by Page (1974b). Braasch and Mayden (1985) imply that spawning occurs from late April through May and verify that spawning sites are as reported for other *Catonotus* (Page, 1974b). Egg-mimicking by males is probably important in courtship (Bart and Page, 1991). Maximum total length 83 mm (3.27 in) for *E. nigripinne* in lower Duck River.

Distribution and Status: Restricted primarily to Highland Rim streams tributary to the Tennessee River from the Paint Rock system of northeastern Alabama downstream to Decatur and Perry counties, Tennessee, including the entire Elk River system and much of the Duck River system, but absent from Cypress Creek system which is inhabited by the closely related *E. corona*. Headwaters of the Barren Fork and Hickory Creek systems, Cumberland drainage, of Cannon, Coffee, and Warren counties contain populations representing a similar recently described species *E. forbesi* Page and Ceas, the Barrens darter (Pl. 241c) (Page et al., 1992).

Similar Sympatric Species: See comments under *E. crossopterum* regarding sympatry with that species, *flabellare*, and *kennicotti*. Also sympatric with *neopterum* group in Tennessee River tributaries from Shoal Creek (Lawrence County) northward to Decatur

County. In the *neopterum* group the 2 branches of the soft dorsal fin rays are adnate (3 branches per ray in adult male and often in adult female *nigripinne*, branches divergent in all sizes), and nuptial males have extremely large knobs on the tips of soft dorsal rays, lacking in *nigripinne*. Modal counts of soft dorsal rays are 13–14 in *nigripinne*, 11–12 in *neopterum*.

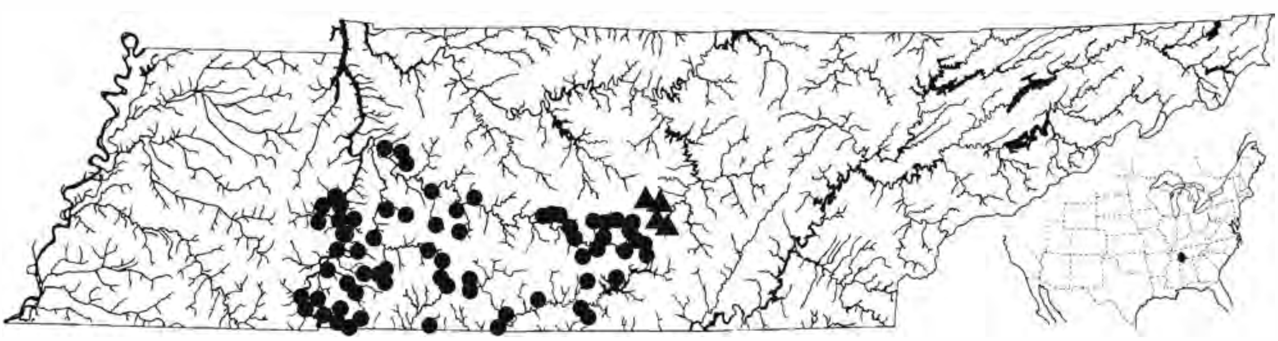
Systematics: A member of the *E. squamiceps* complex of the subgenus *Catonotus*, revised by Braasch and Mayden (1985), who accorded species status to this form and hypothesized it to be sister species to *crossopterum*. Taxonomy and distribution were reinterpreted while this book was in press by Page et al. (1992), who regarded Cypress Creek (see *E. corona*) and upper Caney Fork system populations as separate species based on dorsal fin pattern of breedíng males and genetic attributes (see Distribtuion). Relationships within this group or with other members of the *squamiceps* complex were not resolved. See further comments under *E. squamiceps* and *E. corona*, the crown darter.

Etymology: *nigrum* = black, *pinna* = fin, in reference to the black fins of breeding males; *forbesi*, in tribute to Stephen A. Forbes, a prominent ichthyologist with the Illinois Natural History Survey during the early part of this century.


Plate 241a. *Etheostoma nigripinne*, blackfin darter, female, 44 mm SL, Little Duck R., TN.


Plate 241c. *Etheostoma forbesi*, Barrens darter, breeding male, 65 mm SL, Barren Fork R. system, TN.


Plate 241b. *Etheostoma nigripinne*, blackfin darter, breeding male, 61 mm SL, Little Duck R., TN.


Range Map 232. *Etheostoma nigripinne* group (*E. nigripinne*, blackfin darter, circles; *E. forbesi*, Barrens darter, triangles).

Etheostoma nigrum Rafinesque.

Johnny darter

Plate 242a. *Etheostoma nigrum*, johnny darter, female, 47 mm SL, Obion R. system, TN.

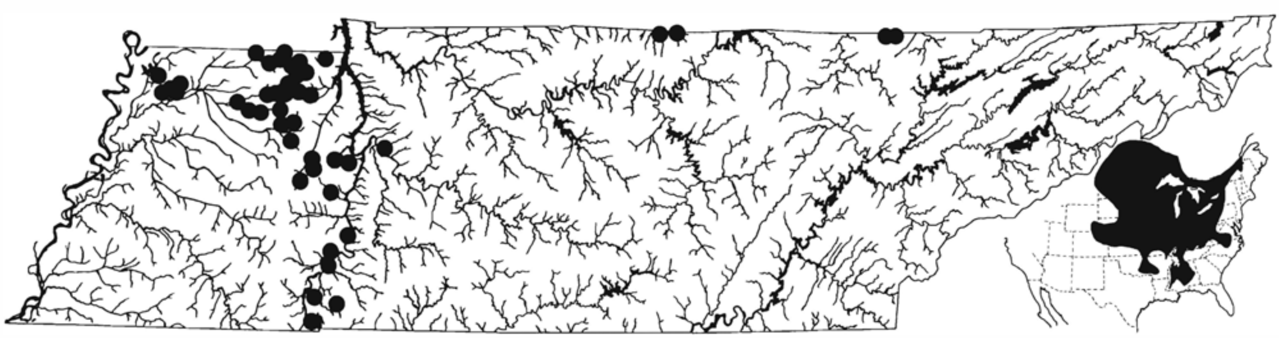
Plate 242b. *Etheostoma nigrum*, johnny darter, breeding male, 62 mm SL, Obion R. system, TN.

Characters: Lateral line complete or nearly so, with 35–58 scales in lateral series and usually fewer than 10 unpored scales. Highest counts occur in the upper Midwest and Ozark region, and lowest counts occur in Atlantic slope populations, especially in the James River. Tennessee populations have mean counts of 45–47 scales in lateral series. Dorsal fin with 8–10 (6–10) spines and 10–14 (9–15) soft rays, modally 11 or 12 except for Tar River drainage of Atlantic slope and eastern Mississippi River Embayment populations where modes are 13. Anal fin with 1 (1–2) spine and 5–10 (modally 7 or 8) soft rays. Pectoral fin rays 10–14, modally 11 or 12 except 12 or 13 in Tar River drainage of Atlantic slope. Principal caudal fin rays modally 16 (14–18). Gill rakers 5–11, length of longest rakers 1–2 times their basal width. Vertebrae 36–39. Branchiostegal rays 6 (5 in most of Ohio River drainage). Gill membranes narrowly joined. Frenum absent. Chromosome number 48 (Ross, 1973; Donahue and Loftus, 1974). Squamation extremely variable. Opercles consistently scaled (except in *E. n. susanae*, and we have seen specimens with naked opercles from the Red River drainage of Oklahoma). Cheeks, nape, breast, belly, and prepectoral area typically naked or nearly so in southern and eastern populations, but these areas often completely covered with exposed scales, especially in upper Midwest. Head canals also variable. Preoperculomandibular canal complete to interrupted at juncture of preoperculum and mandible. Supratemporal canal typically interrupted but consistently complete in several populations. Infraorbital canal typically interrupted with 2 (1–4) posterior and 4 (4–5) anterior pores, but often complete in some populations (see Systematics). Background color straw yellow with brown markings forming six evenly spaced dorsal saddles and a series of W-, M-, or X-shaped midlateral marks. A suborbital bar may be present as well as preorbital bars (interrupted at nares in most upper Cumberland specimens) that extend to the upper lips but do not join on the midline. Rays of the dorsal and caudal fins are speckled. Rays of the pectoral and pelvic fins may have some brown spots, and the anal fin is clear. Nuptial males darken overall and have dark pigment in the anterior spinous dorsal fin membranes and throughout the pelvic and anal fins. Breeding tubercles are lacking, but the pelvic fin rays thicken and fleshy knobs form on the ends of these as well as on the dorsal spines.

Biology: In the South, johnny darters are chiefly inhabitants of sandy streams. Northern populations occur both in streams and on firm shoreline areas of lakes. Favored habitats are moderately flowing runs with substrates of coarse sand. The biology of this wide-ranging species has been relatively well studied. Spawning occurs during April and May and may extend into June in higher latitudes. According to Winn (1958a, b) and Speare (1965), spawning migrations occur, with males moving to spawning areas prior to females and establishing territories near selected breeding sites. Nests, in the form of a cleared area under a submerged object, are cleared of silt and debris by fin movements of the male. Egg-mimicking by males, using swollen tips of the dorsal fin rays, may be important in courtship (Bart and Page, 1991). Females periodically enter the nests and the spawning pair inverts, with females depositing 40–200 adhesive eggs on the underside of the nest object. Females may deposit their entire annual complement of eggs during one spawning act. Nests of individual males may contain over 1,000 eggs, representing spawnings with numerous females. The male maintains the nest site by periodically fanning his fins, thus cleaning away silt. Forbes and Richardson (1920) noted johnny darters to spawn directly on the substrate in an upright position in aquaria where suitable nest sites were absent, and this more primitive darter spawning behavior may occur in natural populations where nest objects are scarce. The 1.5 mm diameter eggs hatch in about 16 days at 12 C, and require only 6 days at water temperature of 21–24 C. Hatchlings are about 5 mm long, and they reach total lengths of 29–38 mm at age 1. Two-year-olds average 43–51 mm, and individuals reaching age 3 are typically over 60 mm TL. Males grow faster than females after the first year. Experiments conducted by R. J. F. Smith (1979) indicated that johnny darters react to predation on conspecifics by reducing their activity level (i.e., probably becoming less conspicuous on the substrate) because of chemical stimuli released from skin and muscle of the victims; this fright-response system parallels that found in minnows and related fishes. As is apparently true of darters in general, johnny darters are sight feeders (Roberts and Winn, 1962). Principal prey items are midge larvae, mayfly nymphs, caddis larvae, and microcrustaceans with young feeding on entomostracans and tiny midge larvae (Turner, 1921; Karr, 1963). Maximum total length 75 mm (3 in).

Distribution and Status: Very widely distributed and common throughout most of the Mississippi River basin above the Fall Line and in many Hudson Bay and Great Lakes tributaries. Also occurs in middle Atlantic slope drainages (James, Roanoke, Tar, and Neuse rivers), and in the Mobile Basin chiefly below the Fall Line. In eastern tributaries to the lower Mississippi River, below the Fall Line, the distribution of *E. nigrum* is sporadic and a bit enigmatic. It occurs in the Obion River system, skips the Forked Deer, Hatchie, Loosahatchie, and probably the Wolf systems, and occurs to the south again in the Yazoo, Big Black, Bayou Pierre, and Homochitto systems. It also occurs in the lower Tennessee River drainage, most commonly in Coastal Plain western tributaries, and sporadically in western and southern Highland Rim tributaries. The upper Cumberland River subspecies *E. n. susanae* is extremely rare in the Tennessee portion of that system. The only known Tennessee population is in Jellico Creek, Scott County (O'Bara, 1988); it formerly occurred in Gum Creek in Scott County (Shoup and Payton, 1940), but results of recent status surveys indicate this population to be extirpated. It is now rare in the Kentucky portion of the upper Cumberland (Starnes and Starnes, 1979; O'Bara, 1988). Records plotted in the middle Cumberland River system in the Atlas (Lee et al., 1980) are apparently not substantiated (J. C. Bruner, pers. comm.), and the occurrence of johnny darters there is doubtful. Medford and Simco (1971) reported *nigrum* from two localities in the Wolf River system of west Tennessee and northern Mississippi. These are apparently in error, as one lot of "*nigrum*" contained a single specimen of *E. blennioides* (of uncertain origin but not from the Wolf River) and the other lot, currently unavailable and perhaps lost, contained two specimens, each with 10 soft dorsal fin rays (counted by W. Starnes in the 1970s). These almost certainly were not *nigrum*, as only 1 of 174 specimens from the Embayment had 10 soft dorsal fin rays, and only 6 had as few as 11.

Similar Sympatric Species: Both *E. chlorosoma* and members of the *E. stigmaeum* complex share the yellow to tan body coloration with X- or W-shaped marks along the side, and six dorsal saddles. In *E. chlorosoma* the preorbital dark bars are continuous around the snout, joining above the upper lip, while in *nigrum* each bar terminates on the upper lip laterad of the midline. In *chlorosoma* fully exposed scales cover the cheeks, opercles, breast, belly, and prepectoral areas, while in *nigrum* many of these areas are naked or have embedded scales. Members of the *E. stigmaeum* complex consistently have 2 anal spines, and at least some red or orange pigment is usually present on adults during the entire year. In *nigrum* there is typically a single anal spine, and bright colors are consistently lacking. In eastern tributaries to the lower Mississippi River, *nigrum* has a mode of 13 dorsal soft rays, while both *chlorosoma* and *stigmaeum* have modes of 11 or fewer. Also rather similar to *Percina copelandi*, which has 2 anal spines, scaled cheeks, and modified midventral scales. The bilobed urogenital papilla of females is unique to the subgenus including the johnny darter,



Range Map 233. *Etheostoma nigrum*, johnny darter.

and its shape is not approached by that of any other Tennessee darters.

Systematics: Subgenus *Boleosoma*. A number of workers have analyzed variation, but a study covering the johnny darter's entire range is lacking. Systematics in southcentral United States (including our area) has been studied by Starnes and Starnes (1979) and M. J. Krotzer (1990). In the Midwest the subspecies epithet *eulepis* has been widely used for populations with scaled napes, cheeks, and breast. These occur sporadically, entirely within the range of the naked form, *E. n. nigrum*, and are most often encountered in lakes and sluggish streams with soft substrates and abundant vegetation. Lagler and Bailey (1947) have shown these differences to be under genetic rather than immediate environmental control. Underhill (1963) concluded that the mosaic distribution of *eulepis* populations within the range of *E. n. nigrum* and the presence of "intergrades" in most populations was incompatible with accepted definitions of subspecies. Underhill's views are shared by us and most recent workers. Rapid morphological adaptations to local conditions are apparently common in the subgenus *Boleosoma*, and a similar situation was investigated in the closely related *E. olmstedi* by J. Shute (1984). He found that the nominal species *E. perlongum*, long considered a Lake Waccamaw, North Carolina, endemic, was a lake ecotype of *E. olmstedi* that does not warrant even subspecies status. In the eastern Great Lakes and Atlantic slope populations, relationships with the closely related *E. olmstedi* have been extensively studied. *Etheostoma olmstedi*, previously considered a subspecies of *E. nigrum*, has been treated as a valid species in recent years by many researchers (Cole, 1957, 1965, 1967, 1971; McAllister et al., 1972; Clark, 1973; Kott and Humphreys, 1978; Chapleau and Pageau, 1985). There are several indications of introgressive hybridization with *E. nigrum*. However, in contrast, Brett (1985) concluded that the two forms represented a single species in the Genessee River system of New York.

In the region of Tennessee, Starnes and Starnes (1979) hypothesized subspecies status for *E. n. susanae* (Jordan and Swain), which is confined to the Cumberland River drainage above the Falls. It differs from the nominate subspecies in lacking scales on the belly, opercles, and top of the head, in having an interrupted preorbital bar, and in consistently having the preoperculomandibular canal interrupted, typically with 3 anterior and 6 posterior pores. Based on intermediate scalation, "intergrades" between this form and *E. n. nigrum* may occur in the adjacent headwaters of the Kentucky River system to the north. However, recently discovered specimens from Poor Fork, Letcher County, Kentucky, in the upper Cumberland drainage, show intermediacy in pigmentation and scalation (Krotzer, 1990), and about half of these have complete preoperculomandibular canals as is generally true for specimens from the Ohio River drainage; these might be construed as intergrades *or* interspecific hybrids.

Our examination of johnny darter populations in eastern tributaries to the Mississippi River in Kentucky, Tennessee, and Mississippi (the lower Mississippi race) indicated them to be strikingly different from adjacent *nigrum* populations in the Ozarks, lower Tennessee River, and Mobile Basin. We noted that they reach much larger size (often over 55 mm SL) than do other johnny darters, have modally 13 soft dorsal fin rays, consistently have complete supratemporal canals, and have well-developed infraorbital canals (complete with 8–9 pores to narrowly interrupted with 4 (4–5) anterior pores and usually 4 (3–5) posterior pores versus broadly interrupted with 4 anterior and 2 (1–3) posterior pores). A more extensive evaluation of these and other characters (M. J. Krotzer, 1990) throughout the range of the johnny darter indicated that maximum size is extremely variable; modal counts of 13 soft dorsal fin rays occur sporadically in populations to the east, north, and west of the lower Mississippi populations; the supratemporal canal, complete in 90% of lower Mississippi specimens, is complete in about 64% of Mobile Basin specimens, consistently interrupted only in the Arkansas and Red River drainages, and complete in about 10% of specimens from elsewhere; and infraorbital canals are equally well developed in numerous populations in the Great Lakes region. This lower Mississippi River race, which we originally thought was so distinctive, is much less so when one considers total variation in *Etheostoma nigrum*, and it appears to warrant no more than racial recognition.

Etymology: *nigrum* = black; *susanae* is a matronym for Mrs. Susan B. Jordan.

Etheostoma obeyense Kirsch.

Barcheek darter

Characters: Lateral line incomplete with 12–25 (10–26) pored scales and 39–56 scales in lateral series. Dorsal fin with 8–10 spines and 12–14 (12–15) soft rays. Anal fin with 2 spines and 7–10 (usually 9) soft rays. Pectoral fin rays 11–14 (usually 12). Principal caudal fin rays modally 16, often 17 (15–18). Gill rakers 7–9

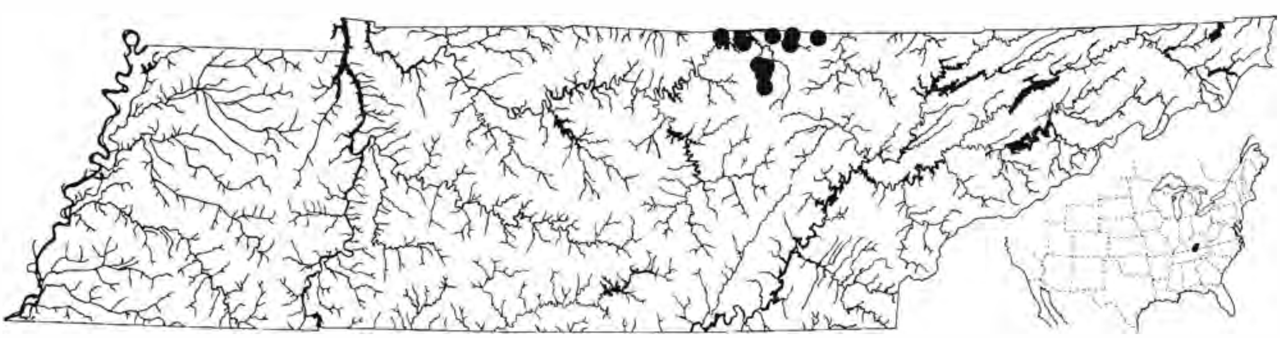
Plate 243. *Etheostoma obeyense*, barcheek darter, male, 43 mm SL, Wolf R., TN.

(7–10), length of longest rakers 1–2 times their basal width. Vertebrae modally 37 (36–37). Branchiostegal rays 6. Gill membranes separate to narrowly joined. Frenum present. Infraorbital and supratemporal canals interrupted. Cheeks, opercles, nape, breast, and prepectoral area naked; belly scaled. The barcheek darter is a straw-colored fish with brownish markings including six to eight dorsal saddles and 9–12 midlateral blotches; dorsolateral markings are variable, ranging from almost plain to having numerous blotchings or vermiculations. A characteristic oblique pale bar is present on the cheek and is outlined by dark pigment. The breast area is usually speckled with melanophores. A large black humeral spot is present above the pectoral fin base. The spinous dorsal fin has a basal dark blotch anteriad and a marginal reddish band. The soft dorsal, caudal, and pectoral fins have dusky to reddish-brown bars. The dorsal, anal, and caudal fins of nuptial males become red and the anal fin margin and lower caudal margin become blue-black. The pectoral and pelvic fins darken, as does the head and breast region; and small, fleshy swellings occur on tips of dorsal spines. Breeding tubercles are absent.

Biology: The barcheek darter is an inhabitant of moderately flowing or sluggish pool areas of small to medium-sized clear upland streams. In larger habitats, such as the Little South Fork of the Cumberland system in Kentucky, it is more abundant towards the headwaters. Preferred substrates consist of slab rubble or small flat stones scattered over bedrock or sand and gravel (Page and Schemske, 1978). The barcheek darter is also present at times in sandy areas with detritus. Inhabited streams are generally relatively free of silt. Biological information is from Page et al. (1981) and Kopp (1985). Spawning season is from late April into June. In typical *Catonotus* fashion, spawning occurs beneath stones where males, mostly larger 2-year-olds, establish and guard nests. Nests examined had single-layered clusters ranging from 22–622 eggs on the underside of a stone. Fecundity of females ranged from 33–158 mature ova per female. Several females probably spawn in the nest of a given male. Larvae are 6–7 mm TL at hatching; their early development was described in detail by Kopp. Young reach about 32–42 mm SL at age 1, and age 2 individuals are 42–60 mm. Males grow faster and are larger in both age classes but few may survive to the 3-year-old age class which is dominated by females. The diet is dominated by midge larvae and mayfly nymphs; young feed heavily on copepods. Maximum total length 85 mm (3.3 in).

Distribution and Status: Restricted primarily to the eastern Highland Rim portion of Cumberland River drainage of Tennessee and Kentucky from Big South Fork downstream through the Obey River, where it is often common in small streams.

Similar Sympatric Species: *Etheostoma flabellare* has broadly connected gill membranes, lacks the oblique pale bar on the cheek, and in the range of *obeyense* has rows of horizontal lines along the sides. Potentially sympatric with *kennicotti*, *virgatum*, and the duskytail darter, *E.* (*Catonotus*) sp. In *E. virgatum*, also a "barcheek," dark horizontal lines are prominent along the sides. In the other two *Catonotus* the dark blotch at the anterior base of the spinous dorsal fin and the pale bar on the cheek are absent.



Range Map 234. *Etheostoma obeyense*, barcheek darter.

Systematics: A member of the *E. virgatum*, or barcheek, species group of the subgenus *Catonotus*. Systematics discussed by Page and Braasch (1976). Hypothesized to be most primitive member of barcheek group (Braasch and Mayden, 1985).

Etymology: *obeyense* = of the Obey River.

Etheostoma olivaceum Braasch and Page.

Dirty darter

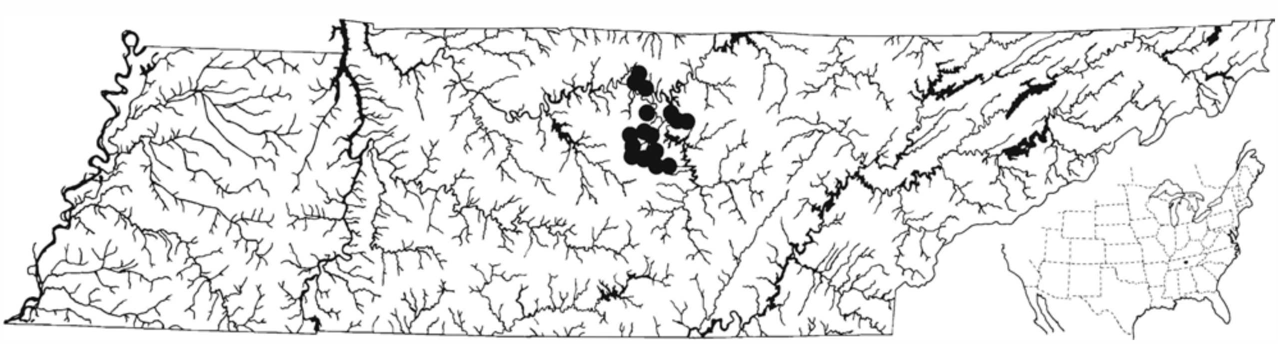
Plate 244a. *Etheostoma olivaceum*, dirty darter, female, 58 mm SL, Caney Fork R. system, TN.

Plate 244b. *Etheostoma olivaceum*, dirty darter, breeding male, 70 mm SL, Caney Fork R. system, TN.

Characters: Lateral line incomplete with 19–38 (13–46) pored scales and 45–53 (44–58) scales in lateral series. Dorsal fin with modally 9 (8–10) spines and 12–13 (11–14) soft rays. Anal fin with 2 spines and 7–8 soft rays. Pectoral fin rays 12 (11–13). Principal caudal fin rays 17 (16–18). Gill rakers 8–11, length of longest rakers 2–3 times their basal width. Branchiostegal rays 6. Gill membranes separate to narrowly joined. Frenum present. Infraorbital canal complete, supratemporal canal interrupted. Scales present on nape, belly, and prepectoral area; cheeks and opercles naked; breast variable. Females, juveniles, and non-nuptial males are dark olive colored and often have about eight darker vertical bars along the sides. Nuptial males are very dark. The spiny dorsal fin is black with fleshy white knobs on the spine tips and a small clear spot behind the distal end of each spine. The soft dorsal fin is black with paler basal and marginal areas and three to five undulating narrow pale yellow bands medially. Soft dorsal fin rays are produced beyond the membranes, and the head and nape become excessively swollen. (Above date from Braasch and Page, 1979, and UT specimens.)

Biology: The dirty darter occurs in small, low gradient streams with primarily limestone bedrock substrates. Adults are most commonly encountered in slabrock pools but are not confined to these habitats. Page (1980) provided the following biological information. In typical *Catonotus* breeding behavior, males establish territories under slabrocks in March. Spawning occurs in April and May, with eggs from one or several females attached to the underside of the slabrock and the male defending the nest until eggs hatch. Swollen dorsal fin tips in males may serve as egg-mimics to entice females to spawn (Bart and Page, 1991). Young reach lengths of 35–45 mm SL during their first year and are sexually mature at age 1. The diet of juveniles consists mainly of midge larvae and microcrustaceans. Adults continue to feed heavily on midge larvae while increasing their utilization of other aquatic insect immatures (mayflies, caddisflies, stoneflies) and shifting from microcrustacea to isopods and amphipods. Life span is about 2.5 years. Males grow faster than females and reach a maximum total length of 82 mm (3.25 in).

Distribution and Status: Restricted to but locally common in Nashville Basin tributaries to the Cumberland



Range Map 235. *Etheostoma olivaceum*, dirty darter.

River and lower Caney Fork River in DeKalb, Putnam, Smith, and Wilson counties, Tennessee.

Similar Sympatric Species: *Etheostoma flabellare* is the only sympatric *Catonotus.* It differs in having dark horizontal lines along the sides, broadly connected gill membranes, a dark basal band on the spinous dorsal fin, and an incomplete infraorbital canal. Adjacent streams in the middle Cumberland drainage contain the very similar *E. crossopterum*, which consistently has scaled cheeks and opercles and an incomplete infraorbital canal.

Systematics: A member of the *E. squamiceps* group of the subgenus *Catonotus* hypothesized to be most closely related to *E. crossopterum* and *E. nigripinne* (Braasch and Mayden, 1985), and regarded as sister species to the remainder of the *squamiceps* species group by Page et al. (1992).

Etymology: *olivaceum* refers to the coloration. We find little justification for abandoning the common name of dirty darter chosen by Braasch and Page (1979) for the alternate common name of sooty darter proposed by Robins et al. (1980).

Etheostoma parvipinne Gilbert and Swain.

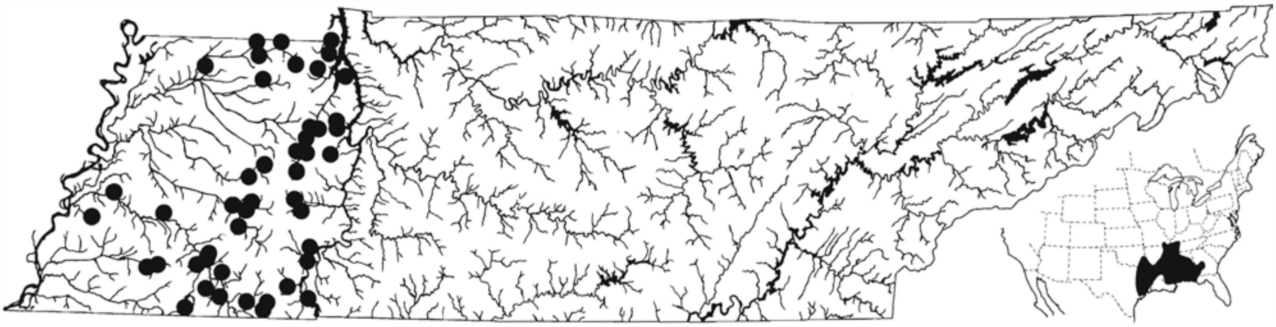
Goldstripe darter

Plate 245. *Etheostoma parvipinne*, goldstripe darter, 53 mm SL, Hatchie R. system, TN.

Characters: Lateral line nearly complete with 38–52 (30–58) pored scales and 44–57 (40–62) scales in lateral series. In west Tennessee and Mississippi scales in lateral series (90 specimens) are 44–51 (42–52). Dorsal fin with 9–11 (8–12) spines and 9–12 (9–13) soft rays (consistently 10–12 in our area). Anal fin with 1–2 spines and 7–10 (7–11) soft rays. Two-thirds of our specimens have a single anal spine, whereas Richards (1963) found about two-thirds of his specimens with two anal spines. Pectoral fin rays 14–16 (13–17). Principal caudal fin rays modally 16 (14–18). Gill rakers 8–12, length of longest rakers about twice their basal width. Vertebrae 36–38. Branchiostegal rays 6. Gill membranes moderately joined. Frenum present. Nape, cheeks, opercles, breast, belly, and prepectoral area scaled, with nape scales deeply embedded. Supratemporal canal broadly interrupted. Infraorbital canal complete. The goldstripe darter is a relatively drab species lacking exceptionally bright colors. Ground color is gray to yellowish. The anterior half of the lateral line (and often the nape) is conspicuously depigmented and may be yellowish in color, which gives the species its common name. In turbid waters or in areas with uniformly sandy substrates specimens are uniformly gray, but in clearer waters seven or eight dorsal saddles and 12 or more midlateral blotches and other body mottlings are present. Dorsal fin rays and often membranes are speckled with dark brown, as are the rays of the caudal and often the pectoral fin. Males have dusky anal fins and a dark blotch at the base of the anterior 2 membranes of the spinous dorsal fin. In breeding individuals, the dorsum and caudal fin become copper colored and traces of yellow appear on the ventral portion of the head and body. Small breeding tubercles develop on distal portions of anal fin rays.

Biology: The goldstripe darter is an inhabitant of small, sandy Coastal Plain streams. Some habitats are well vegetated, especially when associated with springs. Most Tennessee habitats are shallow streams with barren, shifting sand substrates, where this species is associated with clumps of detritus and undercut banks. Seasonal movements within inhabited stream systems are not understood, and collecting success can be difficult to predict. Its life history has not been studied. In Tennessee and Mississippi, peak breeding season is in March and April, based on tubercle development and the appearance of young specimens averaging about 20 mm long from mid-April through May. Spawning may extend into May, as we have taken gravid females that late, and is likely rather extended, since 20-mm juveniles, presumably about 2 months old, appeared in some of these May collections. At least two adult groups are present in early spring collections, averaging 45–50 and 55–65 mm total length. Stomachs examined contained a variety of arthropods including midge larvae, dipteran pupae, caddisfly larvae, dytiscid beetle larvae, and small crayfish. Maximum total length 75 mm (3 in).

Distribution and Status: Widespread, but with a spotty distribution. The goldstripe darter is frequently the dominant darter where it occurs, and collections of 10–40 specimens are not unusual. Range extends from the Savannah River drainage through the Brazos River



Range Map 236. *Etheostoma parvipinne*, goldstripe darter.

drainage of Texas, and north in the Mississippi River Embayment to southwestern Kentucky and southeastern Missouri. It is restricted to areas below the Fall Line, and shows remarkable fidelity to the Coastal Plain in Tennessee, even occurring on the east side of the lower Tennessee River in a small area of Coastal Plain just north of Pickwick Dam.

Similar Sympatric Species: Surprisingly, this very distinctive darter with its very short snout, connected gill membranes, broadly interrupted supratemporal canal, and well-scaled cheeks and breast, is often misidentified. It is sometimes taken with *E. swaini* and might be confused with nonchromatic juveniles and females of that species, but *swaini* has separate gill membranes, a complete or narrowly interrupted supratemporal canal, a naked breast, and consistently 2 stout anal spines. In the Pickwick Reservoir area, the goldstripe's range approaches that of the spring-restricted *E. tuscumbia*, which shares the short snout, drab coloration, and body shape of *parvipinne*, but has separate gill membranes, only about half of the scales in lateral series pored, and scales on top of the head extend to the interorbital area. Also potentially sympatric with two members of the *E. squamiceps* species group (*crossopterum* and *neopterum*), which are very similar in appearance but have separate gill membranes, are less extensively scaled, have 13 or fewer pectoral fin rays, and have many more dorsal soft rays than dorsal spines.

Systematics: Subgenus *Fuscatelum*. Page (1981) erected this monotypic subgenus for *E. parvipinne*, which had formerly been included in *Oligocephalus* but lacks many characteristics of that group. Bailey and Etnier (1988) suggested possible affinities with members of the subgenus *Ozarka*. Systematics have been discussed in part by Moore and Cross (1950), Richards (1963), and Robison (1977).

Etymology: *parvi* = short or small, *pinne* = fin.

Etheostoma proeliare (Hay).

Cypress darter

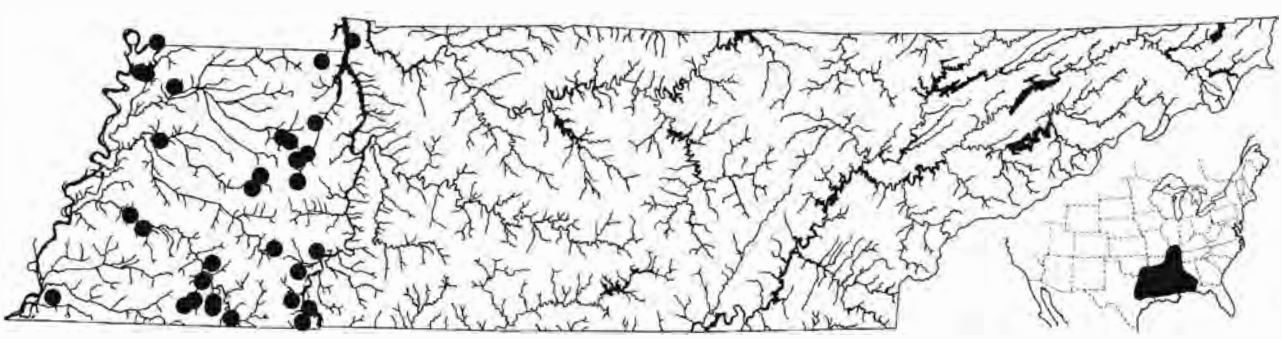
Plate 246. *Etheostoma proeliare*, cypress darter, 31 mm SL, lower Tennessee R. system, TN.

Characters: Lateral line incomplete with 1–6 (0–9) pored scales and 35–37 (34–38) scales in lateral series. Dorsal fin with 7–8 (7–9) spines and 10–12 (10–13) soft rays. Anal fin with 1 (19%) or 2 (81%) spines and 5–6 (4–7) soft rays. Pectoral fin rays 10–11 (9–11). Principal caudal fin rays 11–14, modally 13 in our specimens. Gill rakers 6–10 (including ventral vestiges), with length of longest rakers 3–4 times their basal width. Vertebrae 35–36 (34–37). Gill membranes moderately joined. Branchiostegal rays 6 (5–7). Frenum present. Scales present and typically exposed on cheeks, opercles, and prepectoral region. Breast and nape naked, belly variable. Supratemporal and infraorbital canals interrupted, the latter typically with one posterior and 3 anterior pores. Preoperculomandibular canal with 8 (7–9) pores. Pelvic fins very long, reaching to or past anal fin origin in males. Background color straw to tan, with about six to nine dorsal saddles, 7–12 midlateral dashes, and additional dark mottling. Suborbital bar present. Spinous dorsal fin of males with dark blotch in anterior membrane and otherwise dusky except for vague pale submarginal band. Females have three rows of dark brown spots, mostly on spines, of the spinous dorsal fin. Soft dorsal and caudal fins of both sexes with dark bands, about three to five bands on rays and membranes of former and five or six rows on rays of latter. Pectoral fins with some dark margining on rays, more prominent on males. Anal and pelvic fins clear, becoming uniformly dusky in nuptial males. Females have a distinctly bilobed urogenital papilla. Nuptial males develop red to orange blotches in anterior membranes of the spinous dorsal fin, with this pigment more diffuse posteriad. Pale orange to amber bands occur on the caudal and soft dorsal fins, and anal and pelvic fins blacken. Nuptial tubercles develop on rays of the anal and pelvic fins of males, and the head, soft dorsal fin, and caudal fin become thickened and milky white.

Biology: Cypress darters inhabit sluggish, low gradient streams and also occur in floodplain swamps and oxbow lakes. Burr and Page (1978) studied biology of cypress darters in southern Illinois. Favored haunts are patches of detritus, rooted vegetation, or root masses beneath overhanging banks. Spawning in Illinois extended from March to June, but may begin in January along the Gulf Coast and extend to August in northern portions of the range. Water temperatures at spawning were 9.5–16 C. Females contained 26–116 mature ova, with actual fecundity probably higher than this due to maturation of smaller eggs during the season and the inclusion of partially spent females in the above counts. The eggs are .5–1.1 mm in diameter and have a deep indentation characteristic of the subgenus *Microperca*. Eggs are deposited on the upper and undersides of leaves, sticks, and other objects. Courtship is much like that described for *gracile* and *microperca*, with males pursuing and mounting females and stroking the tops of their heads with the chin. The female selects the spawning site, and acrobatic spawning occurs with the male often mounting the female in an inverted position. His position is maintained by clasping with the enlarged pelvic fins and rapid movement of the pectoral and caudal fins. Unlike *E. microperca*, only the female opens her mouth during oviposition. Eggs are deposited and fertilized one to three at a time, with the spawning pair separating for up to a minute before repeat performances. Eggs hatch in 5.5 days (23 C) to 12.5 days (15 C), and hatchlings are 3.4–3.7 mm long and transform to juveniles at 11–12 mm (Burr and Ellinger, 1980; Simon, 1985b). Cypress darters are about 35 mm long at age 1, with females slightly larger than males. All are sexually mature at age 1, and most die shortly after spawning, with maximum life span about 1.5 years. Food consists primarily of midge larvae and microcrustacea, with isopods, amphipods, and mayfly nymphs important seasonally (Rice, 1942; Burr and Page, 1978). Maximum size 39.6 mm SL (about 50 mm TL, or 2 in).

Distribution and Status: Gulf Coastal drainages from the Choctawhatchee of Florida to the San Jacinto of Texas, and north to southern Illinois in the Mississippi River basin. Most populations occur below the Fall Line. In Tennessee cypress darters occur in western tributaries to the lower Tennessee River and in direct Mississippi River tributaries and are most common in the relatively hard-bottomed streams of the eastern portion of the Coastal Plain (Owl Creek and Holly Springs formations).

Similar Sympatric Species: *Etheostoma fusiforme* and *E. gracile* have more dorsal spines, an upcurved lateral-line canal, and more pored lateral-line scales than *proeliare*, among other differences obtainable from the key and species accounts. The very similar *E. microperca* is occasionally sympatric in the Ozark region but lacks a bilobed urogenital papilla in females, has naked cheeks and weakly scaled opercles, and has fewer pored lateral-line scales.



Range Map 237. *Etheostoma proeliare*, cypress darter.

Systematics: Subgenus *Microperca*. Systematics were treated by Burr (1978), who noted geographic variation in several characters, with Lake Ponchartrain individuals often having serrated preopercles, reaching larger sizes, and having less naked napes than elsewhere. Western Gulf populations consistently have two anal spines and three or fewer pored lateral-line scales. Burr (1978), and Buth et al (1980) based on electrophoretic evidence, hypothesized that *E. proeliare* and *E. fonticola* of Texas are sister species with *microperca* as their closest relative. Page (1981) hypothesized a close relationship between *E. exile* and the subgenera *Microperca* and *Hololepis* and included all in the subgenus *Boleichthys* (but see previous comments in subgeneric definitions under *Hololepis*).

Etymology: *proeliare* = battle, in reference to the Civil War battleground near the type locality at Corinth, Mississippi.

Etheostoma pyrrhogaster Bailey and Etnier.

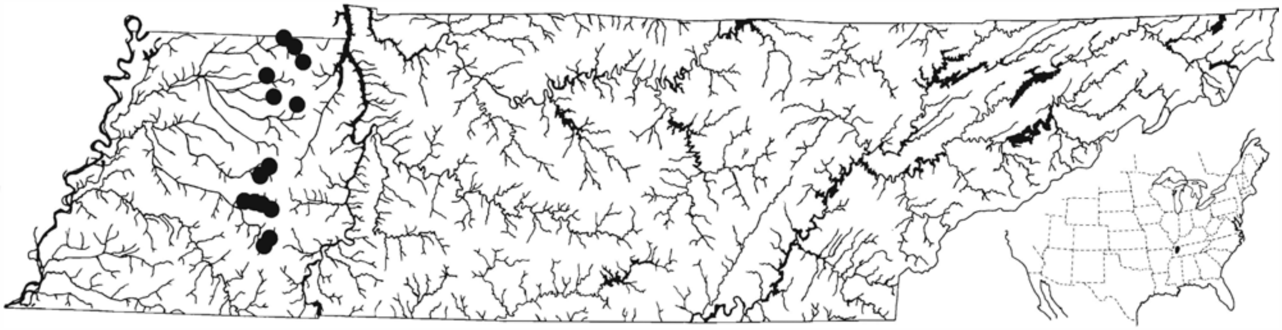
Firebelly darter

Plate 247a. *Etheostoma pyrrhogaster*, firebelly darter, female, 45 mm SL, Obion R. system, TN.

Plate 247b. *Etheostoma pyrrhogaster*, firebelly darter, male, 55 mm SL, Obion R. system, TN.

Characters: Lateral line complete with 40–45 (44–46) or 37–41 (36–45) scales in Obion and Forked Deer river systems, respectively. Dorsal fin with 10–11 (9–12) spines and 11–12 (11–13) soft rays. Anal fin with 2 spines and 7–8 (7–9) soft rays. Pectoral fin rays 14–15 (14–16). Principal caudal fin rays modally 16 or 17 (15–17). Gill rakers 7–11, length of longest rakers 1–1.5 times their basal width. Vertebrae 38–39. Branchiostegal rays 5 (5–6). Gill membranes broadly connected. Frenum absent. Supratemporal and infraorbital canals complete. Belly, nape, cheeks, opercles, and prepectoral area scaled; breast variable, but typically scaled on posterior half. Background color light brown, with about eight midlateral blotches and nine dorsal saddles. A narrow suborbital bar is present and there is a dorsal, ventral, and pair (often fused) of median basicaudal spots. Females have a red ocellus margined with black near the margin of the first spinous dorsal fin membrane, and submarginal red spots on posterior membranes. Soft dorsal fin with alternating brown and clear areas on rays and a submedian row of red spots on posterior membranes. Caudal and pectoral fins with alternating brown and clear areas on rays. Anal and pelvic fins clear. Adult males retain considerable color throughout the year. During breeding season the spinous dorsal fin has a large red ocellus in the first interradial membrane, a broad red median band that occupies the entire fin posteriad, and gray to gray-green at the anterior base. Soft dorsal fin with middle third (anteriad) to basal two-thirds (posteriad) occupied by red band, other portions of fin gray to gray-green. Caudal fin with red base, red throughout in highest males. Anal fin with red in posterior membranes, forming continuous median red band in highest males, gray to gray-green elsewhere. Pelvic fins with rays and often lower membranes stippled with dark pigment. Pelvic fins, breast, and lower sides of head gray to gray-green. Lower sides and posterior portion of upper sides orange. Nuptial tubercles absent.

Biology: Firebelly darters occur in small to medium streams, and adults typically occupy the swiftest waters and coarsest substrates available. In the low gradient streams where they occur, these habitats are gentle riffles with fine gravel substrates. We often encounter them in areas with rooted aquatic vegetation, but this probably reflects a preference for clearer streams rather than the vegetation, since they are abundant in several Obion River system streams where vegetation is absent. Males reach peak color in early spring, indicating a breeding season similar to that of other *Ulocentra*. Bailey and Etnier (1988) suggested that spawning substrates might be submerged logs and snags in the absence of boulders utilized by related species. Young in our collection had reached about 20 mm SL by mid September and were about 35 mm SL at age 1+ (late June). Carney and Burr (1989) provided life history information from a population in the Obion River system. Spawning occurred from March to May or June, peaking in March and April. Age 1 females, except those



Range Map 238. *Etheostoma pyrrhogaster*, firebelly darter.

less than 27 mm SL, were sexually mature, and contained a mean of 28.4 large ova per female. Age 2 and 3 females contained a mean of 144 large eggs per female. These values were thought to underestimate fecundity because of the likelihood of egg recruitment during the spawning season. All males were sexually mature at age 1. Spawning occurred in aquaria at water temperature of 22 C (72 F) only after the fish were injected with chorionic gonadotropin hormones. Eggs were laid singly in typical *Ulocentra* fashion, both on horizontal and vertical surfaces. Mature ovarian and fertilized eggs averaged 1.09 and 1.6 mm in diameter, respectively. Eggs hatched in 6–8 days at water temperature of 25 C (77 F), and hatchlings averaged 4.08 mm TL. At age 1 males were 36 and females 32 mm SL. Maximum life span was 3 years. Food was dominated by midge (Chironomidae) larvae. Maximum total length 70 mm (2.75 in).

Distribution and Status: Confined to upper Coastal Plain streams of the Obion and Forked Deer river systems in Kentucky and Tennessee, where it is locally abundant in the few remaining good quality streams. Many populations have probably been extirpated due to pervasive stream rechanneling in both river systems. The firebelly darter has a Species of Special Concern status in Tennessee (Starnes and Etnier, 1980), and its even more limited distribution in Kentucky suggests that it will eventually be considered Endangered there.

Similar Sympatric Species: This is the only *Ulocentra* species occurring in the Obion and Forked Deer river systems. Juveniles and females might be confused with *parvipinne*, which also has broadly connected gill membranes but lacks red coloration, has a dark blotch at the anterior base of the spinous dorsal fin, typically has an incomplete lateral line, and often has a single anal spine.

Systematics: A member of the *E. duryi* species group of the subgenus *Ulocentra* (Bailey and Etnier, 1988).

Etymology: *pyrrho* = fire, *gaster* = belly. Referred to as "red snubnose darter" prior to its formal description, but Kuehne and Barbour's (1983, Plate 12) illustration of the redbelly snubnose darter represents the subsequently described *E. zonistium*.

Etheostoma rufilineatum (Cope).

Redline darter

Characters: Lateral line complete with 48–58 (43–64) scales. Dorsal fin with 11–13 (8–14) spines and 11–13 (9–14) soft rays. Anal fin with 2 spines and 7–9 (6–9) soft rays. Pectoral fin rays 13–14 (11–16). Principal caudal fin rays modally 17 (16–18). Gill rakers 12–15 (10–17), length of longest rakers 4–7 times their basal width. Vertebrae modally 37–39 (36–40). Branchiostegal rays 6. Gill membranes separate or narrowly joined. Frenum present. Nape, cheek, breast, and prepectoral area naked; opercles and belly scaled. Sexual dimorphism is extreme, but both sexes have orange lips, dark horizontal markings on the cheek, a dark humeral spot, prominent horizontal dark lines between scale rows on posterior sides, and a pair of large, white basicaudal spots; eight to ten dorsal saddles are often present, and 8–11 dark blotches occur midlaterally, often in the form of oblique vertical bars. Females have dark brown background coloration and clear to pale yellow fins (often tinged with orange) sprinkled with large black spots; the soft dorsal, caudal, and anal fins have a black marginal band. Adult males are brightly colored throughout the year, with color intensifying during the breeding season. Background color is paler than in females, and bright red spots occur between the dark lines on the sides. The lower sides are bright orange, and orange blotching often occurs on the cheeks and opercles. The spinous dorsal fin has a narrow, dark margin, red submarginal band, and gray base. Soft dorsal and caudal fin with dark marginal band, pale yellow submarginal band, bright red median band, and dark base; anal fin similarly colored, but dark marginal band only on posterior portion of fin and base of fin pale orange. Paired fins pale with orange submarginal bands. Bright blue or green of breast extends onto bases of pelvic fins.

Biology: Redline darters occur in swift, shallow riffles over rocky substrates in clear streams, with larger males prevalent in the swiftest waters during warmer months. Females and juveniles often occur in pool areas. The redline does not avoid small streams as do other *Nothonotus*, and is found from large rivers to second- and third-order streams. Biological information is from Stiles (1972) and Widlak and Neves (1985). The breeding season extends from May through August at water temperatures of 14–26 C. Females partially bury themselves in sandy areas flanked by boulders, usually after being followed for some time by an adult male. Individual females occasionally reburied themselves several times in the same place, burying less deeply in the substrate each time. Stiles suggested the result of this behavior would be a layering of the eggs in the substrate. Stiles (1972) occasionally noted two or three females buried in the same area and attended by a single male.

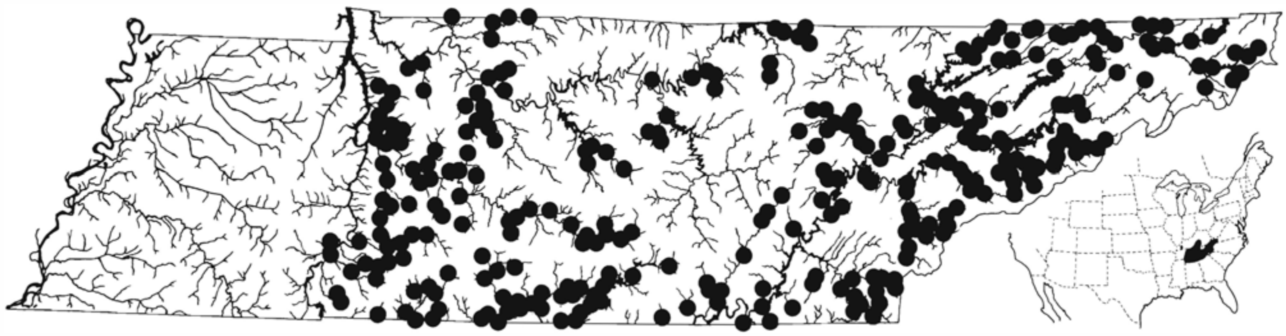
Plate 248a. *Etheostoma rufilineatum*, redline darter, gravid female, 58 mm SL, Holston R., TN.

As in *E. camurum*, males typically defended a spawning site for no more than a few hours. Stiles (1988) noted the possibility of cuckoldry in this species, with young but reproductively functional males, colored as females, perhaps sneaking into the "nests" of larger males to fertilize eggs. Widlak and Neves found 23–131 mature eggs per female. We have noted many apparent hybrids with *chlorobranchium* and *camurum* where these species co-occur, one hybrid with *vulneratum* from Nolichucky River, and even single specimens of intergeneric hybrids with *Percina squamata* and *P. caprodes*. Mayden and Burr (1980) reported a hybrid between *rufilineatum* and *E.* (*Oligocephalus*) *caeruleum*. Food of young and adults is dominated by midge and blackfly larvae, with baetid and heptageniid mayfly nymphs, hydropsychid and hydroptilid caddis larvae, and water mites also prevalent, especially during warmer months. Widlak and Neves noted little sexual difference in growth, but maximum life span for females was only 3 years, while males grew slightly faster and often reached age 4. Average total lengths at ages 1, 2, and 3 were about 43, 55, and 66 mm, respectively. Individuals of both sexes were often mature at age 1 at lengths of about 40 mm. Maximum total length 98 mm (3.9 in).

Distribution and Status: Redline darters are restricted to the Tennessee and Cumberland river drainages, occurring in larger upland streams of all regions except the Big South Fork, upper Caney Fork, and upper Cumberland and its tributaries.

Similar Sympatric Species: Occurs sympatrically with all Tennessee *Nothonotus* except *jordani* and *bellum*, and differs from all these in having orange lips in life, dark horizontal markings on the cheeks and opercles versus a vertical suborbital bar in other species, and an

Plate 248b. *Etheostoma rufilineatum*, redline darter, male, 65 mm SL, Little Pigeon R. system, TN.



Range Map 239. *Etheostoma rufilineatum*, redline darter.

hour-glass-shaped pale area at the caudal fin base. The large, black spots on fins of females are very different from the less discrete and smaller brown speckles on fins of female *aquali*, *microlepidum*, *sanguifluum*, *vulneratum*, and *wapiti*.

Systematics: Subgenus *Nothonotus*. Zorach (1970) studied variation throughout the range and noted the presence of spotted median fins in many adult males from the Hiwassee River system and also considerably lower scale counts in these specimens and specimens from the French Broad River system. Etnier and Williams (1989) postulated the closest relatives of *E. rufilineatum* to be *E. jordani* and the *E. maculatum* species group.

Etymology: *ruf* = red, *lineatum* = lined.

Plate 249a. *Etheostoma rupestre*, rock darter, 59 mm SL, Etowah R., GA.

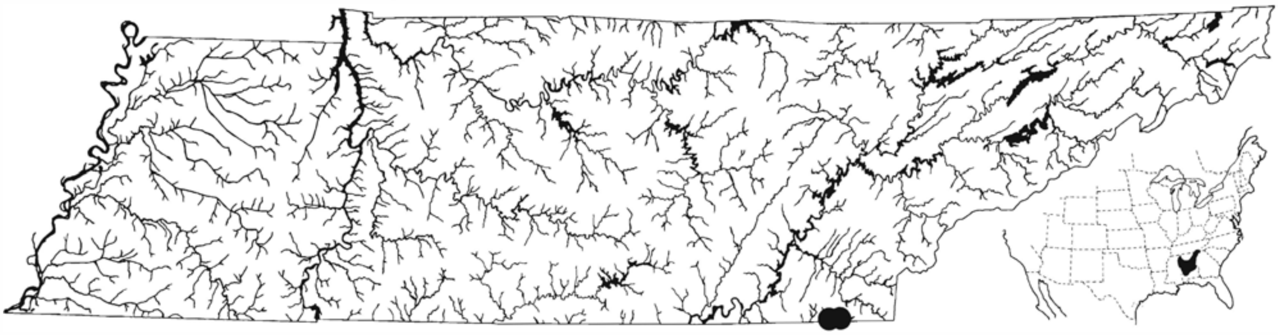
Plate 249b. *Etheostoma rupestre*, rock darter, breeding male, 52 mm SL, Conasauga R., TN.

Etheostoma rupestre Gilbert and Swain.

Rock darter

Characters: Lateral line complete with 49–61 (42–65) scales. Dorsal fin with 11–12 (10–13) spines and 11–12 (9–13) soft rays. Anal fin with 2 spines and modally 7 (5–9) soft rays. Pectoral fin rays 14–16 (13–16). Principal caudal fin rays modally 16 (15–17). Gill rakers 10–14, length of longest rakers about 3 times their basal width. Vertebrae 36–40, modally 38 (Tombigbee River) or 39 (Alabama River). Branchiostegal rays 6. Gill membranes broadly joined. Frenum present. Supratemporal and infraorbital canals complete. Scales absent from cheeks, breast, prepectoral area, and much of belly; opercles scaled, nape fully scaled (Alabama River) to partially naked (Tombigbee River). The rock darter has the appearance of a dimunitive *E. blennioides*. Background color brown to olivaceous green in life, with six dark dorsal saddles and six to nine dark marks along sides, a dark suborbital bar and prepectoral spot, and a pair of median dark spots at the caudal base. Caudal fin with vertical row of three dark bars. Pectoral fins with about five vertical marks formed from dark spots on rays. Anal and pelvic fins often unpigmented, but may have dark marks in larger individuals. Spinous dorsal fin with dark pigment near margin, dark spots at base, and a cluster of melanophores at middle of each spine. Soft dorsal fin with about three horizontal rows of dark spots centered on rays. In nuptial males the normally W- or V-shaped lateral blotches intensify to form green vertical bars, the body darkens, and bright green develops on the distal third of the spinous dorsal, distal half of the soft dorsal, dorsal and ventral edges of the caudal, much of the anal, and lower half of the pectoral fins. Nuptial tubercles are absent.

Biology: The rock darter is an inhabitant of swift rocky riffles and is often associated with attached vegetation such as *Podostemum*. Tsai (1968b) indicated an April to



Range Map 240. *Etheostoma rupestre*, rock darter.

May breeding season. Larger series in our collection indicate that lengths of about 40 mm are reached at age 1 and that life span may be at least three years. Other aspects of its biology are unstudied. Maximum total length 84 mm (3.3 in).

Distribution and Status: Widespread throughout the Mobile Basin both above and below the Fall Line. Although not common in the Conasauga River, it is apparently a very tolerant species, as we have often found *rupestre* to be abundant and one of the few darters present in altered habitats such as tailwaters.

Similar Sympatric Species: In the Conasauga River the only other darter with six evenly spaced dorsal saddles is *stigmaeum*, which lacks a frenum, has less-expansive pectoral fins, a more pointed snout, an incomplete lateral line, and blue and red nuptial colors rather than the green of *rupestre*. In other portions of the Mobile Basin *E. rupestre* is sympatric with *E. histrio*, which is a deeper bodied species with dark blotches on the breast, belly, and ventral surface of the head, and with two large dark blotches at the caudal base that typically fuse to cover the entire area; in *rupestre* the ventral portion of the body is immaculate and the two to four basicaudal spots are small. In addition, lateral blotches of *histrio* are in the form of vertical bands rather than V- or W-shaped, and the spinous dorsal fin has a rusty border.

Systematics: Subgenus *Etheostoma*. Bailey and Etnier (1988) included it in the *E. blennioides* species group as hypothesized sister species of *E. histrio*. Tsai (1968b) recognized the Tombigbee population as racially distinct from other Mobile Basin populations based on the presence of larger scales, naked areas on the nape, and modally 38 rather than 39 vertebrae.

Etymology: *rupestre* = living among rocks.

Etheostoma sagitta (Jordan and Swain).

Arrow darter

Characters: Lateral line nearly complete with 50–61 (49–66) pored scales and 59–68 (55–69) scales in lateral series. Dorsal fin with 10–11 (9–11) spines and 13–15 (12–15) soft rays. Anal fin with 2 spines and 10–12 (9–12) soft rays. Pectoral fin rays 14–15 (13–16). Principal caudal fin rays modally 17 (15–18). Gill rakers 10–12, length of longest rakers 1.5 to 2 times their basal width. (Characters above are for *E. s. sagitta*; *E. s. spilotum* is contrasted under Systematics.) Vertebrae 39–40. Branchiostegal rays 6. Gill membranes separate to narrowly joined. Frenum present. Cheeks, opercles, breast, and prepectoral area naked. Nape scaled, belly fully scaled or with naked areas anteriad. Infraorbital canal complete, supratemporal canal occasionally interrupted. Ground color straw yellow to pale greenish. Dorsum with five to seven weak saddles and mottled dorsolateral area. Sides with seven or eight U-shaped blotches which often become indistinct in larger specimens. The pair of distinct caudal spots is characteristic (sometimes fused into one bilobed spot). Spines and membranes of the spinous dorsal fin are variously speckled as are the rays of the soft dorsal and caudal fins. Nuptial males are one of the most splendidly colored fishes. Blue-green pervades most of body. The sides are traversed by scarlet to orange vertical bars which are connected ventrally, at the height of coloration, by an orange belly stripe, and scattered scarlet spots are present. The spinous dorsal fin, which is blue-green centrally, is adorned by a scarlet marginal band; the soft dorsal and caudal fins are speckled with scarlet. The anal fin is blue-green, and vertical green bars develop at the caudal fin base and posterior caudal peduncle. Pelvic fins are black. Females remain pale straw yellow with grayish markings during the breeding season. Males develop nuptial tubercles on the ventral scales from near the pelvic fin base to the caudal fin base.

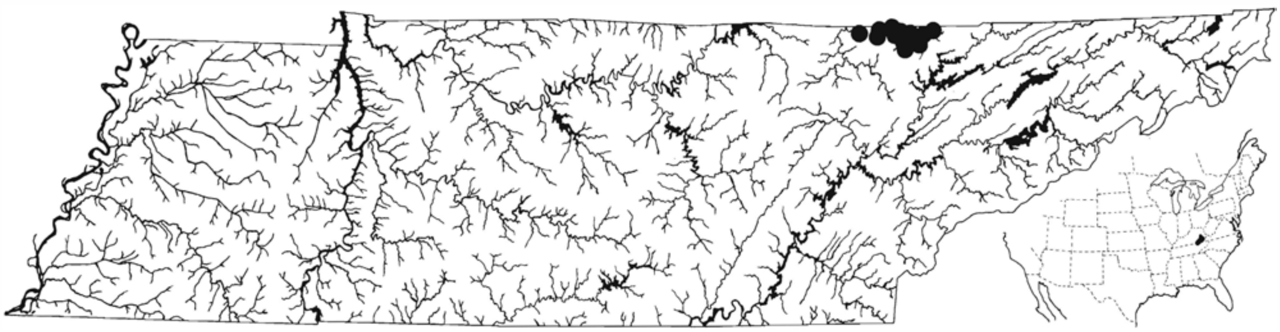
Biology: The arrow darter inhabits mostly smaller streams of the Cumberland Plateau region but is occasionally collected from the main channel of the Cumberland River (in Kentucky). Unaltered, these streams typically have bedrock and rock rubble substrates interspersed with sandy areas. The advent of extensive surface mining in the upper Cumberland region has now introduced considerable silt into many arrow darter habitats. Unaltered streams are generally quite cool (21 C or less), being shaded by dense riparian growth of rhododendron, hemlock, and decidous trees. The arrow darter prefers rocky pool and run areas where current is sluggish to moderate. In dry years, many Plateau streams cease to flow but *E. sagitta* appears to weather these droughts quite easily by persisting in isolated shaded pools. Lowe (1979) studied the biology of the arrow darter. Spawning occurs principally during April when water temperatures are near 13 C. One-year-olds are generally sexually mature and participate in spawning along with older age classes. Females contained 67 to 265 mature eggs. Based on observations in an artificial raceway, spawning occurs beneath or near rocks where males have fanned out a depression in the substrate. The males defend these sites vigorously. Initial courtship behavior involves rapid dashes, fin-flaring, nudging, and quivering motions by the male followed by similar quivering responses of the female who then precedes the male to the nest. The female buries herself partially in the substrate, is mounted by the male, and spawning occurs. Presumably the male continues to defend the nest site at least until the eggs have hatched. Both Lotrich (1973) and Lowe (1979) reported arrow darters grow to about 50 mm TL the first year of life. Lotrich indicated mean length at age 2 of about 65 mm and was unable to differentiate between older fishes (age 3+). Lowe (1979) reported four age classes, but growth was extremely variable after age 1. The diet of *E. sagitta* includes large percentages of mayfly nymphs (heptageniids, baetids), blackfly and midge larvae, and lesser numbers of caddisfly, stonefly, and beetle larvae. Juveniles feed on microcrustaceans and dipteran larvae. Maximum size 100 mm SL (= 116 mm or 4.6 in) reported by Page (1981).

The biology of the arrow darter is generally similar to that reported for the closely related Niangua darter, *E. nianguae*, of southcentral Missouri by Pflieger (1978b). However, the Niangua darter is an inhabitant of larger order streams with predominantly gravel substrates and warm summer temperatures quite different from those inhabited by *E. sagitta*.

Plate 250a. *Etheostoma sagitta*, arrow darter, female, 72 mm SL, upper Cumberland R. system, TN.

Distribution and Status: The arrow darter is strictly an inhabitant of the Cumberland Plateau physiographic province and avoids the adjacent Highland Rim. It occurs both above and below Cumberland Falls in the upper Cumberland River drainage (*E. s. sagitta*) and in tributaries to the upper Kentucky River system of the Ohio River drainage (*E. s. spilotum*). It is also known from eastern tributaries to the Big South Fork of the Cumberland system in Kentucky and Tennessee (Per-

Plate 250b. *Etheostoma sagitta*, arrow darter, male, 83 mm SL, upper Cumberland R. system, TN.



Range Map 241. *Etheostoma sagitta*, arrow darter.

kins Cr., Scott Co.). This occurrence (along with that of *E. kennicotti*) is believed to be the result of stream alterations in the Stearns, Kentucky area (Comiskey and Etnier, 1972). The arrow darter seems moderately tolerant of siltation but has probably been eliminated from a considerable number of habitats by heavy siltation and acid drainage associated with regional surface mining for coal. It is included on Tennessee's list of Species in Need of Management due to its limited range, all of which is in coal producing areas (Starnes and Etnier, 1980).

Similar Sympatric Species: The only darter commonly associated with *E. sagitta* is *E. kennicotti*, which has 8 or fewer dorsal spines and a vertically striped caudal fin.

Systematics: Subgenus *Litocara*, with *E. nianguae* of Missouri. Systematics studied by Bailey (1948) who regarded *E. spilotum* Gilbert as a subspecies (Kentucky R. system) of *E. sagitta*. Possible subspecies origins are discussed by Kuehne and Bailey (1961). The Kentucky River subspecies differs from *E. s. sagitta* in having modally 10 or 11 (versus 10) dorsal spines, modally 13 (versus 14) dorsal soft rays, modally 10 (versus 11) anal fin rays, modally 14 (versus 15) pectoral fin rays, a mean of 56.4 (versus 63) scales in lateral series, and a mean of 46 (versus 58.4) pored lateral-line scales.

Etymology: *sagitta* = arrow.

Etheostoma sanguifluum (Cope).

Bloodfin darter

Characters: Lateral line complete with 53–61 (50–67) scales. Dorsal fin with 12–13 (12–14) spines and 11–13 (11–14) soft rays. Anal fin with 2 spines and 7–9 (7–10) soft rays. Pectoral fin rays 13–14 (13–15). Principal caudal fin rays modally 17 (16–17). Gill rakers 13–14 (10–16), with length of longest rakers 4–5 times their basal width. Vertebrae modally 39 (38–40). Branchiostegal rays 6. Gill membranes narrowly joined. Frenum present. Scales absent from nape, breast, and prepectoral area; opercles and belly scaled, cheeks with a few scales at postorbital spot. Supratemporal and infraorbital canals complete. Background color brown to dark olive. Coloration essentially identical to that described for *E. vulneratum* except fins have pale rather than dark margins, and males have bright orange anal and pelvic fins and pale orange pectoral fins (gray to greenish in *vulneratum*). Females also have yellow to orangish pigment in the anal fin, dark spots on soft dorsal and caudal fins are larger and darker than on *vulneratum* (approaching those of female *rufilineatum*), dark anal fin pigmentation is identical with that of the soft dorsal and caudal fins, and paired fins are spotted rather than shaded with gray pigment. Oblique vertical dark bars on the sides are more often apparent in *sanguifluum* than in *vulneratum*, but are identical in appearance with those described for the latter.

Biology: The bloodfin darter occurs from rivers to medium sized creeks and is typically encountered in swift to moderate riffles with boulder to coarse gravel substrates. Preferred habitats appear to be somewhat swifter and shallower than those described for *vulneratum*. In our larger May and June collections 1-year-old fish are 35–45 mm TL and sexually dimorphic, and it seems likely that at least some of these would have spawned that summer. Additional size groups are less apparent, but it appears that at least two are present, and the largest individuals may represent specimens 4 years old. These data are similar to the more refined age and growth data for *E. maculatum* (Raney and Lachner, 1939), but they found no indication of sexual maturity at age 1. The bloodfin's biology has not been studied but is presumably similar to that of *E. vulneratum*. Maximum total length 89 mm (3.5 in).

Distribution and Status: Confined to the Cumberland River drainage from the Rockcastle River, Kentucky, downstream through the Caney Fork system in middle Tennessee. The bloodfin occurs in streams slightly smaller than those inhabited by other members of the *E. maculatum* species group, is locally abundant, and in spite of its restricted range appears to be less jeopardized than any other member of the species group.

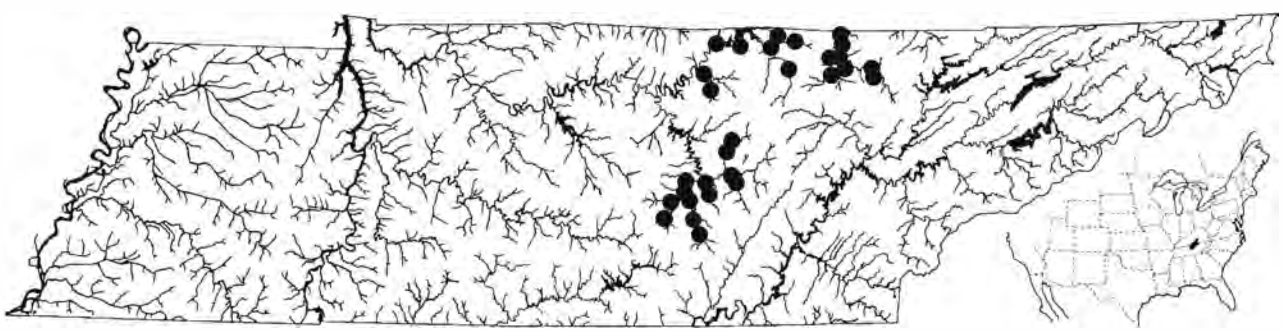
Plate 251a. *Etheostoma sanguifluum*, bloodfin darter, female, 63 mm SL, Barren Fork R., TN.

Similar Sympatric Species: Most similar to *E. rufilineatum*, but lacking the orange lips, dark marginal and pale submarginal bands on median fins, and dark horizontal marks on cheeks and opercles of that species. Juveniles might be confused with *E. tippecanoe*, which has an incomplete lateral line, orange males, prominent dark basicaudal bar and nape saddle, or members of the subgenus *Catonotus*, which have incomplete lateral lines and modally 9 or fewer dorsal spines.

Systematics: A member of the *E. maculatum* species group of the subgenus *Nothonotus*. Zorach and Raney (1967) studied variation and treated *sanguifluum* as a subspecies of *E. maculatum*. Page (1985) treated it as a species and included *E. vulneratum* as a subspecies of *sanguifluum*. Etnier and Williams (1989) recognized both it and *vulneratum* as species and considered *aquali* and *maculatum* as closest relatives of *sanguifluum*.

Etymology: *sangui* = blood, *fluum* = flowing.

Plate 251b. *Etheostoma sanguifluum*, bloodfin darter, male, 68 mm SL, Barren Fork R., TN.



Range Map 242. *Etheostoma sanguifluum*, bloodfin darter.

Etheostoma simoterum (Cope).

Snubnose darter

Characters: Lateral line complete with 45–53 (42–59) scales in *E. s. simoterum* and 50–58 (45–62) scales in *E. s. atripinne*. Dorsal fin with 10–12 (9–13) spines and 10–12 (9–13) soft rays. Anal fin with 2 spines and 6–8 (5–9) soft rays. Pectoral fin rays 13–15 (12–16). Principal caudal fin rays modally 17 (15–18). Gill rakers 7–9, length of longest rakers 1.5–3 times their basal width. Vertebrae modally 39 (38–40). Branchiostegal rays 5 (5–6). Gill membranes broadly joined. Frenum narrow. Scales present on nape, cheeks, opercles, belly, and prepectoral area; breast naked to well scaled. Supratemporal and infraorbital canals complete.

Plate 252a. *Etheostoma simoterum atripinne*, snubnose darter, female, 50 mm SL, Caney Fork R. system, TN.

Plate 252b. *Etheostoma simoterum atripinne*, snubnose darter, male, 57 mm SL, Caney Fork R. system, TN.

Background color of brown to gray, with eight to nine dorsal saddles and 8–11 lateral blotches. A narrow suborbital bar and pair of small, submedian basicaudal spots are present. Both sexes with red ocellus in first membrane of spinous dorsal fin. In females the spinous dorsal fin often has a narrow dark margin and a median row of dark marks on the membranes, some of which may be red or orange. Each spine has two or three dark dashes interrupted by clear areas. Soft dorsal fin may show some brick red on posterior membranes and, like the caudal and pectoral fins, has dark markings on the rays forming three or four bands. Anal and pelvic fins clear or with a few scattered dark marks on rays. A few orange spots may occur on posterior upper sides, and the lower sides may show a trace of yellow or orange. Nuptial males brightly colored. Spinous dorsal fin with red ocellus in first or first and second membrane. In *E. s. simoterum* middle membranes have oblique, brick red dashes or reticulations that merge posteriad to occupy the entire membrane. In *E. s. atripinne* there is a median row of bright red spots in the spinous dorsal fin. Both subspecies have a dusky basal band and may show an orange to brick red margin. Soft dorsal fin with brick red membranes throughout and dark basal band anteriad. Caudal fin with green on upper and lower margins and a pair of orange spots at base. Anal fin dark green, pelvic fins blue-green, pectoral fins dusky. The lower face is green, the breast and prepectoral area are dusky orange, and the entire venter is orange. The upper sides have scattered bright orange to red scales that are more prominent posteriad, and the dark lateral blotches may assume a blue-green color. Much of this color persists throughout the year. Nuptial tubercles do not develop.

Biology: An extremely common and successful species, the snubnose darter occurs from trout streams and

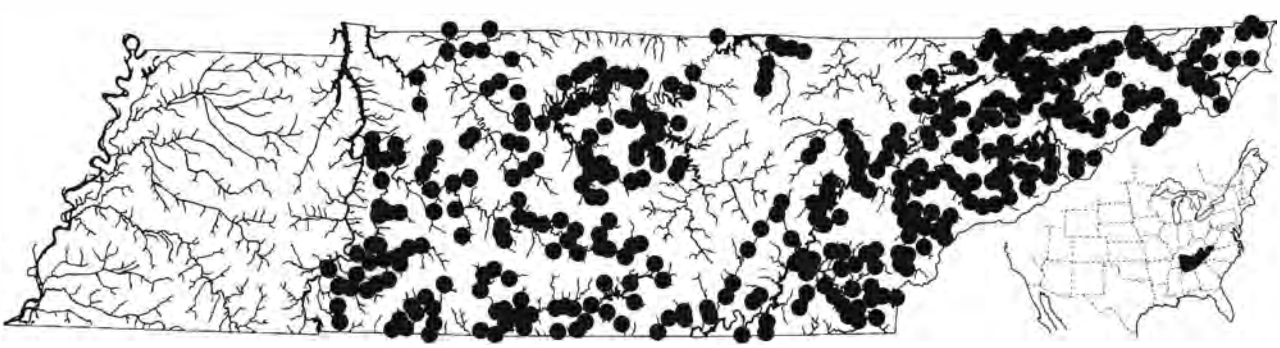
Plate 252c. *Etheostoma simoterum simoterum*, snubnose darter, male, 63 mm SL, Pigeon R. system, TN.

spring runs to low-elevation habitats in gravel-bottom pools and gentle riffle areas of small creeks as well as medium sized rivers. Where it occurs with the very similar *E. duryi* or *E. flavum*, it tends to inhabit the swifter riffles while *duryi* or *flavum* occupy pools and more gentle riffles. Peak spawning occurs from April through early May. Reproductive behavior has been observed for *E. s. simoterum* in natural settings by R. A. Stiles (pers. comm.), and for *E. s. atripinne* by Page and Mayden (1981) in aquaria. Males court females by flashing their dorsal fins, and, although not territorial, are aggressive to other males that approach within 10 cm. Receptive females select the spawning site, typically the side of a large rock, where one or two eggs are deposited per spawning act. The male mounts the female with his paired fins straddling the female's nape region, and both fish have their caudal peduncles near the substrate. Depending on egg deposition site, the spawning pair's position may vary from nearly horizontal to vertical to almost completely inverted. Page and Mayden noted occasional spawning while the female was buried in the substrate, but this may be an artifact of confinement, since Stiles has not noted this behavior in numerous field observations. Breeding is promiscuous, with no pair bonds established, but preferred spawning sites may be utilized by several females or several times by the same female. Page and Mayden's (1981) study on *E. s. atripinne* provides additional information. Females produce 110–240 eggs per year. In the Smith County, Tennessee, population they studied, females averaged 44 and males 49 mm SL at age 1, were sexually mature, and did not survive to age 2 to spawn a second time. This agrees with our data for *E. s. atripinne*, but several large, early spring collections of *E. s. simoterum* from cooler streams clearly contain two age groups, with age 1 fish averaging about 35 (females) and 42 (males) mm SL, and age 2 fish 48 (females) and 55 (males) mm SL. Food of young and adults was primarily midge larvae, supplemented by mayfly nymphs, caddis larvae, and microcrustacea. Maximum total length 76 mm (3 in), or 64 mm SL.

Distribution and Status: A very common species that occurs from the lower Blue Ridge of the upper Tennessee drainage throughout all upland physiographic provinces of both the Tennessee and Cumberland river drainages. It is absent from the Coastal Plain, and does not occur above Cumberland Falls in the Cumberland drainage. Robert Jenkins and Noel Burkhead have provided several recent collections from the upper Ohio River drainage (Bluestone River system, tributary to New River, Tazewell County, Va.; and Big Sandy River system of Dickenson County, Va.). These are typical of *E. s. simoterum*, and their sudden appearance in several localities in each of these systems plus their absence from earlier collections suggest a recent accidental introduction.

Similar Sympatric Species: Juveniles of *blennioides*, *swannanoa*, and *zonale* are somewhat similar, but have only six or seven dorsal saddles versus eight or nine in *simoterum*. The only sympatric *Ulocentra*, *duryi* and *flavum*, have a slightly more produced snout, a single median basicaudal dark spot versus a small spot above and below the midline in *simoterum*, and lack a frenum. In adult males of *simoterum* the pair of basicaudal spots may be obscured, but the presence or absence of a frenum plus details of spinous dorsal fin pigmentation (three or more rows of red spots or vermiculations in *duryi*, concolorous brown to brown and clear in *flavum*) are sufficient for certain identification of most specimens.

Systematics: Subgenus *Ulocentra*. Bailey and Etnier (1988) suggested that the affinities of *simoterum* are with other northern *Ulocentra* (*baileyi*, *barrenense*, *rafinesquei*) which share with it the presence of a frenum and lack prevomerine teeth. Etnier and



Range Map 243. *Etheostoma simoterum*, snubnose darter.

Bouchard (unpublished) recognized *E. atripinne* (Jordan) as being conspecific with *E. simoterum*, but retained *atripinne* as a subspecies occurring in the Cumberland drainage and in the Duck and Buffalo river systems of the Tennessee drainage. A broad area of intergradation extends from above the mouth of Duck River upstream through the Elk River system, with specimens from the Paint Rock System and upstream typical of *E. s. simoterum*. The taxa differ primarily in lateral line scale counts and coloration of the spinous dorsal fin of adult males (see Characters).

Etymology: *simoterum* = snub-nosed; *atripinne* = black fin.

Etheostoma smithi Page and Braasch.

Slabrock darter

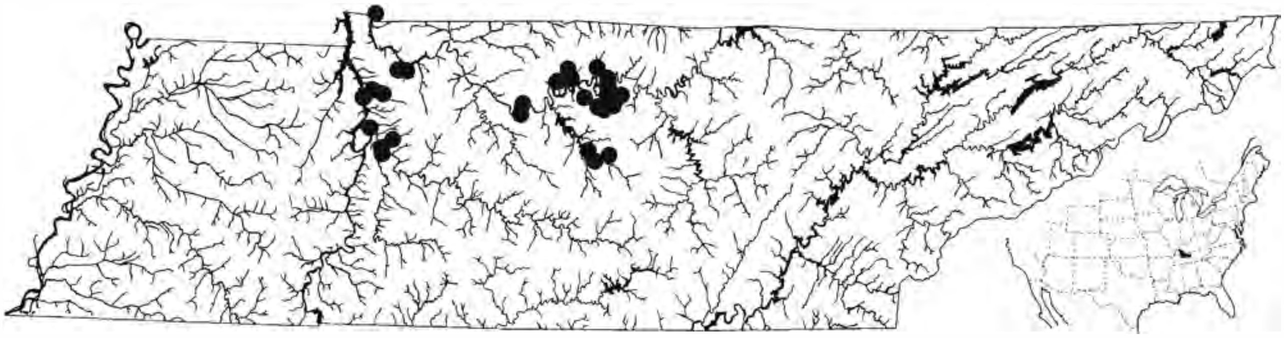
Characters: Lateral line incomplete with 4–11 (2–13) pored scales and 39–54 scales in lateral series. Dorsal fin with 8–9 (7–10) spines and 13–15 (12–15) soft rays. Anal fin with 2 spines and 8–9 (7–11) soft rays. Pectoral fin rays modally 12 (11–13). Principal caudal fin rays modally 16 (13–18). Gill rakers 9–11, length of longest rakers 2–3 times their basal width. Branchiostegal rays 6. Gill membranes separate to narrowly joined. Frenum present. Cheeks, opercles, nape, breast, and prepectoral area naked; belly scaled. Infraorbital and supratemporal canals interrupted. Females, juveniles, and non-breeding males with straw-colored background, an iridescent pale bar on the cheek, about ten lateral blotches that often extend ventrad to the midline on the caudal peduncle, and six to eight dorsal saddles. Spinous dorsal fin with a dark basal blotch anteriad and a red marginal band. Other fins, except pelvics, with some dark reddish pigment that forms dark bands on the soft dorsal, caudal, and pectoral fins, and is restricted to the base of the anal fin. Nuptial males develop black borders on the otherwise red caudal, anal, and pectoral fins, a bright red spinous dorsal fin with a more pronounced dark blotch, black pelvic fins and breast, and small fleshy knobs on tips of dorsal spines (Page and Braasch, 1976; Braasch and Mayden, 1985; plus data from UT specimens). Breeding tubercles are absent.

Plate 253a. *Etheostoma smithi*, slabrock darter, 34 mm SL, East Fork Stones R., TN.

Biology: The slabrock darter is an inhabitant of slabrock pool areas in small to medium streams (Page and Schemske, 1978). Biology was studied by Page and Burr (1976). Males establish territories under slabrocks in April, and spawning occurs from mid-April through June. Fecundity is about 40 (17–69) eggs per female per year, and several females typically contribute to each nest, with eggs attached to the undersurface of the slab-rock in a single layer. Eggs hatched in 12–14 days at 21 C and in 29–31 days at 13 C; larvae averaged 6.7 mm TL at hatching. Lengths of about 30–35 mm SL are reached in 1 year, and most 1-year-olds were sexually mature. Life span is rarely 2 years. The diet consists primarily of midge, mayfly, and caddisfly immatures, with copepods and other microcrustacea more prevalent in the diet of juveniles. Maximum total length 64 mm (2.5 in), with males larger than females.

Distribution and Status: *Etheostoma smithi* is a moderately common species in tributaries to the Cumberland River in the eastern portion of the Nashville Basin

Plate 253b. *Etheostoma smithi*, slabrock darter, breeding male, 40 mm SL, Cumberland R. system, TN.



Range Map 244. *Etheostoma smithi*, slabrock darter.

west to the Nashville area, and to the west in the lower Cumberland drainage from eastern Stewart County, Tennessee, downstream. In the Tennessee River drainage it occurs in eastern tributaries downstream from the mouth of Duck River, and rarely in tributaries to lower Duck River. It apparently has some reservoir tolerance, as it occasionally appears in samples from Barkley Reservoir. Its distribution is largely complimentary to that of other barcheek darters occurring in the Cumberland drainage; *E. virgatum*, for instance, apparently only occurs in the West Fork Stones River but not East Fork where *smithi* does occur and vice versa (see further under *E. virgatum*).

Similar Sympatric Species: Sympatric *Catonotus* (*flabellare*, *crossopterum*, *neopterum*) lack red coloration, have more than 13 pored lateral-line scales, and lack a dark blotch at the anterior base of the spinous dorsal fin. In addition, *flabellare* has broadly connected gill membranes and (where sympatric with *smithi*) dark horizontal lines along the sides; *crossopterum* and *neopterum* are much darker fishes with dark spots at the caudal fin base and scales on the head and breast. *Etheostoma virgatum*, thus far not syntopic with *smithi*, occupying the portion of the middle Cumberland drainage where *smithi* is absent, has conspicuous rows of dark horizontal lines along the sides.

Systematics: A member of the *E. virgatum*, or barcheek, species group of the subgenus *Catonotus*. Hypothesized to be sister species to *E. barbouri* (Braasch and Mayden, 1985). Previously thought to be most closely related to *E. obeyense* (Page and Braasch, 1976).

Etymology: *smithi* is a patronym for Dr. Philip W. Smith, for many years a prominent vertebrate zoologist with the Illinois Natural History Survey.

Etheostoma spectabile (Agassiz).

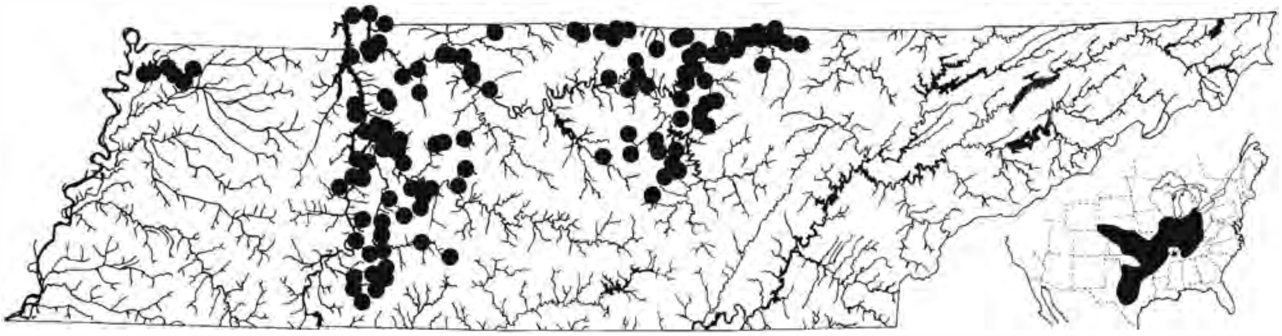
Orangethroat darter

Characters: Information is from *E. s. spectabile* populations east of the Mississippi River from our data and Distler (1968). Comments concerning other subspecies, all of which occur west of the Mississippi River, and western populations of *E. s. spectabile*, appear under Systematics. Lateral line incomplete with 17–31 (10–38) pored scales and 35–47 (30–52) scales in lateral series. Dorsal fin with 9–10 (8–12) spines and 12–14 (11–15) soft rays. Anal fin with 2 spines and 6–8 (4–8) soft rays. Pectoral fin rays 11–13 (11–14). Principal caudal fin rays 14–16 (14–17). Gill rakers 8–12, length of longest rakers 2–3 times their basal width. Vertebrae modally 36 (35–37). Branchiostegal rays 6. Gill membranes narrowly joined. Frenum present. Nape, opercles, and belly scaled. Cheek with at least a few scales posterior to eye. Breast and prepectoral area naked or with a few scales. Supratemporal canal complete. Infraorbital canal interrupted under eye, rarely complete. Background color tan, with about eight irregular dorsal saddles often apparent and with about eight lateral blotches that form oblique vertical bars from the anal fin origin posteriad. Faint brown horizontal lines are usually apparent on the upper sides. A suborbital bar is present, and the three fused dark blotches at the caudal base often form a trident-shaped mark. Females have orange on branchiostegal membranes during much of the year, especially during or near the breeding season. The spinous dorsal fin has a gray to pale blue margin, may show a red median band, and has gray pigment at its base. Soft dorsal fin with dark dashes on rays, dusky pigment on membranes near base of fin may extend to near margin, and the margin is usually clear. Caudal fin with dark marks on rays forming four or five irregular vertical bands. Other fins typically lacking pigment. Spinous dorsal fin of nuptial males with marginal third dark blue, this band confluent with the dark red basal band posteriad, but separated from the basal band by a clear band on the anterior three-fourths of the fin. Soft dorsal fin with narrow blue marginal and clear submarginal band, a broad median and narrow basal red band, and a dark blue band separating the two red bands. Caudal fin with uniformly dark rays, clear to reddish membranes, green at the upper and lower base, and a pair of orange to red spots between the tines of the dark trident mark. Anal fin blue-green, rarely with some red near base. Pectoral fins with dark rays and clear to yellowish membranes. Suborbital region and lower caudal peduncle blue-green, with the belly white to blue-green. Branchiostegal membranes bright red-orange, shading to yellow-orange on operculum and posterior cheek. Breast and gular region white to dusky. Oblique bars on sides blue-green, with orange to bright red interspaces, especially posteriad. Tubercles develop on the anal fin rays and on scales along the anal fin base and lower caudal peduncle. Tubercles may also appear on the lower surface of the pelvic fin rays, and the ventral rays of the caudal and pectoral fins.

Biology: The orangethroat darter is an inhabitant of small to medium upland streams where it frequents moderate to sluggish flowing, gravel-bottomed runs and pools. It also frequents the slower waters near the margins of riffles. Where *E. spectabile* occurs with the very similar rainbow darter, *E. caeruleum*, the latter tends to be more common in areas with overall faster current. The orangethroat darter also shows a preference for spring habitats in some areas, apparently being physiologically adaptable to stable thermal conditions (Hill and Matthews, 1980). However, throughout a considerable portion of its range in Tennessee, this niche may be filled by another closely related species, *E. luteovinctum*. Spawning behavior approximates that of the rainbow darter with males moving into riffles and defending territories; however, the orangethroat generally spawns in slower portions of the riffle over finer gravel (Winn, 1958a,b). The season is slightly earlier than that of *E. caeruleum*, beginning in mid-March (see comments under *E. caeruleum* regarding hybridization). Gravid female *E. spectabile* were reported to contain 300–1,200 eggs by Small (1975) but only 20–250 by Hubbs et al. (1968). Eggs are tolerant of a wide range of temperature with good hatching success from 10 to 27 C (Hubbs, 1961). At 17–18 C, hatching requires 9–10 days. After hatching, larvae have been noted to move to and occupy the nests of smallmouth bass (Pflieger, 1966), where they presumably are afforded some protection against small predators and where microcrustacean food items were found to be more abundant. A number of studies have been conducted on various aspects of the orangethroat darter's reproduction (Hubbs, 1958, 1961; Hubbs and Armstrong, 1962; Hubbs et al., 1968). Small (1975), studying a Kentucky population, reported young growing to about 45 mm TL the first year, with lengths of 60–70 mm attained the second year. Spring collections examined by us contain three apparent age classes ranging 30–35, 49–55 and

Plate 254a. *Etheostoma spectabile*, orangethroat darter, female, 43 mm SL, Barren R. system, TN.

Plate 254b. *Etheostoma spectabile*, orangethroat darter, breeding male, 60 mm SL, Barren R. system, TN.



Range Map 245. *Etheostoma spectabile*, orangethroat darter.

60+ mm TL, respectively. Sexual maturity occurs at age 1, at sizes as small as 30 mm SL or slightly smaller. The diet of *E. spectabile* consists of midge and blackfly larvae, mayfly nymphs (*Baetis*, *Stenonema*), isopods, amphipods, and caddisfly larvae (Cross, 1967; Small, 1975). Feeding behavior is, surprisingly, highly similar to that of the similar rainbow darter, *E. caeruleum*, which is often syntopic (Vogt and Coon, 1990). Maximum total length 74 mm (2.9 in), but usually much smaller.

Distribution and Status: Widespread and abundant west of the Mississippi River from southern Nebraska and Iowa south to Texas. East of the Mississippi River the orangethroat occurs throughout Illinois, much of the Ohio River drainage from eastern Kentucky downstream, southern Great Lakes tributaries in Ohio and southern Michigan, the Cumberland drainage below Cumberland Falls, and in the lower Tennessee drainage upstream to the Pickwick Reservoir area. In Tennessee, it is most abundant in streams of the northern and western Highland Rim. Isolated populations occur in streams draining bluffs (Jackson Formation) along the Mississippi River in the vicinity of Reelfoot Lake.

Similar Sympatric Species: Often sympatric and easily confused with *E. caeruleum*. In life colors *caeruleum* males have red in the anal fin (rarely present in *spectabile*) and lack any indication of horizontal lines on the upper sides in Tennessee populations. Since both of these species are often common, modal values of pectoral fin rays (12 in *spectabile*, 13 in *caeruleum*) are useful, but about 25% of eastern *spectabile* have 13 rays. Better separation is provided by counts of caudal fin rays, with only 1 of 115 eastern *spectabile* having 17 principal caudal rays (branched rays plus 2) (usually 15–16); in *caeruleum* 60–70% of specimens have 17. This character also applies to the western subspecies *E. s. pulchellum* and *E. s. squamosum*; we have not examined specimens of the additional subspecies, *fragi* and *uniporum*. Other characters are included in the key. We have not taken *spectabile* with *luteovinctum*, but the two are potentially sympatric in the upper Stones and upper Caney Fork river systems. In *luteovinctum* the throat is never orange, scales in lateral series are 50 or more (rarely as few as 46), there are no horizontal brown lines on the upper sides, and scales are more abundant and conspicuous on the cheeks, breast, and prepectoral area.

Systematics: Subgenus *Oligocephalus*. Distler (1968) recognized five subspecies. The nominate subspecies is the only one east of the Mississippi River, and it also occurs in Iowa (extirpated), much of Missouri, east-central Kansas, and the White River system of northern Arkansas. *Etheostoma s. uniporum*, with a single pore in the posterior segment of the infraorbital canal and an interrupted supratemporal canal, and *E. s. fragi*, which lacks breeding tubercles and has a red gular region in nuptial males, both have a restricted range in the Black River system of northeastern Arkansas and southeastern Missouri. To the west, *E. s. pulchellum*, with mean lateral scale series counts of 48 or more and few if any scales on the nape, cheeks, opercles, breast, or prepectoral region, is widespread from southern Nebraska through most of Kansas (except Osage River system), westcentral Missouri in Missouri River tributaries above the Osage River, Oklahoma except for the northeast corner, Arkansas River tributaries of central Arkansas, and Texas. *Etheostoma s. squamosum* also has mean lateral scale series counts of 48 or more and is typically scaled on areas naked in *pulchellum*; it occurs in the Grand and Illinois river systems in a restricted four-state range immediately adjacent to the shared borders of Oklahoma, Kansas, Missouri, and Arkansas. The electrophoretic studies of Wiseman et al. (1978) largely supported Distler's findings. Ceas and Page (1989) indicated that variation east of the Mississippi River is also considerable, and that several subspecies may eventually be recognized in what Distler (1968) considered to be the range of the nominate subspecies.

Etymology: *spectabile* = conspicuous.

Etheostoma squamiceps Jordan.

Spottail darter

Plate 255a. *Etheostoma squamiceps*, spottail darter, female, 37 mm SL, Red R. system, TN.

Plate 255b. *Etheostoma squamiceps*, spottail darter, breeding male, 61 mm SL, Red R. system, TN.

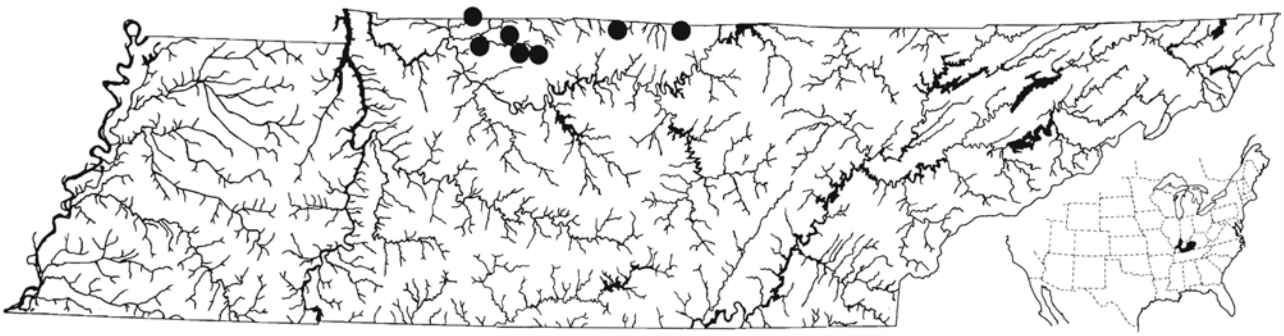
Characters: Lateral line incomplete with 12–51 pored scales and 41–60 scales in lateral series. Dorsal fin with 8–9 (7–11) spines and 12–15 (modally 13) soft rays. Anal fin with 2 spines and 7–8 (6–9) soft rays. Pectoral fin rays 11 (10–12). Principal caudal fin rays 15–17 (14–19). Gill rakers 8–10, longest rakers 1-2 times their basal width. Branchiostegal rays 6. Gill membranes slightly joined. Frenum present. Cephalic sensory system with incomplete infraorbital and supratemporal canals. Scales present on cheeks, opercles, nape, breast, belly, and prepectoral area. Coloration of females and non-nuptial males essentially identical to that of *crossopterum*, *neopterum*, and *nigripinne*. Ground color tan, sides mottled, dorsum pale with eight or nine dark saddles often present. Three basicaudal spots, a humeral spot, and a subocular bar usually present; cheek area usually with additional dark mottling. Spinous dorsal fin with basal and submarginal dusky bands. Soft dorsal, caudal, and pectoral fins with dark speckles or bands. Breeding males darken, especially on their swollen head, and dark bars may be present laterally. Spinous dorsal fin black with pale knobs at tips of spines, clear spots submarginally, and a clear band basally. Soft dorsal fin black with a marginal pale band and four to six rows of small, pale crescents in the membrane medially. Soft dorsal fin rays extend well past membranes and have elongate swellings at their tips. Breeding tubercles are lacking.

Biology: The spottail darter is a resident of small, upland streams in gentle riffles and pool areas with slabrock rubble substrates. The biology was studied in detail by Page (1974b) and is essentially identical to that reported under *E. crossopterum* herein. Egg-mimicking by males during spawning is also probably important in this species (Bart and Page, 1991). Simon (1985a) studied early development; larvae are 5–6 mm TL at hatching and transform to juveniles at about 14–15 mm. Maximum total length 95 mm (3.75 in), with males reaching larger sizes than females.

Distribution and Status: The spottail darter occurs in the northern Highland Rim (Interior Low Plateau) region of southern Illinois and Indiana, Kentucky, and northcentral Tennessee where it occurs in tributaries to the Ohio and Cumberland rivers. As construed by Braasch and Mayden (1985), Tennessee distribution is restricted to a few tributaries of the Barren River (Ohio River drainage) and the Red River portion of the Cumberland drainage, with the remainder of the Cumberland inhabited by other members of the complex. It is not common in collections from Tennessee.

Similar Sympatric Species: Occurs with *E. flabellare* and *E. kennicotti* in portions of its range; see *E. crossopterum*, as characters listed for separating it from these two species will also suffice for the virtually identical *E. squamiceps*. Occurs with the "barcheek darters" *E. barbouri* and *E. virgatum* (subgenus *Catonotus*) in the Barren and Red river systems, respectively, and differs from these in lacking the pale, oblique bar on the cheek characteristic of the barcheeks.

Systematics: Member of the *E. squamiceps* complex of the subgenus *Catonotus*. This group, which occurs throughout much of the lower Ohio, Cumberland, and lower Tennessee river drainages, chiefly in the Highland Rim, has been under scrutiny by several workers in recent years. Braasch and Mayden (1985) offered a full revision of the complex, and described southern populations of what had previously been regarded as *squamiceps* as two new species, *E. crossopterum* and *E. nigripinne* (see those accounts). Page et al. (1992) consider the form restricted to Cypress Creek in Alabama and Tennessee (see *Etheostoma* sp, "crown darter") as a



Range Map 246. *Etheostoma squamiceps*, spottail darter.

valid species. Primary diagnostic characters of these four species are developed only on breeding males, making comparisons difficult. Considerable work remains to be done in areas of potential intergradation or introgression between the three taxa before their status can be resolved with full confidence. Braasch and Mayden hypothesized *squamiceps* and *neopterum* to be sister species.

Etymology: *squami* = scales, *ceps* = head, in reference to the scaly cheeks and opercles.

Etheostoma stigmaeum (Jordan).

Speckled darter

Plate 256a. *Etheostoma stigmaeum jessiae*, speckled darter, female, 43 mm SL, Little R., TN.

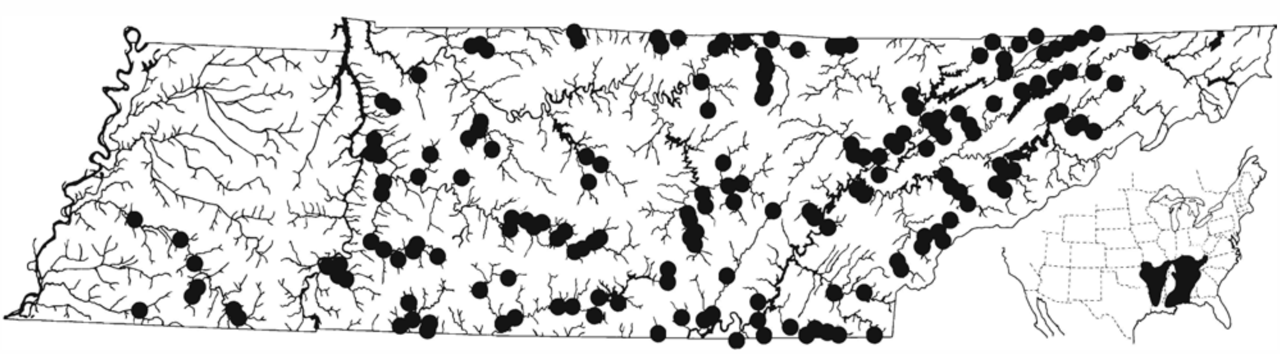
Characters: Lateral line complete or incomplete, with 20–55 pored scales and 39–67 scales in lateral series. Dorsal fin with 9–14 spines and 9–14 soft rays. Anal fin with 2 spines and 7–10 soft rays. Pectoral fin rays 12–16. (See Systematics for counts for each of the five included taxa.) Principal caudal fin rays 14–17. Gill rakers 8–10, with length of longest rakers 1–1.5 times their basal width. Vertebrae 38–42. Branchiostegal rays 6. Gill membranes separate to narrowly joined. Frenum broad to absent. Cephalic sensory system typically complete. Belly and opercles scaled, breast naked, nape and cheek fully scaled to mostly naked. Coloration of females and non-breeding males tan on upper sides with dark brown mottlings in the form of six dorsal saddles (often constricted on the midline and hour-glass shaped), a basicaudal spot, and pre-, post-, and suborbital spots or bars. The series of about nine brown midlateral blotches is mostly below the lateral line, and isolated brown X-, W-, or M-shaped marks occur between lower ends of blotches. In nuptial males the lateral blotches become vertical blue to turquoise bars, and this color is present on the base of the anal fin, the side of the head, and often in the basal and marginal dark bands of the spinous dorsal fin. The median red band of the spinous dorsal fin is separated from the

Plate 256b. *Etheostoma stigmaeum stigmaeum*, speckled darter, 50 mm SL, Conasauga R., TN.

black, blue, or turquoise basal and marginal bands by narrow clear bands, and red spots (occasionally forming a basal red band) are often evident at the extreme bases of the spines. Pelvic fins are black. Remaining fins are dusky, often with blue or turquoise, and in some forms elongate orange spots occur on the fin rays. Orange spots may also occur on the upper and lower sides. Males develop nuptial tubercles on rays of the anal and pelvic fins and on scales of the lower sides. Nuptial females lack conspicuous bright colors and have an elongate, tubular urogenital papilla. Palatine teeth, reported as present by W. Howell (1968) but as absent by Page (1983a) are present in the nominal species *jessiae*, *meadiae*, and *stigmaeum*, but were not seen in the Caney Fork form (see Systematics below). We have not seen specimens of the *jessiae*-like form from Stones River.

Biology: In all members of the *E. stigmaeum* complex, habitats are silty sand to fine gravel substrates in sluggish to moderate current. During late March through April adults congregate on areas with coarser substrates and swifter current where spawning occurs. Eggs are buried shallowly in the substrate during a typical darter embrace, in which the male straddles the nape region of the female with his pelvic fins while flexing his caudal peduncle downward to approximate their urogenital papillae (Winn, 1958a,b). O'Neil (1980) provided additional information for an Alabama population of *E. s. stigmaeum*, where both sexes reached about 35 mm SL at age 1, with larger 1-year-olds sexually mature. Spawning was dominated by 2-year-olds, with males and females averaging 41 and 38 mm SL, respectively. He estimated mean fecundity of about 300 eggs for age 1 and age 2 females combined, and up to 440 eggs per 2-year-old female. Few individuals lived to age 3. Food was dominated by midge larvae (58%), supplemented with microcrustacea and mayfly nymphs. Maximum TL (*E. s. jessiae*) 77 mm (3 in), with other members of the complex (except the Stones River form) considerably smaller.

Distribution and Status: The three nominal taxa in this complex (*stigmaeum*, *jessiae*, *meadiae*) are moderately common in good quality streams and rivers, but may suffer from habitat alteration more than other common darters (Etnier, 1972). The two undescribed forms are rare and have very limited distributions. *Etheostoma s. stigmaeum* occurs in Gulf Coast drainages from Pensacola Bay, Alabama and western Florida, west through the Sabine River drainage of western Louisiana. It extends north in the Ozarks to the Arkansas and White river systems in southwestern Missouri. East of the Mississippi River, *E. s. stigmaeum* occurs in the Barren and Green river systems of the Ohio River drainage, the Cumberland drainage (excluding the Caney Fork) upstream through Big South Fork, the Hatchie River system, Tennessee, and several other direct tributaries to the Mississippi River in Mississippi, and in the Tennessee River drainage in Clarks River and Jonathan Creek in western Kentucky, the Duck and Buffalo river systems of Tennessee, and Bear Creek, Alabama. *Etheostoma s. jessiae* occupies the remainder of the Tennessee drainage (excluding upper Clinch and Powell rivers) from Whiteoak Creek, Humphreys County, Tenn., upstream into North Carolina in the French Broad River system and into Virginia in the North Fork Holston River system. *Etheostoma s. meadiae* occurs in the Clinch and Powell river systems above Norris Reservoir in Tennessee and Virginia. Caney Fork River of the Cumberland drainage is inhabited by a distinctive undescribed form allied to *E. s. stigmaeum*. It is restricted to larger Caney Fork tributaries above Center Hill and Great Falls reservoirs, and is included in Tennessee's Rare Wildlife (Starnes and Etnier, 1980). An additional form, similar to *E. s. jessiae* and perhaps extinct, is known from a single 1963 collection of 30 specimens (Cornell Univ. 46558) from Stones River



Range Map 247. *Etheostoma stigmaeum*, speckled darter.

below the dam at Walter Hill, 6.5 miles north of Murfreesboro, Rutherford County, Tenn. where it was sympatric with *E. s. stigmaeum*.

Similar Sympatric Species: Members of the subgenus *Etheostoma* with six dorsal saddles (*blennioides*, *lynceum*, *swannanoa*, *zonale*) have broadly connected gill membranes. Most similar to and formerly placed in the same subgenus with both *E. chlorosoma* and *E. nigrum,* but differing from both in having bright breeding colors and 2 (versus 1) anal spines. Further differing from sympatric *chlorosoma* in having preorbital bars that are not continuous around the snout and in lacking the complete covering of exposed ctenoid scales on the cheek of that species. Further differing from sympatric *nigrum* in its complete head canals, scalier nape, and (females) tubular rather than biloped urogenital papilla.

Systematics: Subgenus *Doration*. No group of darters is taxonomically so poorly understood. Until about 1970 most authorities used the single name, *stigmaeum*, for members of the complex. The unpublished dissertation by W. M. Howell (1968) includes discussion of three subspecies—*stigmaeum*, *jessiae* (Jordan and Brayton), and the undescribed form of the Caney Fork River system of the Cumberland drainage. Examination of additional material from the upper Clinch and Powell rivers later convinced Howell that these specimens, which in his dissertation were treated as *stigmaeum* X *jessiae* intergrades, warranted a name, for which *meadiae* (Jordan and Evermann) was available. This reassessment coupled with consideration of the former sympatry of *jessiae* and *stigmaeum* forms in the lower Stones River resulted in Howell's (pers. comm.) impression that all taxa in the group should, with some reservation, be treated as species. Bailey et al. (1970) and Robins et al. (1980) treated *jessiae* and *stigmaeum* as species, while Howell (1980) considered all five forms as species. Examination of 1,000 or so additional specimens from our collection, many from areas where specimens were not available to Howell, indicates that at present a conservative treatment of the group approximating Howell's original conclusions is in order, as follows:

We consider *E. s. meadiae* of the Clinch and Powell rivers above Norris Reservoir as warranting only subspecies or racial status. It differs from *E. s. jessiae* in having a noticeably shorter snout (less than 8.3% of SL), a frenum in only about half the specimens (94% with frenum in *jessiae*), fewer scales in lateral series (43–51, mean 47 vs. 46–56, mean 50 or more in *jessiae*), a more complete lateral line (0–10 unpored, mean about 5 vs. usually 5 or more unpored, mean about 8 in *jessiae*), modally 11 (9–13) vs. 12 dorsal fin soft rays, modally 8 (7–10) vs. 9 anal fin soft rays, and modally 14 (13–16) vs. 15 pectoral fin rays. It is less likely to have orange spots on fins of nuptial males than is *jessiae*, and maximum size is typically less than 50 mm SL (more than 50 mm in *jessiae*). Pored lateral-line scales 38–49 (32–55). Dorsal spines modally 12 (11–13). Tributaries to Norris Reservoir and Clinch River below Norris Dam (including Obed River) contain apparent intergrades with *jessiae*, but the possibility that these represent populations of introgressed hybrids between two species cannot be fully discounted.

Etheostoma s. jessiae, differentiated from *meadiae* above, differs from *s. stigmaeum* in having a longer snout (8.3% of SL or more vs. less than 8% in *s. stigmaeum*), a frenum (98% of *s. stigmaeum* lack a frenum), a more complete lateral line (usually 36–50, range 25–55, pored scales in *jessiae* vs. 27–38 pored scales in most *s. stigmaeum* populations), modally 12–13 (10–14) vs. 11 dorsal fin soft rays, modally 9 (8–10) vs. 8 anal fin soft rays, and modally 15 (13–16) vs. 14 pectoral fin rays. Scales in lateral series 46–52 (42–58). Dorsal spines modally 12–13 (10–14). Pectoral fin rays modally 14 in Little Tennessee River system. Nuptial males have elongate orange spots on rays of the soft dorsal, caudal, and pectoral fins that are typically absent in *s. stigmaeum*, and *s. stigmaeum* rarely exceeds 45 mm SL while adult male *jessiae* are typically 50 mm SL or larger. In most characters that are diagnostic between *jessiae* and *stigmaeum*, *meadiae* has *jessiae* characters or is intermediate (frenum, snout length, maximum size). This, coupled with earlier theories concerning a major stream piracy between the Cumberland drainage and Powell River of the Tennessee drainage (discounted by Starnes and Etnier, 1986), certainly influenced Howell's originally identifying *meadiae* as *stigmaeum* x *jessiae* intergrades.

What appear to be actual intergrades between *stigmaeum* and *jessiae*, from the Bear Creek system in Alabama, were discussed in W. M. Howell's (1968) dissertation. Duck-Buffalo River system specimens visually appear to be *s. stigmaeum*, and the five specimens available to Howell were identified as such. We have examined 46 additional specimens from this system. They have the *jessiae* characters of higher modal fin counts (12 or 13 dorsal fin spines, 11 or 12 dorsal fin soft rays, 9 anal fin rays, 15 pectoral fin rays) and 15% (7 of 46) have a frenum. These may represent an additional intergrade population, resulting from a past invasion of *s. stigmaeum* from the adjacent Cumberland drainage. A different approach is to consider *stigmaeum* and *jessiae* as valid species in which past episodes of introgressive hybridization have resulted in changes of some characters, presumably of near neutral selective value (fin ray counts, presence or absence of a narrow frenum), toward those of *jessiae*, with *stigmaeum* "continuing to evolve separately from others (*jessiae*) and with its own unitary evolutionary role and tendencies" (Simpson, 1961). Either of these views is supported by the number of fish taxa exclusively shared (*Etheostoma luteovinctum*, *E. simoterum atripinne*) or virtually so (*Nocomis effusus*, *Fundulus julisia*, *Etheostoma flavum*, *E. virgatum* species group) by the Cumberland drainage and the Duck-Buffalo system of the Tennessee drainage. The possibility that an *E. s. stigmaeum* form evolved independently in the Duck-Buffalo system seems less likely. Indian Creek, Hardin County, contains the only known population between Duck River and Bear Creek. The 17 available specimens are typical of *jessiae* in all characters, except 7 of 17 lack a frenum. The single specimen from Whiteoak Creek (downstream from Duck River, Humphreys Co.) is typical of *jessiae* in all characters, while those from Clarks River (near mouth of Tennessee River) are typical of *s. stigmaeum* in all characters.

Etheostoma s. stigmaeum has the lateral line incomplete with 24–39 (21–46) pored scales and 42–55 (39–58) scales in lateral series. Dorsal fin with modally 11 (10–13) spines and 11 (10–13) soft rays over much of range. Dorsal spines are modally 12 in Ozark region and Cumberland River drainage, modally 12–13 (10–14) in Green River system. Anal fin with 2 spines and modally 8 (6–10) soft rays, but modally 8–9 in Green system and Cumberland drainage. Pectoral fin rays modally 14 (12–15).

The undescribed form from upper Caney Fork River differs from *E. s. stigmaeum* in having fully scaled cheeks, modally 15 (13–15) pectoral fin rays (vs. 14), and a mean of 45 pored lateral-line scales (vs. about 31). Lateral line complete or nearly so with 40–50 (37–50) pored scales and 42–50 (40–51) scales in lateral series. Dorsal fin with modally 11 (10–13) spines and 11 (10–12) soft rays. Anal fin with 2 spines and modally 8 (8–9) soft rays. Although it may prove to warrant species status, it certainly differs less from *s. stigmaeum* than does *jessiae*.

The problematic *jessiae* form from Stones River (see Distribution and Status) further complicates matters. Typical *s. stigmaeum* persists in the Stones, but it is not common. Thus, at least until 1963, both *jessiae* and *s. stigmaeum* forms occurred there in sympatry with no suggestion of introgressive hybridization or intergradation. It occurred to us (as it did to Howell) that these might have been Tennessee River *jessiae* whose locality information had been confused. This can not be the case, as the collectors recalled taking the specimens when questioned by Howell, and the high counts of scales in lateral series (mean 57.4) are not duplicated in any Tennessee River *jessiae* populations. Lateral line incomplete with a mean of 42 (33–50) pored scales and 53–67 scales in lateral series. Dorsal fin with modally 12 (11–13) spines and 12 (11–13) soft rays. Anal fin with 2 spines and modally 9 (8–10) soft rays. Pectoral fin rays modally 15 (14–15).

The *stigmaeum* complex thus consists of from one to five species. Evidence currently available suggests that where different forms come into contact they may behave more like subspecies than species, with Stones River providing the single exception. A less equivocal assessment awaits examination of additional characters. Color pattern of nuptial males, according to Howell (in litt.) may be important but, unfortunately, he had access to little fresh material from potential problem areas. Collectors are urged to record color notes from adult males, especially extent of orange spotting on fins, during the months of March through May. A thorough electrophoretic analysis of the complex might be rewarding. Following is a key, adapted from W. M. Howell (1968 and in litt.), suggestions from S. R. Layman, who is studying systematics of the group, and our data, which attempts to emphasize the important taxonomic characters in the group.

KEY TO THE TAXA OF THE *Etheostoma stigmaeum* COMPLEX

1. Frenum usually well developed, groove not continuous around snout; nuptial males with bright orange spots on rays of soft dorsal, caudal, and pectoral fins, and face and underside of head gray; snout long and pointed (8.3–9.6% of SL); dorsal fin soft rays modally 12; anal fin soft rays modally 9; maximum SL often 50 mm or larger 2
   Frenum often to usually absent (at least a shallow groove continuous around snout); nuptial males lacking orange spots on rays of soft dorsal, caudal, and pectoral fins, or if bright orange spots present, face and underside of head orange; snout short and rounded (6.5–8.2% of SL); dorsal fin soft rays modally 11; anal fin soft rays modally 8; maximum SL less than 50 mm 3
2. Scales in lateral series with mean of 53 or fewer . . . . *jessiae*
   Scales in lateral series with mean about 57 . . . . Stones River form
3. Cheek well scaled; lateral line nearly complete; modally 15 pectoral fin rays . . . . Caney Fork form
   Cheek with about 0–10 scales confined to area behind eye; lateral line variable; modally 14 pectoral fin rays 4
4. Lateral line with 10 or fewer (range 0–13) unpored scales; frenum present in about 50% of specimens; modally 12 dorsal fin spines . . . . *meadiae*
   Lateral line with 11 or more (range 9–25) unpored scales; frenum present in less than 10% of specimens; modally 11 dorsal fin spines . . . . *stigmaeum*

Etymology: *stigmaeum* = speckled; *jessiae* and *meadiae* are, respectively, named in honor of Mrs. A. W. (Jessie) Brayton and Mrs. B. W. (Meadie) Evermann.

Etheostoma striatulum Page and Braasch.

Striated darter

Plate 257a. *Etheostoma striatulum*, striated darter, 40 mm SL, Duck R. system, TN.

Characters: Lateral line incomplete with 5–16 (2–18) pored scales and 40–46 (38–50) scales in lateral series. Dorsal fin with 8–9 spines and 13–14 (12–14) soft rays. Anal fin with 2 spines and 8–9 (7–10) soft rays. Pectoral fin rays 11–12 (10–12). Principal caudal fin rays 15–16 (14–17). Gill rakers 9–12, length of longest rakers about twice their basal width. Branchiostegal rays 6. Gill membranes separate. Frenum present. Infraorbital and supratemporal canals interrupted. Scales absent from cheeks, opercles, nape, breast, and prepectoral area; belly scaled. Both sexes with faint horizontal lines on sides formed from dark pigment on middle of exposed portion of scales, an iridescent pale bar on cheek, dark blotch at base of anterior dorsal spines, six to seven dorsal saddles, a weak suborbital bar, prominent dark humeral spot, and body background color of straw yellow with about eight darker marks midlaterally. Nuptial males with median fins red; anal, pec-

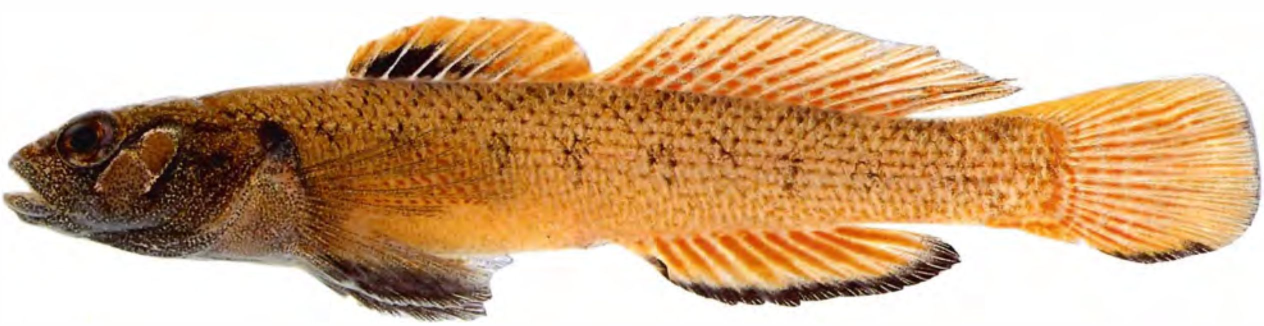
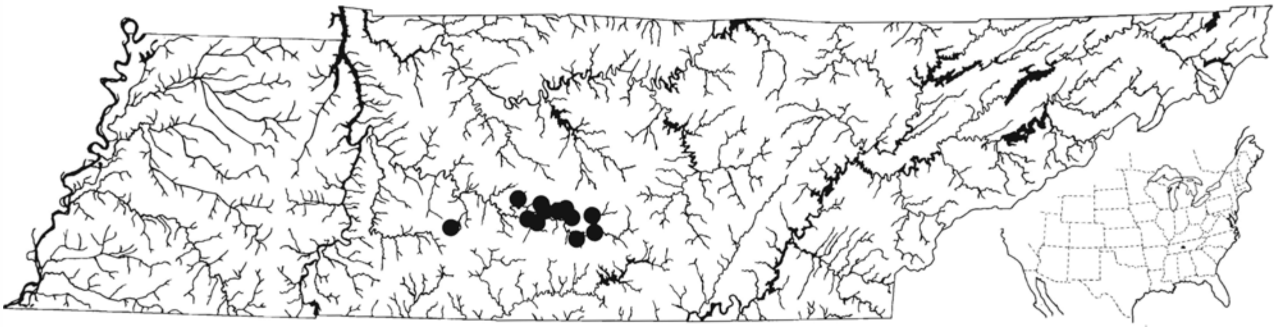


Plate 257b. *Etheostoma striatulum*, striated darter, breeding male, 50 mm SL, Duck R. system, TN.



Range Map 248. *Etheostoma striatulum*, striated darter.

toral, and lower caudal fin with dark margins; pelvic fins black. (Above data primarily from Page and Braasch, 1977.)

Biology: *Etheostoma striatulum* is a small species occurring in slabrock pools in small to medium, low-gradient creeks. Page (1980) provided information on its biology. Males in breeding condition have been collected from mid-March through April. As is typical for the subgenus, eggs are deposited on the underside of slabrocks, with each nest guarded by a single male. Females produced about 50 (19–108) eggs per year. Sexual maturity is reached in 1 year at about 30 (females) to 35 (males) mm SL, and very few individuals survived for a second spawning season. Food of both juveniles and adults was dominated by midge larvae and microcrustacea. Maximum total length 60 mm (2.3 in).

Distribution and Status: Confined to tributaries of the Duck River in Bedford, Lewis, Marshall, and Maury counties, Tennessee, where it is uncommon. Although not currently protected by state or Federal endangered species legislation, its occurrence in fewer than a dozen creeks in a four-county area makes it extremely vulnerable to significant depletion. Recent attempts to collect *E. striatulum* from four of these localities have met with no success, making its status very questionable.

Similar Sympatric Species: Other *Catonotus* likely to be encountered with *striatulum* (*flabellare*, *crossopterum*, *nigripinne*) have more than 12 pored lateral-line scales, lack red pigment, and lack an iridescent bar on the cheek. The only other barcheek darter occurring in the Tennessee River drainage, *E. smithi*, has been taken in the lower Duck River well downstream of the known range of *striatulum*. It differs from *striatulum* in lacking fine horizontal lines on the sides, and tends to have slightly higher counts of dorsal and pectoral fin elements.

Systematics: A member of the barcheek, or *E. virgatum*, species group of the subgenus *Catonotus*. Formerly thought to be most closely related to *E. virgatum* (Page and Braasch, 1977), but Braasch and Mayden (1985) hypothesized a closer relationship with *barbouri* and *smithi*.

Etymology: *striatulum* refers to the striated appearance given by the faint dark horizontal lines along the sides.

Etheostoma swaini (Jordan).

Gulf darter

Plate 258a. *Etheostoma swaini*, gulf darter, female, 49 mm SL, Obion R. system, TN.

Plate 258b. *Etheostoma swaini*, gulf darter, male, 45 mm SL, Obion R. system, TN.

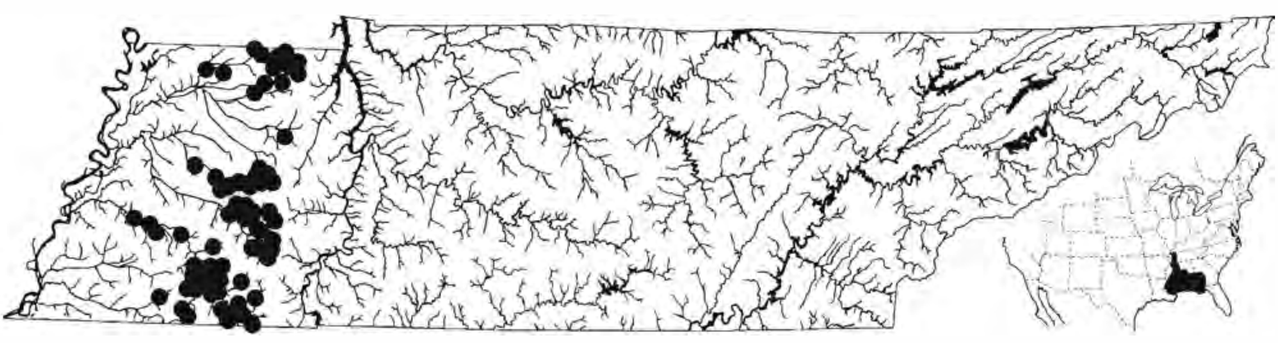
Characters: Lateral line incomplete with 30–43 (28–46) pored scales and 38–50 (35–53) scales in lateral series. Dorsal fin with 10–11 (9–12) spines and 11–12

(10–14) soft rays. Anal fin with 2 spines and 6–8 soft rays. Pectoral fin rays 12–14 (11–15). Principal caudal fin rays 15–17 (14–18). Gill rakers 9–12, length of longest rakers twice their basal width. Vertebrae 35–37. Branchiostegal rays 6. Gill membranes separate. Frenum present. Cheeks, opercles, and belly fully scaled. Nape naked anteriad to covered with embedded scales. Breast and prepectoral area usually naked. Head canals typically complete, but supratemporal canal interrupted in some populations. Dorsum mottled brownish with about ten, sometimes ill-defined, saddles. The nape is conspicuously depigmented in Tennessee populations, but in some populations nearer the Gulf Coast predorsal saddles completely traverse this area. The sides are usually patterned with horizontal lines formed by darkened scale centers and dark vertical bars are often present posterior to the anal fin origin. A suborbital bar may be moderately developed or absent, and the caudal fin base has three fused spots forming a trident. Females have a dark marginal band beneath which is a clear band and a narrow red band on the spinous dorsal fin. The soft dorsal and caudal fins have dark marks alternating with clear areas on the rays. Remaining fins are clear. In nuptial males the belly is red, and red and blue vertical bars alternate posterior to the anal fin origin. Both portions of the dorsal fin have a dusky margin, and progressing basally, clear, red, clear, blue, and red bands. Pelvic and anal fins are bluegreen, and some red may be present at the anal fin base. Nuptial tubercles are absent.

Biology: Gulf darters occur in small to medium streams and frequent areas with moderate current over sandy substrates with detrital accumulations or near undercut or brushy banks. Habitats in Tennessee typically lack submerged vegetation, but in Gulf Coastal streams vegetation is often pervasive. Breeding season in our area is in March and April (Burr and Mayden, 1979, and our data). Ruple et al., (1983, 1984) reported a February to March breeding season in southern Mississippi, with females burying their eggs in gravel. In their study, young reached average lengths of about 38 mm at age 1, 48 mm at age 2, and 53 mm at age 3. Age 1 females as small as 38 mm were sexually mature, and annual egg production was 7–90 (mean 39), with egg diameter 1.1–2 mm. In west Tennessee, lengths at age 1 are 40–53 mm, and larger yearlings are sexually mature. Two-year-olds are about 55–65 mm, and larger specimens probably represent 3-year-olds. According to Ruple et al. the diet consists primarily of midge larvae supplemented with isopods and immature blackflies, *Stenonema* mayflies, hydroptilid and hydropsychid caddisflies, and dragonflies; juveniles ate small midge larvae, copepods, and cladocera. Food of Tennessee specimens examined was exclusively midge larvae. Maximum total length about 77 mm TL, or 3 in (65 mm SL).

Distribution and Status: In Tennessee the Gulf darter is confined to eastern tributaries to the Mississippi River in the higher Coastal Plain above the Mississippi Alluvial Plain, where it occurs in sandy and hard clay-bottomed streams associated with the Wilcox and Owl Creek geological formations (Starnes, 1973). South of Tennessee (Starnes, 1980) it occurs from eastern tributaries to the Mississippi River (where it was formerly confused with *E. asprigene*) east through the Ochlockonee drainage of Georgia and Florida. It is restricted to areas below the Fall Line, and is mostly absent from the silty Black Belt region of the central Coastal Plain. It also occurs in the Tennessee River drainage in the Bear Creek system of northeastern Mississippi (Wall, 1968), but has not been taken from the Tennessee portion of that system.

Similar Sympatric Species: Similar to *E. asprigene*, but differing in typically having a depigmented nape (in Tennessee populations) with scales absent or embedded



Range Map 249. *Etheostoma swaini*, gulf darter.

(dark and fully scaled in *asprigene*), and in lacking a dark blotch at the posterior base of the spinous dorsal fin. In *asprigene* there are no dorsolateral rows of horizontal brown lines. These two easily confused species are seldom if ever taken together, with *asprigene* more prevalent in lower-gradient areas in close proximity to the Mississippi River where their ranges overlap. Drab individuals are similar in appearance to *E. parvipinne*, which lacks red colors and has broadly connected gill membranes (separate in *swaini*).

Systematics: Subgenus *Oligocephalus*. Within that subgenus, shares highly similar pigmentation with *E. ditrema*, *E. nuchale*, and *E. collettei*, which presumably form a close-knit species group.

Etymology: *swaini* is a patronym for J. S. Swain, an ichthyologist active in the late 1800s.

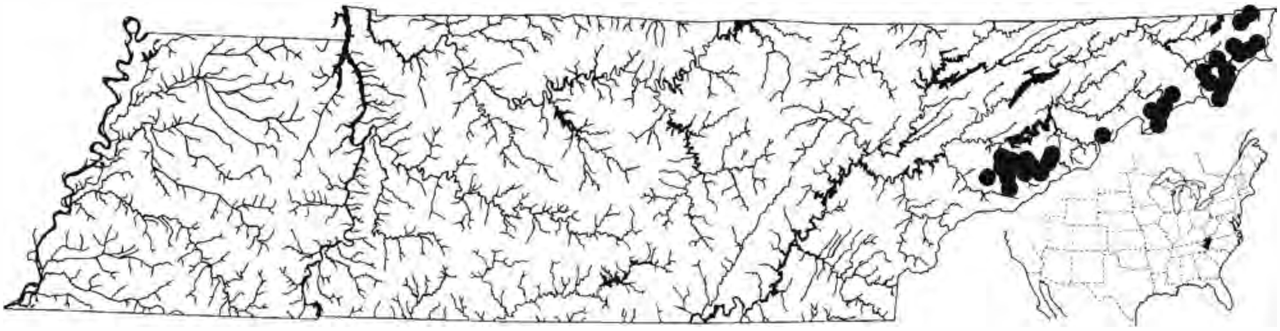
Etheostoma swannanoa Jordan and Evermann.

Swannanoa darter

Characters: Lateral line complete with 48–58 (46–62) scales. Dorsal fin with 11–13 (10–13) spines and 12–13 (11–14) soft rays. Anal fin with 2 spines and 8–9 (7–9) soft rays. Pectoral fin rays 15–16 (14–17). Principal caudal fin rays modally 16 (14–17). Gill rakers 10–11, length of longest rakers 4–5 times their basal width. Vertebrae 40–43. Branchiostegal rays 6. Gill membranes broadly connected. Frenum present. Supratemporal and infraorbital canals complete. Cheeks, breast, opercles, and prepectoral area naked; belly scaled, nape variable. Background color tan to pinkish, with six dorsal saddles and 9–11 lateral blotches. The anterior saddle is typically the darkest, and between it and the occiput is a pale tan to cream-colored area. A dark suborbital bar is lacking. There is a single dark spot at the caudal fin base, above and below which is an oval shaped tan area. Dark spots on scale centers are aligned to form vague horizontal stripes dorsolaterally. Females have a narrow dark brown marginal and basal band on the spinous dorsal fin, with the middle portion of the fin brown to gray. The soft dorsal fin has dark pigment in the membranes basad. Soft dorsal and caudal fin rays each with three dark dashes aligned to form three bands. Anal fin clear or with scattered dark marks. Pelvic fins clear. Pectoral fins with faint dashes on rays. Nuptial males have narrow rusty marginal and basal bands on the otherwise blue-green spinous dorsal fin. The soft dorsal fin is greenish at the base, shading to brick red distally. The caudal fin has blue-green dorsal and ventral margins, and other fins and the lower portion of the head are blue-green. Red spots occur on centers of all lateral scales. Nuptial tubercles occur as bluntly pointed projections on about six midventral scale rows from the anterior belly to the caudal fin base. The urogenital tube is long and cylindrical, extending slightly past the tip of the first anal spine in nuptial females.

Plate 259a. *Etheostoma swannanoa*, Swannanoa darter, female, 67 mm SL, Little Pigeon R. system, TN.

Plate 259b. *Etheostoma swannanoa*, Swannanoa darter, breeding male, 68 mm SL, Pigeon R. system, TN.



Range Map 250. *Etheostoma swannanoa*, Swannanoa darter.

Biology: The Swannanoa darter is a species of mountain rivers that inhabits riffles and flowing pools over boulder and bedrock substrates in cool, clear streams. It is often associated with longnose dace, saffron shiners, and trout. Breeding season is in early spring, with Richards (1966) noting that specimens were collected in apparent spawning pairs on 2 April. Growth is apparently rapid, with lengths of about 45 mm and apparent sexual maturity reached at age 1. The notable lack of small juvenile specimens in our collections from summer and early fall suggests that their habitat (perhaps deep, rocky pool areas that are difficult to sample with seines) is different from that of adults. Other aspects of its biology have not been studied. Maximum total length 96 mm (3.7 in).

Distribution and Status: Confined to headwaters of the Tennessee River, mostly in the Blue Ridge, from the Clinch and Powell River systems (Virginia but not Tennessee) through the upper Holston and French Broad river systems along the Tennessee, Virginia, and North Carolina borders. The Swannanoa darter is a common species, but can be difficult to collect due to the clear water and slippery, boulder substrates of its preferred habitats. We are unable to relocate the source of the Atlas record (Starnes, 1980) from the Little Tennessee River system, and suspect it to be an error.

Similar Sympatric Species: The six prominent dorsal saddles are shared by *blennioides*, *stigmaeum*, and *zonale*. All of these have scales on the cheeks, lack any indication of horizontal stripes, and lack the distinctive pale tan area between the anterior dorsal saddle and the occiput.

Systematics: Subgenus *Etheostoma*; *E. swannanoa*, *E. thalassinum* from the Santee River drainage, and *E. inscriptum* of the Altamaha and Savannah river drainages compose the *thalassinum* species group of Richards (1966). However, Thompson (1973), Burr (1979), and Bailey and Etnier (1988) hypothesized closest affinities with *E. blennius*.

Etymology: Named after the Swannanoa River, North Carolina, from which some of the types were collected.

Etheostoma tippecanoe Jordan and Evermann.

Tippecanoe darter

Plate 260a. *Etheostoma tippecanoe*, Tippecanoe darter, female, 31 mm SL; Red R., TN.

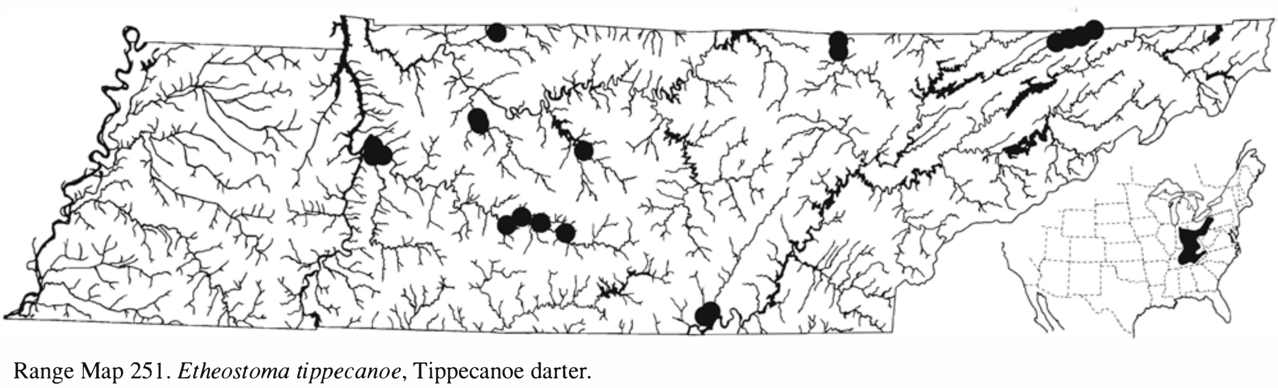
Plate 260b. *Etheostoma tippecanoe*, Tippecanoe darter, male, 26 mm SL, Clinch R., TN.

Characters: Lateral line incomplete with 19–33 (17–34) pored scales and 45–52 (40–56) scales in lateral series. Dorsal fin with 11–13 (10–14) spines and 11–13 (10–13) soft rays. Anal fin with 2 spines and 7–9 soft rays. Pectoral fin rays 12–13 (11–13). Principal caudal fin rays modally 15 (14–16). Gill rakers 8–11, length of longest rakers about twice their basal width. Vertebrae modally 36 (35–37). Branchiostegal rays 6. Gill membranes narrowly joined. Frenum present. Infraorbital (only 7 pores, 8 in all other *Nothonotus*) and supratemporal canals complete. Nape, cheek (except in Tennessee drainage), breast, prepectoral area, and anterior portion of belly naked; opercles scaled. A dusky suborbital bar is present. Adult males with background color of orange-gold. Dorsal and anal fins have dark bases and are orange distally, with a dark marginal and paler orange submarginal band on spinous dorsal. Females with olivaceous background coloration and speckled median fins. Both sexes with 6–11 oblique dark bars on sides (blue in males) that are often continuous across the back; the anterior saddle on the nape and the dark bar at the caudal fin base are particularly prominent. Both sexes with a dark humeral spot and a pair of yellow to orange spots at the base of the orange (males) or speckled (females) caudal fin. Nuptial males with blue-green breast.

Biology: The tippecanoe darter occurs only in medium to large rivers and occupies shallow riffle areas with substrates of fine, cherty gravel approximating the background color of the males. Annual population fluctuations in *E. tippecanoe* are apparently large, and in a single area it may vary from extremely common to virtually undetectable over a period of several years. Although its dimunitive size suggests a very short lifespan, possibly of only 1 year, R. T. Bryant (pers. comm.) has noted at least two size classes in several collections. Food of a limited number of specimens examined by Bryant consisted of 58% midge larvae and 29% baetid mayfly nymphs. Warren et al. (1986a) have studied reproductive behavior. In Kentucky spawning occurs in July, apparently in deep gravel runs. In aquaria, males established territories near stones. Females burrowed into the substrate leaving only the caudal fin exposed. Males assumed a head-to-head orientation above the female (or females) and both sexes began rapid gill flaring and presumably released eggs and milt. The male then vigorously nuzzled the gravel about the buried female who soon departed. Eggs were thus attached to gravel deep in the substrate. At 24.5 C hatching required 9 days. Spawning individuals were 1 year old. Females averaged only about 30 mature ova. Hybrids between *E. tippecanoe* and *E. camurum*, which spawns in similar manner, are known (Mayden and Burr, 1980). This is the smallest species of the subgenus *Nothonotus*, and one of our smallest darters, with a maximum total length of 43 mm (1.7 in) in specimens seen by us and Zorach (1969). Trautman (1957) reported a 46-mm (1.8 in) specimen.

Distribution and Status: Widespread and locally abundant, but with a very spotty distribution throughout the Ohio, Cumberland, and Tennessee river drainages. Because of its very restricted riverine habitat, the Tippecanoe darter has been eliminated from many areas by impoundments and siltation. Once common in the Duck River in the area below Normandy Reservoir, it has apparently disappeared from there, perhaps in response to black manganese deposits on the normally orange chert gravel substrates. Populations in the middle Duck River below the influence of Normandy Reservoir continue to thrive. Although it presently does not warrant protected status throughout its range, it is likely to be granted protected status from many states within its range, especially in the Ohio River drainage.

Similar Sympatric Species: Other sympatric *Nothonotus* (*aquali*, *camurum*, *maculatum*, *microlepidum*, *rufilineatum*, *sanguifluum*, *vulneratum*) have fine horizontal lines between scale rows on posterior sides, have complete lateral lines and scaled bellies, and lack orange-gold body coloration and the prominent anterior saddle and vertical basicaudal bar. The oblique lateral banding pattern is somewhat similar to that of *E.*



Range Map 251. *Etheostoma tippecanoe*, Tippecanoe darter.

(*Oligocephalus*) *caeruleum*, which has a completely scaled belly, red bands in the dorsal fin, and an orange rather than blue throat region.

Systematics: Subgenus *Nothonotus*. Systematics were studied by Zorach (1969), who noted that Clinch River specimens tend to have a few scales on the cheek immediately behind the eye. This condition persists in other Tennessee drainage populations (Sequatchie, Duck, and Buffalo rivers) not available to Zorach. This and several other minor differences noted in Tennessee drainage populations were not considered sufficiently large to warrant subspecies recognition. Warren et al. (1986a) felt that *tippecanoe* is most closely related to *E. camurum*, *E. rufilineatum*, and *E. juliae* based on similar egg-burying behavior, but this behavior would appear primitive within the subgenus and perhaps not indicative of close relationships. Etnier and Williams (1989) were uncertain concerning its relationships within subgenus *Nothonotus*.

Etymology: Named for the Tippecanoe River in Indiana, the type locality.

Etheostoma trisella Bailey and Richards.

Trispot darter

Plate 261a. *Etheostoma trisella*, trispot darter, female, 36 mm mm SL, Conasauga R. system, TN.

Plate 261b. *Etheostoma trisella*, trispot darter, male, 39 mm SL, Conasauga R. system, TN.

Characters: Since previously published standard meristic characters are virtually unavailable for this species, we provide the following from about 100 UT specimens from the Conasauga River system. Counts include those already published in Etnier (1970). Lateral line complete with 41 (1 specimen), 42 (2), 43 (6), 44 (5), 45 (8), 46 (12), 47 (12), 48 (11), 49 (14), 50 (12), 51 (11), 52 (5), or 53 (1) scales. Dorsal fin with 7 (1), 8 (18), 9 (71), or 10 (11) spines and 10 (21), 11 (66), or 12 (12) soft rays. Anal fin with 0 (7) or 1 (100) spine and 8 (21), 9 (51), or 10 (5) soft rays. (The number of specimens lacking an anal spine may be an underestimate, as nuptial specimens develop an opaque fleshy covering over the first anal fin element, which necessitates dissection in order to determine the identity of the structure.) Pectoral fin rays 13 (35), 14 (59), or 15 (4). Principal caudal fin rays 14 (1), 15 (15), 16 (64), or 17 (1). Gill rakers 7 (1), 8 (6), 9 (10), or 11 (1), with length of longest rakers 1–2 times their basal width. Vertebrae modally 36 (35–39). Branchiostegal rays 6–6 (37), 6–7 (3), 7–6 (1), or 7–7 (2). Gill membranes separate. Frenum present. Exposed scales present on nape, cheeks, opercles, and belly. Prepectoral area often and breast occasionally with a few embedded cycloid scales. Supratemporal and infraorbital canals complete. Dorsum brown with three darker saddles, located anterior to the first dorsal fin spine, anterior to the first dorsal fin soft ray, and anterior to the tips of the depressed posterior dorsal soft rays. Midlateral blotches are weakly developed. The belly is yellowish to white. Suborbital bar present. Spinous dorsal fin with submarginal dark band, median band of red, and dark base in males; females with scattered dark marks on spines. Other fins of both sexes with scattered dark marks on rays. Nuptial males develop iridescent green blotches along the sides and reddish-orange lower sides. The red band in the spinous dorsal fin intensifies, and the anal, pelvic, and soft dorsal fins darken. Nuptial tubercles occur on rays of the anal fin of males, but are apparently very transient (Ryon, 1981, 1986).

Biology: The trispot darter, like the related slackwater darter, is a highly specialized species requiring distinct habitats for growth and reproduction. Its biology has been studied by Ryon (1981, 1986). The resident habitat of the trispot consists of slackwater areas along the margins of the Conasauga River (upper Coosa River system, Mobile Basin) and some of its tributaries, usually in association with detritus or rooted vegetation (water willow). The Conasauga is a small upland river averaging about 15 m wide. Inhabited tributaries, where resident populations seem to be much smaller, range from small to large creeks. In late fall, trispots begin to migrate to tributaries and may be encountered in riffle areas at this time. By December, they have congregated in proximity to spawning habitats, which are shallow seepage areas adjacent to these tributaries. One known habitat is an often-flooded pasture laced with shallow drainage ditches. Vegetation consists of arrowhead (*Sagittarius* sp.), rushes (*Juncus* sp.), several other aquatic vascular plants, filamentous green algae in the ditches, and a variety of terrestrial grasses and herbs. This area was probably a perennially flooded wooded marsh prior to its conversion to pasture. A second known spawning habitat is a wooded seepage area adjacent to the Conasauga River in north Georgia. During flooding, the darters enter these areas to spawn (December through April). Spawning behavior is ritualistic, with spawning pairs swimming side by side in short dashes. Males nip and nudge and females apparently solicit by swimming upward at a 45° angle. During spawning, the pair, with the male mounted and straddling the female with his pelvic fins, swims upward in unison, extruding, fertilizing, and broadcasting the adhesive eggs which stick to plants and other objects. Males guard the spawning site. Females contain 200–300 ova at the beginning of the season. Eggs are about 1.0 mm in diameter prior to water hardening and hatch in 30 days at 12 C. Hatchlings are 5 mm long, and grow to 10 mm in 6 weeks. Surviving adults and young presumably exit flooded areas prior to drying and return downstream to resident habitat areas. Total length at age 1 is 42–48 mm, and females at the lower end of this range may delay sexual maturity until age 2. Lengths at age 2 are about 50 mm, and very few individuals live to age 3. Trispot darters feed on a wide range of invertebrates dominated by midge larvae and mayfly nymphs. Other prey such as stonefly nymphs, caddisfly larvae, and copepods, were seasonally important, especially during migration. Maximum total length about 59 mm, or 2.3 in (49.4 mm SL).

Distribution and Status: *Etheostoma trisella* was known from a single specimen collected in 1947 from Cowan Creek, Cherokee County, Alabama (now innundated by Weiss Reservoir) at the time it was described by Bailey and Richards (1963). A second specimen was subsequently discovered in a 1954 collection from Swamp Creek, a lower Conasauga River tributary in Whitfield County, Georgia (Howell and Caldwell, 1967). They were unable to locate additional specimens in Swamp Creek during 1966, and reported considerable habitat change due to construction of I-75; a second specimen was taken in 1967 in Swamp Creek, after publication of their note. The presence of an upper Conasauga River population was brought to our attention by the 1969 collection of a single specimen in the Conasauga in Polk County, Tennessee, by R. W. Bouchard and W. C. Starnes, with additional collecting producing seven more specimens (Etnier, 1970). Many additional specimens have been collected (Bryant et al., 1979a; Ryon, 1981, 1986; Freeman, 1983, 1985), with the trispot known to inhabit the Conasauga River system from about 4 km above the Tenn. 74 crossing (extreme southwest Polk County) to about 65 river km downstream in Whitfield County, Georgia. It also occurs in tributaries such as Coahulla and Mill creeks in Bradley County, Tennessee. Trispot darters may have originally occurred throughout much of the Ridge and Valley corridor portion of the Conasauga River, but known reproducing populations are currently restricted to the portion of the Conasauga mentioned above. Its status was recently reviewed by the U.S. Office of Endangered Species, and it was not recommended for protected status (U.S. Federal Register, 1986). It remains on Tennessee's list of rare vertebrates as a Threatened Species (Starnes and Etnier, 1980), and is considered to be threatened in Georgia and extirpated in Alabama (Helfman and Freeman, 1979). Unless land use practices change in this area, its status is reasonably secure. Alteration of spawning habitats could rapidly eliminate populations and focus additional concern on this unique darter.

Range Map 252. *Etheostoma trisella*, trispot darter.

Similar Sympatric Species: Because of the dorsal saddle pattern, *trisella* resembles the amber darter, *Percina antesella*, which has a fourth saddle near the caudal fin base, modified midventral scales, and other differences. Pallid juveniles might be confused with *E. stigmaeum* and *E. coosae*, which are often collected with trispots. These species have six to eight dorsal saddles and 2 anal spines; the former has an incomplete lateral line, and the latter has broadly connected gill membranes.

Systematics: Member of the recently erected subgenus *Ozarka* (Williams and Robison, 1980), with whose members it shares several derived characters and peculiar reproductive habits. With its single anal spine and complete lateral line, it is the most aberrant member of that group and is hypothesized to be the most primitive member of the subgenus (Mayden, 1985). Formerly included in the now monotypic subgenus *Psychromaster* (with *E. tuscumbia*) by Bailey and Richards (1963).

Etymology: *tri* = three, *sella* = saddle.

Etheostoma tuscumbia Gilbert and Swain.

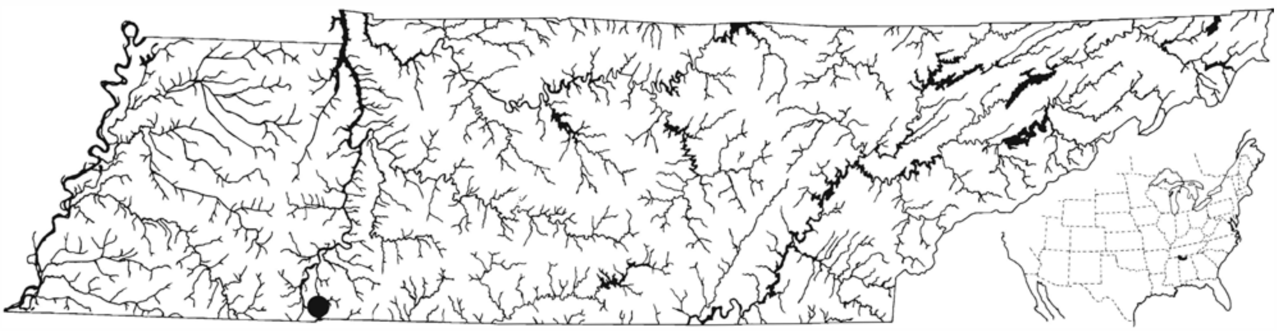
Tuscumbia darter

Plate 262. *Etheostoma tuscumbia*, Tuscumbia darter, male, 39 mm, Tennessee R. system, AL.

Characters: Lateral line incomplete with about 15–30 pored scales and mean scales in lateral series about 45 (37–51) in a limited number of specimens from our collection and available literature. Dorsal fin with 8–11 spines and 11–14 soft rays. Anal fin with single spine and 7–9 soft rays. Pectoral fin rays 10–13. Principal caudal fin rays 15–16. Vertebrae 35–37. Gill rakers 6–7 (5–9), with length of longest rakers equal to their basal width. Branchiostegal rays 6. Gill membranes separate. Frenum present. Nape, cheeks, opercles, belly, breast, prepectoral area, and top of head forward to orbital region covered with exposed scales. Scales may also occur on branchiostegal rays, an extremely rare character in perciform fishes (e.g., priacanthids). Infraorbital and supratemporal canals complete. The dorsum has five or six dark saddles and the sides are mottled with dark pigment. Midlaterally, a row of six or seven small blotches is usually evident. A prominent suborbital bar and two basicaudal spots are present. Rays of all fins except the pelvics are speckled. Ground color of the body is pale greenish, and bright breeding colors are lacking. So far as known, breeding tubercles are not developed.

Biology: The Tuscumbia darter is strictly a denizen of ponded spring-fed habitats. It occurs in well-vegetated (watercress, milfoil, algae, etc.) areas with clean substrates of fine gravel. Such habitats are usually crystal clear and maintain water temperatures in the 15.5–17 C (60–63 F) range. The biology of *E. tuscumbia* has been studied in northern Alabama springs by Koch (1978a). Tuscumbia darters spend much of their time beneath the cover of mats of vegetation. There seems to be no definite reproductive season, as gravid females and ripe males can be found throughout the year. However, the spawning peak (and the only period in which spawning has been actually observed) is apparently January to March. Spawning occurs in open areas on well-oxygenated gravel substrates. Both male and female burrow into the gravel during the spawning act, and the eggs are thus left buried in the substrate. Females contain about 40–100 mature ova dependent on body size. Hatching of eggs requires about 120 hours at 17 C and probably requires additional time at the normal spawning temperature (15.5 C). Larvae are about 4 mm at hatching and grow to 5–6 mm in 10 days or so, at which time the yolk sac is absorbed and ingestion of food begins. Young attain lengths of about 30 mm in their first year, with males being generally larger. Life span is probably 2–3 years. Tuscumbia darters feed on typical spring-associated invertebrates including amphipods, physid snails, and, most of all, midge larvae. Of lesser importance are isopods and small crayfish (Koch, 1978b). Maximum total length 65 mm (3.6 in).

Distribution and Status: The Tuscumbia darter is apparently restricted to some of the numerous valley-floor springs in the southern bend of the Tennessee River region (Highland Rim province) of northern Alabama and, formerly, extreme southern Tennessee. So far as known, it does not occur in the higher-gradient spring outflows at higher elevations on the Highland Rim which have been moderately well collected (Armstrong and Williams, 1971). It is represented in Tennessee only by single collections from Spring Branch, tributary to Dry Creek, and Big Spring at Dry Creek Cave in Hardin County, collected in the 1940s (catalogued at University of Michigan Museum of Zoology). These areas are now beneath Pickwick Reservoir. The valley of the



Range Map 253. *Etheostoma tuscumbia*, Tuscumbia darter.

Tennessee River within the Tennessee portion of the Highland Rim province is very restricted and almost totally inundated by impoundments. The valley embracing the river downstream of Pickwick Dam has Coastal Plain characteristics. Chances that additional populations of *E. tuscumbia* will be discovered in Tennessee seem remote and the species is considered to be probably extirpated from the state. In Alabama, the species survives in at least ten localities but probably has been extirpated from several others (Ramsey, 1976). It is considered of special concern in that state (Ramsey, 1986).

Similar Sympatric Species: Potentially sympatric with several members of the *E. squamiceps* species group (*crossopterum*, *neopterum*, *nigripinne*), all of which share the approximate pigmentation and body form of *tuscumbia*. None of these have scales on top of the head; and scales on the cheeks, branchiostegals, and breast are absent, embedded, or inconspicuous. *Etheostoma parvipinne* is potentially sympatric in the area adjacent to Pickwick Reservoir. It shares the short snout of *tuscumbia* and is similar in appearance, but differs in having broadly connected gill membranes and in lacking scales on the top of the head.

Systematics: In monotypic subgenus *Psychromaster*.

Etymology: The species epithet is derived from the type locality, Tuscumbia Spring, Tuscumbia, Alabama.

Etheostoma virgatum (Jordan).

Striped darter

Characters: Lateral line incomplete with 6–20 (0–25) pored scales and 41–52 (38–58) scales in lateral series. Dorsal fin with 8–9 (7–10) spines and 12–15 (11–17) soft rays. Anal fin with 2 spines and 8–10 (7–11) soft rays. Pectoral fin with modally 12 (10–14) rays. Principal caudal fin rays modally 17 (16–18) in our specimens, but reported as modally 16 in Kuehne and Small (1971) and Kornman (1980). Gill rakers 7–11, many vestigial, with length of longest rakers 1–1.5 times their basal width. Vertebrae modally 36 (35–37). Branchiostegal rays 6. Gill membranes narrowly joined. Frenum present. Cheeks, opercles, nape, breast, and prepectoral area naked; belly fully scaled. Infraorbital and supratemporal canals interrupted. Ground color straw yellow. Dorsum with about five to eight saddles and sides with 9–12 small midlateral blotches. Sides conspicuously marked with 10–12 horizontal dark lines. A dark humeral spot is present, and an oblique pale bar bordered by black is present on the cheek. Anterior membranes of spinous dorsal fin blackened basally and medially, fin margin orange. Soft dorsal, anal, caudal, and pectoral fins speckled. Breeding males darken overall, especially on the head and paired fins, develop black margins on the anal fin and lower lobe of the caudal fin, and have red-orange median fins. Small fleshy knobs develop on tips of dorsal spines, but breeding tubercles are absent.

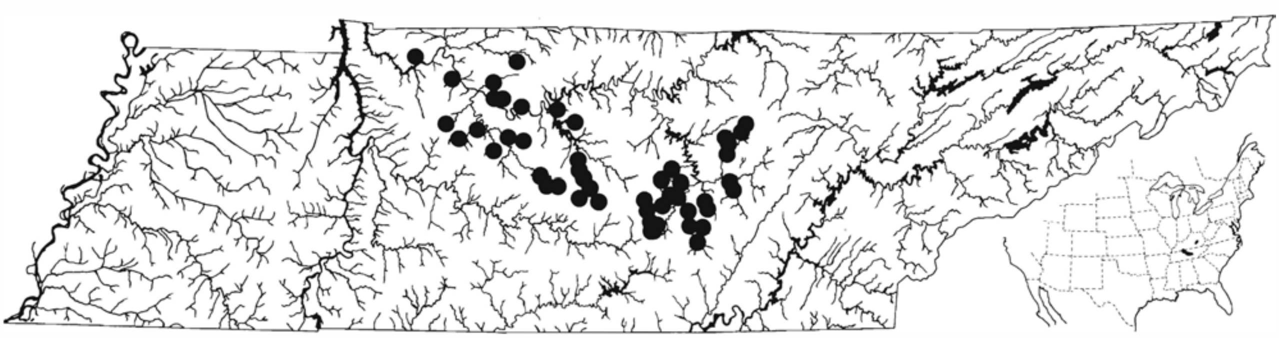
Biology: Kornman (1980) provided life history information on a population of *E. virgatum* from the Rockcastle River system, Kentucky. Favored habitats were small streams in areas with gentle currents adjacent to riffles, with substrates of sand, gravel, and larger rocks. He noted an upstream migration to a favored spawning area during March as water temperatures reached 10 C; males developed breeding colors during this time. Spawning activity occurred from mid-April through May, and was slightly later than that of *E.* (*Catonotus*) *flabellare* occurring in the same creek. In typical *Catonotus* fashion, males constructed and defended nest sites under rocks and slabs, with nests located in areas with slightly less current than were *flabellare* nests. Nest sites typically had a single entrance on the downstream side of the rock. Females contained about 40 (9–93) mature ova, but nests contained an average of 361 (48–887) eggs. The large number of eggs per nest relative to eggs per female is due, at least in part, to the fact that 1-year-old males were not involved in reproduction while both 1- and 2-year-old females were. Also, counts of mature eggs per female may drastically underestimate fecundity in this subgenus (see account for *E.* (*Catonotus*) sp., the duskytail darter). Water-hardened eggs averaged 2.5 mm in diameter, and newly hatched young were 6.5 mm long. Mean standard length at age 1 was 28.5 mm for males and 30.6 mm for females. At age 2, males (50 mm SL) were larger than females (46 mm SL). Maximum life span for both sexes was just over 2 years. Maximum total length 78 mm (3.1 in).

Plate 263a. *Etheostoma virgatum*, striped darter, female, 50 mm SL, Caney Fork R. system, TN.

Distribution and Status: Moderately common in the three disjunct portions of the Cumberland River drainage that comprise its range: extreme eastern Highland Rim in Rockcastle and adjacent river systems (Kentucky), upper Caney Fork system in Highland Rim, and western Rim and adjacent Nashville Basin from Stones River system downstream to western Montgomery County, Tennessee. The striped darter is typically collected in small numbers, but this may be more a reflection of habitat than rarity. The striped darter allopatrically "fills in" the distributional gaps between other ecologically similar barcheek darters (*obeyense*, *smithi*) in the Cumberland drainage (see Page and Schemske, 1978 and comments under *E. smithi*).

Similar Sympatric Species: Similar in appearance to *E. flabellare*, which is sympatric throughout its range but is easily separated by its broadly connected gill membranes, lack of red coloration, and lack of the distinctive pale bar on the cheek. Also occurs with *Catonotus* of the *E. squamiceps* species group (*crossopterum*, *squamiceps*), which are much darker colored, have a vertical row of dark spots at the caudal fin base, and lack horizontal dark stripes and a pale bar on the cheek.

Plate 263b. *Etheostoma virgatum*, striped darter, breeding male, 53 mm SL, Caney Fork R. system, TN.



Range Map 254. *Etheostoma virgatum*, striped darter.

Systematics: A member of the *E. virgatum* (barcheek darter) group of the subgenus *Catonotus*. Systematics are discussed by Page and Braasch (1977), who felt that slight differences in counts from the three disjunct areas of occurrence were not sufficient to justify recognition of subspecies. Closest relatives are collectively the group composed of *E. barbouri*, *E. smithi* and *E. striatulum* (Braasch and Mayden, 1985).

Etymology: *virgatum* = streaked.

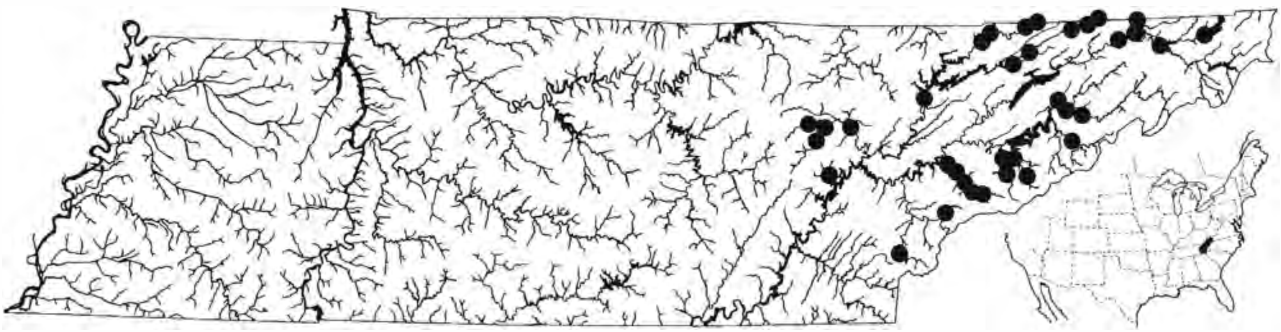
Etheostoma vulneratum (Cope).

Wounded darter

Plate 264. *Etheostoma vulneratum*, wounded darter, male, 56 mm SL, Little Pigeon R., TN (female coloration essentially as in *E. sanguifluum*).

Characters: Lateral line complete with 52–62 (50–66) scales. Dorsal fin with 12–13 (11–15) spines and 12–13 (11–13) soft rays. Anal fin with 2 spines and 7–9 (7–10) soft rays. Pectoral fin rays 13–14 (12–15). Principal caudal fin rays modally 17 (16–18). Gill rakers 12–15, with length of longest rakers 3–5 times their basal width. Vertebrae modally 40 (39–41). Branchiostegal rays 6. Gill membranes narrowly joined. Frenum present. Scales absent from nape, breast, and prepectoral area; belly and opercles scaled, cheeks with a few scales underlying postorbital spot. Supratemporal and infraorbital canals complete. Background color gray to dark olive. Juveniles (and occasionally adults) with about eight dark saddles and ten dark midlateral blotches which may extend vertically to be continuous with dorsal saddles. A dark humeral spot and dusky suborbital bar are present. Sides with dark horizontal lines between scale rows. Caudal fin base with a vertical row of four dark spots, two of these marginal and two located near the midline. Soft dorsal, anal, and caudal fins with narrow dark margins and vague pale submarginal bands. Spinous dorsal fin dusky with pigment concentrated to form dark blotch at anterior base. Adult females with pale yellow membranes and rays speckled with brown on soft dorsal and caudal fins, anal fin and paired fins clear or with some dusky pigmentation. Bright colors of female restricted to an orange submarginal band on spinous dorsal fin, and a few red spots may occur on the posterior sides. Adult males retain bright colors throughout the year. The spinous dorsal fin has bright red spots near the fin margin on one to several anterior membranes and often on posterior membranes. Soft dorsal fin with reddish membranes. Caudal fin typically with dark center bordered above and below by broad red area, but entire basal portion of fin may be red. Anal fin dark gray, green between the anal spines. Paired fins are gray, with a dark marginal band often present on upper portion of pectoral fins. Bright red lateral spotting is more prominent on the posterior two-thirds of the body, and the breast is green.

Biology: The wounded darter is an inhabitant of moderate to large rivers where it occupies depths of one-half meter or more in areas of gentle to moderate current. It is typically associated with boulder or coarse rubble substrates, and Stiles (1972) noted that overhanging ledges or rocks piled on top of each other were necessary to provide optimum nesting and resting areas. Our experience suggests that the closely related *E. aquali* and *E. sanguifluum* are more inclined to occur in areas of swift currents than are *vulneratum* and its presumed sister species, *E. wapiti*. Stiles (1972) has studied the biology of *vulneratum* in Little River, Tennessee, where spawning occurred from late May through late July at water temperatures of 16–20 C. Behavior is similar to that of *E. maculatum* (Raney and Lachner, 1939). Females deposit eggs on the undersides of rock ledges or rocks supported by other rocks. Nests contained 17–166 (mean 48) eggs. Clutches often contained eggs resulting from more than one spawning act and presumably from several females. Stiles noted that females would occasionally deposit eggs while the male was stationed outside the nest site, with these eggs presumably being fertilized later. Males apparently defend their nest until eggs hatch. In the Little River study, the same male was observed at his nest for 17 consecutive days. Stiles surmised that male territoriality was based on an attachment to the site rather than to the eggs themselves. Lengths of 22–40 mm are reached at age 1, and sexual maturity does not occur until age 2. This agrees closely with Raney and Lachner's (1939) data for first year *E. maculatum*. In that study, *E. maculatum* averaged 44 (females) and 48 (males) mm SL at age 2 and had a life span of 4 or possibly 5 years. Figures for *vulneratum* are probably quite similar. Adult food during winter months was over 90% midge larvae; during warmer months midge larvae comprised 70% of the diet (Stiles, 1972; Bryant, 1979), with the remainder com-



Range Map 255. *Etheostoma vulneratum*, wounded darter.

prised of mayfly nymphs, water mites, and larval blackflies, craneflies, and hydropsychid caddisflies. Maximum total length 87 mm (3.4 in).

Distribution and Status: Confined to the upper Tennessee River downstream through Whites Creek and Little Tennessee River. Sequatchie River records reported by TVA (1972) and appearing in the Atlas (Etnier, 1980) are not represented by specimens, and, while possibly correct, are not accepted. Locally abundant in Little Tennessee River of North Carolina (above Fontana Reservoir) and Clinch River (above Norris Reservoir) and Little River in Tennessee, but most other localities are represented by very few specimens. Only 76 specimens were available to Zorach and Raney (1967) for their analysis of variation. Habitats occupied by *vulneratum* are difficult to collect, and it is probably somewhat more common than existing records would indicate. It has, however, disappeared from much of its former range due to the prevalence of impoundments on most rivers in the upper Tennessee drainage. It does not currently warrant protected status, but periodic monitoring of existing populations is certainly prudent in light of the rarity, jeopardized status, and very restricted ranges of most members of the apparently very intolerant *E. maculatum* species group (*aquali*, *maculatum*, *microlepidum*, *moorei*, *rubrum*, *sanguifluum*, *vulneratum*, *wapiti*).

Similar Sympatric Species: Differs from *chlorobranchium*, *camurum*, and male *rufilineatum* in lacking distinct pale submarginal bands on median fins. Differs from female *rufilineatum* in having the median fins yellowish with pale brown spots rather than clear with black spots, in addition to lacking orange lip pigment and dark horizontal marks across the cheeks and opercles. Differs from *acuticeps* in having the opercles well scaled and in having red spots on the sides. Juveniles might be confused with *tippecanoe* (orange males, prominent basicaudal dark bar and nape saddle, incomplete lateral line) and several species of the subgenus *Catonotus*, which have modally 9 or fewer dorsal fin spines and incomplete lateral lines.

Systematics: A member of the *E. maculatum* species group of the subgenus *Nothonotus*. Zorach and Raney (1967) studied variation of *vulneratum* and treated it as a subspecies of *E. maculatum*. Page (1985) treated *vulneratum* as a subspecies of *sanguifluum*. Etnier and Williams (1989) considered both it and *sanguifluum* as species, and hypothesized *E. wapiti* (Elk River system) to be sister species of *vulneratum*.

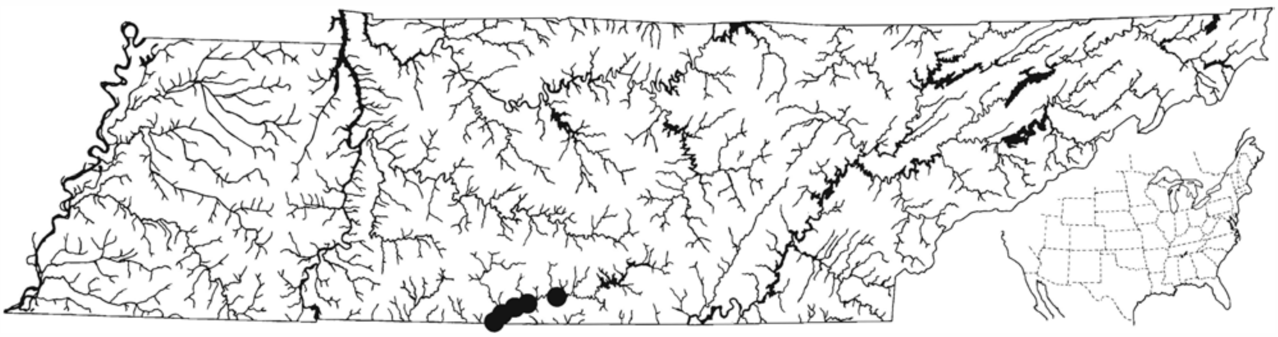
Etymology: *vulneratum* = wounded.

Etheostoma wapiti Etnier and Williams.

Boulder darter

Plate 265. *Etheostoma wapiti*, boulder darter, male (the holotype), 70 mm SL, Elk R. system, TN (photo J.R. Shute).

Characters: Lateral line complete with 56–64 (55–69) scales. Dorsal fin with modally 13 (12–14) spines and modally 12 (11–13) soft rays. Anal fin with 2 spines and modally 8 (7–9) soft rays. Pectoral fin rays 13–14 (12–14). Principal caudal fin rays modally 17. Gill rakers 12–13, length of longest rakers 5–7 times their basal width. Vertebrae 39 (4), 40 (5) or 41 (1). Branchiostegal rays 6. Gill membranes narrowly joined. Frenum present. Scales absent from nape, breast, and prepectoral area; cheeks usually with a few embedded



Range Map 256. *Etheostoma wapiti*, boulder darter.

scales near postorbital spot; belly and opercles fully scaled. Supratemporal and infraorbital canals complete. Background coloration olivaceous, with eight to nine dorsal saddles and 10–11 midlateral blotches often present, especially in juveniles. Sides with 10–14 dark horizontal lines between scale rows. Dark suborbital bar, humeral spot, and pair of submedian but discrete basicaudal spots present. In adult females, red pigment may be present near the margins of the first one or two membranes of the spinous dorsal fin. Adult males completely lacking red coloration on fins and body, with chromatic colors restricted to pale yellow submarginal bands on spinous dorsal, soft dorsal, and caudal fins; and pale blue on the gular area, bases of the pelvic fins, and between the anal spines. Males are otherwise uniformly dark gray on the body and fins except for the horizontal lines on sides and dark margins on the median fins.

Biology: The boulder darter is an inhabitant of deep, flowing pools with boulder substrates in large creeks and rivers. Its biology is unstudied, but probably similar to that of the closely related *E. vulneratum*. Maximum total length 84 mm (3.3. in).

Distribution and Status: Presently known from the Elk River system of Alabama and Tennessee, where adults have been taken from lower Richland Creek, Giles County, Tenn., the mouth of Indian Creek, Giles County (River Mile 52.5), and the main channel of Elk River from Fayetteville, Lincoln County, Tenn. (River Mile 89.7), downstream to River Mile 29.7, just above Wheeler Reservoir embayment and .5 mile below the Alabama State Highway 127 (Smith Hollow Road) bridge, Limestone County. All adults have been taken in association with limestone rubble from broken mill dams and bridges, or natural accumulations of limestone slabs. These habitats are presumably essential for spawning substrate, and are infrequent in lower Elk River, where gravel substrates predominate. Juveniles apparently disperse widely and have appeared in several Elk River collections from gravel riffles and in lower Indian Creek. Two juveniles were collected in 1884 in Shoal Creek near Florence, Lauderdale County, Ala., but recent extensive collections from Shoal Creek have failed to produce additional specimens. The boulder darter is considered as Endangered (Biggins, 1988).

Similar Sympatric Species: *Etheostoma rufilineatum* has orange lips in life, horizontal dark marks on the cheeks (vertical suborbital bar in *wapiti*), red and orange fin and body pigmentation in males, and large black spots on median fins in females. *Etheostoma camurum* also occurs with *wapiti* and differs in having a more blunt snout, more distinct pale submarginal bands on median fins, a blue breast, red spots on the sides, little sexual dimorphism, and lacking a suborbital bar and any scales on the cheek.

Systematics: A member of the *E. maculatum* species group of the subgenus *Nothonotus*, and most closely related to *E. vulneratum* according to Etnier and Williams (1989).

Etymology: *wapiti* is a well known American Indian (presumably Iroquois) name for the American elk and refers to the Elk River type locality.

Etheostoma zonale (Cope).

Banded darter

Characters: Lateral line complete with 44–58 (39–63) scales throughout range. Dorsal fin with modally 11 (8–13) spines and 11–13 (10–14) soft rays. Anal fin with 2 spines and 7–9 (6–9) soft rays. Pectoral fin rays 13–15 (12–16). Principal caudal fin rays modally 16 or 17 (15–18). Gill rakers 9–11 (7–12), with length of longest rakers 3–5 times their basal width. Vertebrae modally 38–40 (37–42). Branchiostegal rays 5 or 6. Gill membranes broadly joined. Frenum present. Supratemporal and infraorbital canals complete. Nape and opercles scaled; cheek, breast, belly, and prepectoral area scaled to naked in various races. Background color gray to yellowish, with six dorsal saddles, about ten vertical bars on sides, a suborbital bar, and four dark basicaudal spots. Dark markings often present on lower surface of head. Spinous dorsal fin of females with dark basal band and gray elsewhere, other fins with dark marks that may align to form banding patterns. Males (and often females) with bars on sides bright green. In males there is a dark red basal band on both dorsal fins. During the breeding season much of the remainder of these fins becomes bright green, as do the anal fin and paired fins. Green also develops at the upper and lower margins of the caudal fin base and along the lower sides. Nuptial tubercles do not occur, but tips of pelvic, lower pectoral, and anterior anal fin elements become swollen in breeding males.

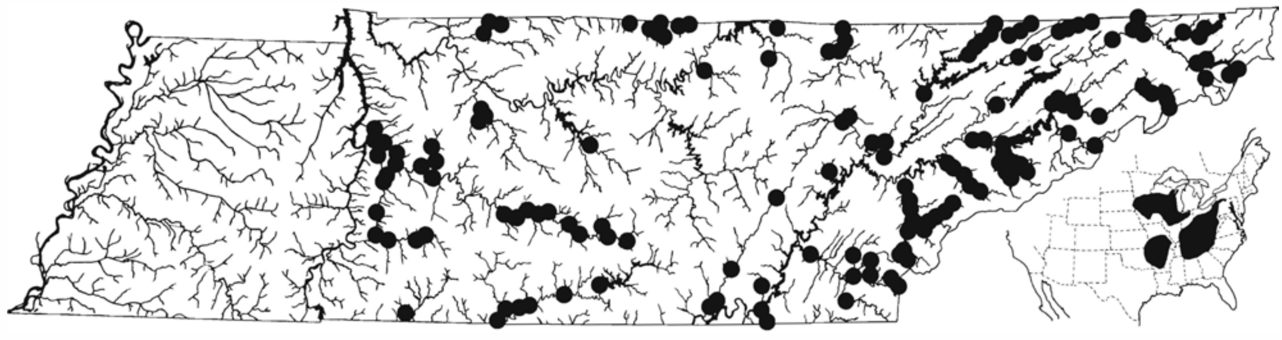
Biology: The banded darter is an inhabitant of gravel riffle areas in habitats ranging from medium sized streams to rivers. It reaches maximum abundance in areas where riffles have lush growths of attached vegetation, particularly *Podostemum*. McCormick and Aspinwall (1983) found this preference for vegetation to be based on olfactory sense, but visual cues may have played a role. Spawning occurs in April and May in our area, with females attaching their eggs to vegetation in riffle areas (Trautman, 1957; Pflieger, 1975). Growth has been studied by Lachner et al. (1950) and Lutterbie (1979) in western Pennsylvania and Wisconsin, respectively. In both studies, lengths at ages 1–4 were about 35, 47, 55, and 60 mm, with males averaging larger than females. Larger yearlings spawned at age 1 in the Pennsylvania population and appear to be sexually mature in Tennessee. Various studies of the diet of the banded darter indicate that midge larvae, followed by mayfly nymphs and blackfly larvae, are dominant foods (Adamson and Wissing, 1977; Bryant, 1979; Cordes and Page, 1980; Wynes and Wissing, 1982). Very little feeding occurs during winter months, with peak activity in May through August. Adamson and Wissing (1977) observed rather uniform food consumption over the course of a day but Cordes and Page (1980) observed a midday peak. Maximum total length (Trautman, 1957) 89 mm (3.5 in).

Plate 266a. *Etheostoma zonale*, banded darter, 45 mm SL, Little R., TN.

Distribution and Status: Widespread but occurring only above the Fall Line throughout the Ohio, Cumberland, Tennessee, and much of the Mississippi river drainages, and also with introduced populations established in the Susquehanna and upper Savannah rivers. The banded darter continues to be very common, but has disappeared from large portions of Indiana and Illinois, presumably in response to siltation from intensive agriculture in this area.

Similar Sympatric Species: Members of the subgenus *Ulocentra* are similar in form but have eight or nine ver-

Plate 266b. *Etheostoma zonale*, banded darter, breeding male, 63 mm SL, Nolichucky R., TN.



Range Map 257. *Etheostoma zonale*, banded darter.

sus six dorsal saddles. Other sympatric darters with six dorsal saddles lack connected gill membranes (*chlorosoma, nigrum, stigmaeum*), have drastically different snout shapes (*blennioides, stigmaeum*), or lack green as the prominent color on the body (*chlorosoma, histrio, nigrum, stigmaeum, swannanoa*). Most similar to *blennioides*, which has U-shaped rather than linear lateral markings, and *histrio*, which has a marginal rusty rather than a basal red band in the spinous dorsal fin.

Systematics: Subgenus *Etheostoma* (see Page, 1981, for alternate view). Systematics were studied by Tsai and Raney (1974), who noted many racial differences in scale counts and squamation of the breast and cheeks. They considered *E. lynceum* as a subspecies of *zonale*, but *lynceum* was recognized as a distinct species by Etnier and Starnes (1986).

Etymology: *zonale* = banded.

Etheostoma zonistium Bailey and Etnier.

Bandfin darter

Characters: Lateral line complete with 42–49 (40–52) scales. Dorsal fin with 10–11 (9–12) spines and 10–12 soft rays. Anal fin with 2 spines and 6–8 soft rays. Pectoral fin rays 13–15. Principal caudal fin rays modally 17 (15–18). Gill rakers 7–10, length of longest rakers 1–1.5 times their basal width. Vertebrae modally 38 (37–39). Branchiostegal rays 5 (5–6). Gill membranes broadly connected. Frenum absent. Supratemporal and infraorbital canals complete. Nape, belly, opercles, cheeks, and prepectoral area scaled; breast variable, typically with scales on posterior half. Background color tan, with scattered darker mottling, nine lateral blotches, eight dorsal saddles, and at the caudal base a pair of median (often fused) and pair of marginal dark spots. Suborbital bar narrow, dark blotch in prepectoral area. Females with red ocellus in first interradial membrane of spinous dorsal fin, posterior to which is a submarginal dark band. Additional dark banding (at fin margin and submedian) may be present in darkly colored specimens. Soft dorsal fin often with some red in middle of posterior membranes; this fin, caudal fin, and pectoral fin otherwise with alternating brown and pale areas on rays. Anal and pelvic fins clear. Spinous dorsal fin of nuptial males with three horizontal dark bands separated by clear bands. Marginal band black to blue, median band rusty and extending posteriad from red ocellus in first membrane, submedian band dark. Soft dorsal fin with distal third black to blue, and the oblique red band on the posterior two-thirds of the fin separated from the marginal dark color by a clear area. Caudal fin with basal third orange to brick red. Anal fin with broad blue-green margin and red pigment proximal to this band continuous through fin or restricted to anterior and posterior membranes. Pelvic fins gray, pectoral fins clear with alternating brown and pale areas on rays. Breast blue to gray. Bright orange of lower sides continuous with orange of posterior upper sides. Lateral line pale, appearing as a white line back to the soft dorsal fin origin; above lateral line a narrow, brick red band is continuous to the caudal fin or may be obscured posteriad by orange of upper sides. Nuptial tubercles are absent.

Biology: Bandfin darters inhabit small streams with low gradients, and typically occur over fine gravel substrates of gentle riffles and pools. Bailey and Etnier (1988) indicated an April to May breeding season, sexual maturity at age 1 at 25–35 mm SL, and a 3-year life span. Carney and Burr (1989) studied the biology of a population in Clarks River, Kentucky. Spawning occurred from March to May or June, but peaked in March and April. Both males and females were sexually mature at age 1, at mean sizes of 34 and 31 mm SL, respectively.

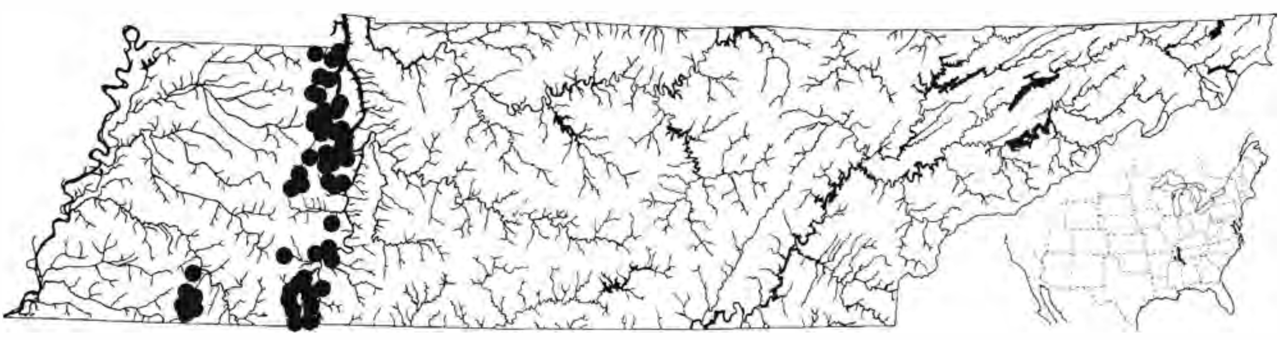
The mean number of large ova contained in females 1 year old was 77, with age 2 and 3 females averaging 128 large ova. These values were thought to underestimate fecundity, as they felt it likely that smaller eggs would mature during the breeding season. Spawning occurred in aquaria at water temperatures of 17–22 C (63–72 F), with eggs laid singly in typical *Ulocentra* fashion, both on horizontal and vertical surfaces. Mature ovarian and fertilized eggs averaged 1.08 and 1.7 mm in diameter, respectively. Eggs hatched in 7 days at water temperature of 20 C (68 F), and hatchlings averaged 4.3 mm TL. Maximum life span was 3 years. Food was dominated by midge (Chironomidae) larvae. Maximum total length 75 mm (3.0 in).

Plate 267a. *Etheostoma zonistium*, bandfin darter, female, 48 mm SL, lower Tennessee R. system, TN.

Distribution and Status: This is a common species in western tributaries to the lower Tennessee River from Pickwick Reservoir north to southern Kentucky. In this area it is restricted to the Coastal Plain, and it occurs in a few eastern tributaries to the lower Tennessee just north of Pickwick that are in the Coastal Plain or have similar habitats. The western Highland Rim extends west of the lower Tennessee River in a few areas, where *zonistium* is replaced by the related *E. duryi*. In the Tennessee drainage, the bandfin's distribution accurately reflects the boundary between Coastal Plain and western Highland Rim. Also present in the Hatchie River system, where most records are from the Spring Creek watershed south of Bolivar, Hardeman County. Also present in headwaters of Black Warrior River system (Mobile Basin) of Lawrence and Winston counties, Alabama. In the Black Warrior it occurs in the southern edge of the Cumberland Plateau in clear, cool streams with sand and bedrock substrates—very unlike the Coastal Plain streams it inhabits elsewhere.

Similar Sympatric Species: Potentially sympatric with additional *Ulocentra* (*duryi*, *flavum*, *simoterum*), but it has not been taken with any of these species, none of

Plate 267b. *Etheostoma zonistium*, bandfin darter, breeding male, 53 mm SL, lower Tennessee R. system, TN.



Range Map 258. *Etheostoma zonistium*, bandfin darter.

which has three horizontal dark bands in the spinous dorsal fin of males. Both *histrio* and *lynceum* have six rather than eight dorsal saddles and are gray to greenish rather than tan. The only other sympatric *Etheostoma* with broadly connected gill membranes is *parvipinne*, which has a much shorter snout, gray to olive body colors, no red or orange pigment, and usually an incomplete lateral line.

Systematics: Bailey and Etnier (1988) place *zonistium* in the *E. duryi* species group of the subgenus *Ulocentra*, with possible affinities with *E. coosae* of the Mobile Basin. Specimens from the Black Warrior River system have higher scale counts than elsewhere, but otherwise differed little from specimens from Coastal Plain areas.

Etymology: *zone* = band, *istium* = fin, referring to the diagnostic banding pattern of the spinous dorsal fin of males. Prior to its formal description the bandfin was occasionally referred to as "lowland snubnose darter." Kuehne and Barbour's (1983) illustration of the "redbelly snubnose darter" (Pl. 12) represents *E. zonistium*.

Etheostoma brevirostrum Suttkus and Etnier

Holiday darter

(Description of this species was published while this book was in press.)

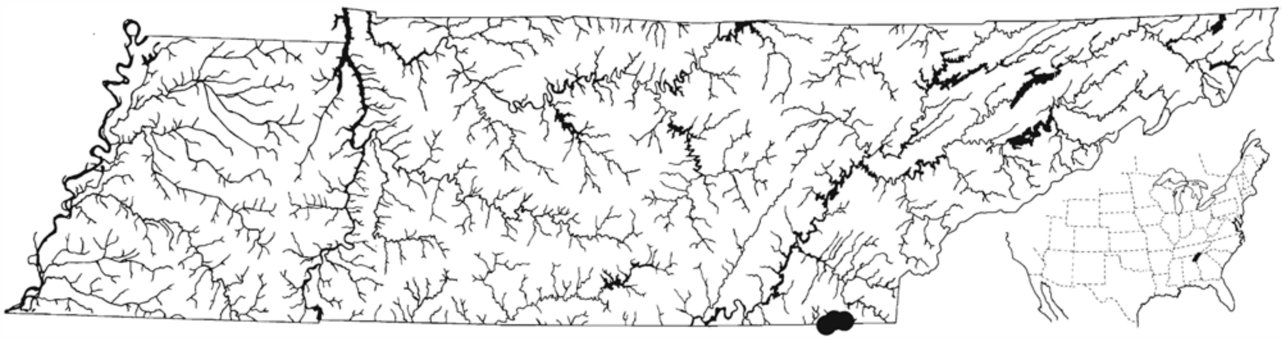
Plate 268a. *Etheostoma brevirostrum*, holiday darter, female, 41 mm SL, Conasauga R., TN-GA.

Plate 268b. *Etheostoma brevirostrum*, holiday darter, male, 43 mm SL, upper Coosa R. system, GA (photo N.M. Burkhead).

Characters: Lateral line complete with 45–52 (42–54) scales. Dorsal fin with 10–11 (9–12) spines and 10–12 soft rays. Anal fin with 2 spines and 7–8 (5–8) soft rays. Pectoral fin rays 13–14. Principal caudal fin rays 15–17. Gill rakers 8–10, longest rakers about 2–3 times their basal width. Vertebrae usually 38 (37–38). Branchiostegal rays 5. Gill membranes broadly connected. Frenum absent. Breast naked. Opercles, cheeks, nape, prepectoral area, and belly scaled. Prevomerine teeth are occasionally present, and head canals are complete. Dorsum with eight saddles. Sides with about eight or nine blotches, those from the origin of the anal fin posteriad with green ventral extensions that continue around the venter. The spinous dorsal fin has a narrow blue-green marginal band that widens posteriad. Below this is a clear area, then a red band that is most prominent posteriad, and a basal dark band. The bright red ocellus in the first interradial membrane, characteristic of the subgenus *Ulocentra*, is typically present. The soft dorsal fin is similarly banded. Anal fin with blue-green on spines and their interradial membrane, and a median red band. Pelvic fins mostly blue-green, often with a red blotch at base of median rays. Pectoral and caudal fins yellowish with dark brown mottling. Lower sides with bright red to orange streak extending from caudal fin base to pelvic fin origin, but interrupted by vertical green extensions of posterior five or six lateral blotches. Above data from Suttkus and Etnier (1991).

Biology: The holiday darter occurs in typical *Ulocentra* habitats of bedrock and gravel pool areas in small creeks to moderate sized rivers. We have found it most abundant in upland streams that are cool enough to provide at least marginal trout habitat, but it extends well into warmwater habitats in the Conasauga River where we have taken it a few miles below the Tennessee-Georgia border. It is often associated with lush growths of river weed (*Podostemum*), where its green banding pattern would certainly make it inconspicuous. We have also observed this species perched high on bedrock protrusions with sparse *Podostemum* growth. Its biology is otherwise unstudied, but is probably similar to that of other *Ulocentra*. Maximum total length 58 mm (2.3 in).

Distribution and Status: Apparently uncommon throughout its limited range in the upper Coosa River system. Of 39 lots listed by Suttkus and Etnier (1991), 28 contained three or fewer specimens, and only three lots had more than ten specimens. It is very uncommon in the Conasanga River based on our snorkeling observations. Our largest series, nine specimens, was taken



Range Map 259. *Etheostoma brevirostrum*, holiday darter.

in the Conasauga River at Georgia Highway 2, Murray County. It occurs sporadically in the Conasauga from that locale to slightly above the mouth of the Jacks River and appears to be more abundant in high elevation streams in the Ellijay River system in north Georgia. It is not currently given protected status in Tennessee, but occurs on lists of vulnerable Georgia (Helfman and Freeman, 1979) and Alabama (Ramsey, 1976) fishes. It certainly warrants inclusion on Tennessee's list; and because of its restricted range in small portions of only three states, it is a likely candidate for future consideration for Federal protected status.

Similar Sympatric Species: See comments under *Etheostoma coosae*.

Systematics: Subgenus *Ulocentra*. The lack of a frenum and presence of prevomerine teeth place it in the *E. duryi* species group (Bailey and Etnier, 1988; Suttkus and Etnier, in 1991).

Etymology: *brevirostrum* = short snout.

Etheostoma (*Catonotus*) sp.

"Duskytail darter"

Characters: (Data from 54 UT specimens from throughout present range, and R. E. Jenkins.) Lateral line incomplete with 18–28 (16–32) pored scales and 40–45 (38–48) scales in lateral series. Dorsal fin with modally 7 (6–8) spines and 11–12 (10–13) soft rays. Anal fin with 2 spines and 7–8 (6–8) soft rays. Pectoral fin rays 12–13 (12–14). Principal caudal fin rays modally 17 or 18 (15–19). Gill rakers 10–11 (8–11), length of longest rakers about twice their basal width. Vertebrae modally 34 (33–35). Branchiostegal rays 6. Gill membranes moderately joined. Frenum present. Infraorbital and supratemporal canals interrupted. Scales absent from cheeks, opercles, nape, breast, prepectoral area, and midline area of belly. Body color brown with a series of 10–15 darker brown vertical bars on sides and 6–7 brown saddles often visible on dorsum. A dark humeral spot is consistently present, and the breast and lower half of the head are sprinkled with large melanophores. The spinous dorsal fin has dark pigment at the base and a dark brown submarginal band. Soft dorsal and caudal fins are speckled with brown, and some brown may occur on posterior anal fin rays. Pectoral and pelvic fins are clear. In nuptial males, the head becomes darkened and swollen, overall pigmentation darkens, black borders develop on the pectoral and anal fins, the remainder of the anal fin becomes milky white, and fleshy gold knobs develop on tips of the dorsal spines. Breeding tubercles are absent.

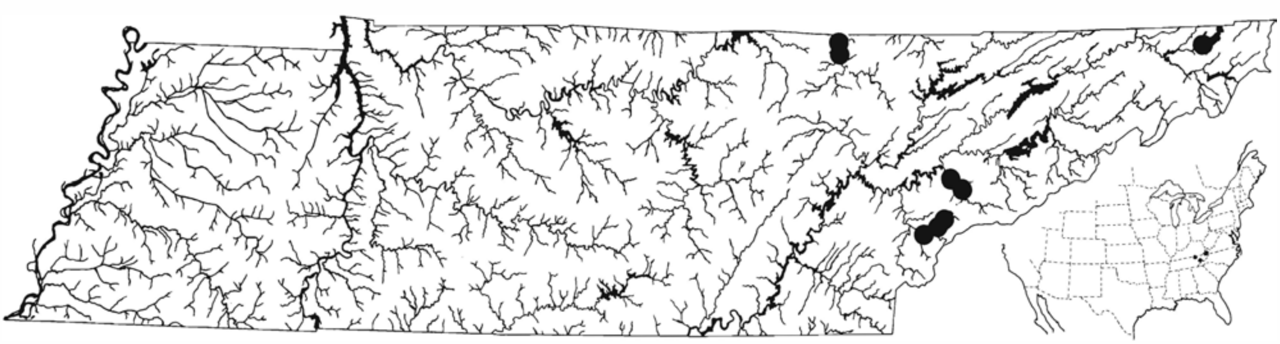
Plate 269a. *Etheostoma* (*Catonotus*) sp., "duskytail darter," female, 46 mm SL, Little R., TN.

Plate 269b. *Etheostoma* (*Catonotus*) sp., "duskytail darter," breeding male, 56 mm SL, Little R., TN (caudal fin heavily damaged from spawning activities).

Biology: Unlike other members of the subgenus *Catonotus*, the undescribed "duskytail darter" is an inhabitant of major streams ranging from larger creeks to moderately large rivers. It occurs in gently flowing pools, generally in the vicinity of riffles, with substrate of large rocks strewn over bedrock or sand and gravel, and depths of .3 to 1.2 m. Siltation in those few habitats where this species persists is usually minimal. The habitat is the same as that generally preferred by the ashy darter, *E. cinereum.* Layman (1984a,b; 1991) studied the biology of this species in Little River, Tennessee. Breeding began in late April and continued through June. Males established territories under large rocks in the same pools they inhabited the rest of the year. In Copper Creek, Virginia, Jenkins and Musick (1980) reported duskytails to move into riffles during spawning, possibly due to competition with the closely related *E. flabellare*, which is absent from duskytail darter habitats in Little River. In aquaria, males from Little River cleaned nest sites of silt and debris, and emerged from the nest to court passing females by erecting their fins, tail-wagging, and nipping. This behavior continued if and when the female entered the nest. Shortly thereafter the female inverted, pressing her abdomen against the underside of the rock. Her vibrations just prior to deposition of an egg apparently caused the male to invert, head to tail, and fertilize the egg. The female remained inverted throughout the spawning session, which lasted for up to 5 hours or more. Males resumed an upright position after each egg was fertilized. A mean of 26 (19–44) mature eggs was found in dissected females, and this was essentially the same as the number of eggs laid per spawning act. A female captured in April and held in an aquarium produced six clutches of 7+ to 40 eggs each during a single spawning season, indicating that actual fecundity is much greater than mature eggs per female at any given time. Nests contained a mean of 79 (23–200) eggs, indicating that several females may spawn in a single nest. Eggs hatched in 11–14 days at 18–27 C and young were 5.2 mm TL at hatching. Males were larger than females after 6 months and averaged 40.4 mm SL at age 1; females averaged 34.7. Both sexes were mature at age 1, but only 39 mm SL or larger 1-year-old males were found guarding nests; females as small as 28 mm SL were gravid. Life span was slightly more than 2 years. Food consisted primarily of midge larvae, mayfly nymphs (mostly heptageniids), and microcrustacea. Maximum total length 64 mm (2.5 in).

Distribution and Status: Restricted to four known populations—Little River, Blount County, Tenn., from the U.S. 411 bridge downstream to just below the Tenn. 33 bridge; the lower several miles of Citico Creek, Monroe County, Tenn., where it is rare; Copper Creek, tributary to Clinch River, Scott County, Va.; and in the Cumberland River drainage from Big South Fork near the mouth of Station Camp Creek, Scott County, Tenn. Earlier records from lower Abrams Creek, Blount County, Tenn., and South Fork Holston River, Sullivan County, Tenn., represent populations presumably extirpated. This relict distribution indicates that the duskytail was formerly a more widespread species. It and other darters such as the ashy darter, dependent upon silt free, rocky pools in large streams and rivers, have apparently suffered more from the effects of siltation than have darters typical of swift riffles. The Threatened status accorded this darter in Tennessee (Starnes and Etnier, 1980) is certainly warranted throughout its limited range, and it is a likely candidate for federal protection in the future.

Similar Sympatric Species: Sympatric with the very similar *E. flabellare* in Copper Creek, Virginia, and approaching sympatry with *E. kennicotti* throughout its range. It differs from *kennicotti* in having extensive naked areas on the belly from the anus forward, and in having less prominent banding on the caudal fin and



Range Map 260. *Etheostoma* (*Catonotus*) sp., "duskytail darter."

basal dark pigment in the spinous dorsal fin, and from *flabellare* in having less broadly connected gill membranes.

Systematics: A member of the *E. flabellare* species group of the subgenus *Catonotus* Braasch and Mayden (1985). Its description is being prepared by R. E. Jenkins.

Etheostoma corona Page and Ceas

Crown darter

(Description of this species was published while this book was in press.)

Characters: Lateral line incomplete with 25–44 pored scales and 40–55 scales in lateral series. Dorsal fin with modally 8 or 9 (8–10) spines and modally 14 (13–15) soft rays. Anal fin with 2 spines and 7–8 (6–9) soft rays. Pectoral fin rays modally 12 (11–13). Principal caudal fin rays 17–18 (16–18). Gill rakers 8–9, length of longest rakers about twice their basal width. Branchiostegal rays 6. Gill membranes separate. Frenum present. Infraorbital canal interrupted with 4 anterior and typically 3 posterior pores. Supratemporal canal interrupted. Preoperculomandibular canal complete with 10 pores. Scales present on cheeks, opercles, nape, belly, and prepectoral area; breast with embedded scales posteriad. Pigmentation essentially identical to that of *E. crossopterum*, except nuptial males have a yellow margin on the soft dorsal fin (Page et al., 1992).

Plate 270a. *Etheostoma corona*, crown darter, female, 43 mm SL, Cypress Cr. system, TN.

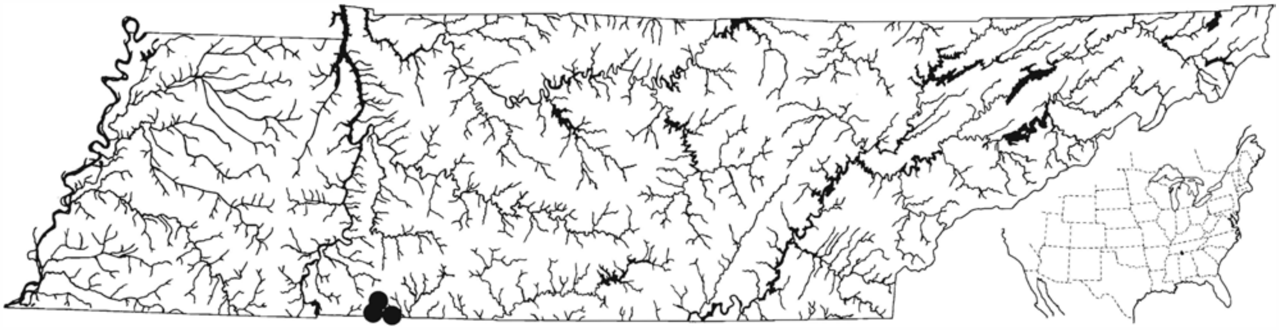
Biology: The biology of the crown darter is unknown but presumably similar to that of other members of the *E. squamiceps* species group such as *E. crossopterum*. Specimens in breeding condition have been collected from beneath rocks and undercut banks in mid-April. Our largest specimen is 78 mm (3 in) total length.

Distribution and Status: Confined to the Cypress Creek system of northern Alabama and Wayne County, Tennessee, where it is common in suitable habitats.

Similar Sympatric Species: Currently thought to be the only member of the *E. squamiceps* group occurring in the Cypress Creek system (Page et al., 1992), in which case *E. flabellare* is the only sympatric *Catonotus*. The crown darter lacks the connected gill membranes and rows of horizontal dark lines on the sides of *E. flabellare* and has the distinctive vertical row of three dark spots at the caudal fin base typical of members of the *squamiceps* group.

Systematics: Subgenus *Catonotus*. Braasch and Mayden (1985) included Cypress Creek in the range of *E. crossopterum*. Page et al. (1992) recognized specimens from that system as representing a species distinct from *crossopterum* based on coloration of breeding males (yellow margin on soft dorsal fin) and relative lengths of third branches on rays of these fins (equal in this

Plate 270b. *Etheostoma corona*, crown darter, breeding male, 66 mm SL, Cypress Cr. system, TN.



Range Map 261. *Etheostoma corona*, crown darter.

form versus much longer in *crossopterum*), and most closely related to *E. nigripinne* and *E. forbesi*, with which it forms a subgroup of the *squamiceps* complex.

Etymology: *corona* = a crown, in reference to golden margin of soft dorsal fin of breeding males.

Genus *Perca* Linnaeus

This holarctic genus contains but three species, the Eurasian *Perca fluviatilis* and *P. schrenki*, and *P. flavescens* of North America.

Perca flavescens (Mitchill).

Yellow perch

Characters: Lateral line complete with 51–65 scales (usually 55–65 in our area). Dorsal fin with 13–15 spines in anterior portion and 1–2 spines plus 12–15 rays in posterior portion. Anal fin with 2 spines and 6–8 rays. Pectoral fin rays 15 (13–16). Principal caudal fin rays 17. Branchiostegal rays 7 (6–8). Gill rakers about 20, length of longest rakers about 6–8 times their basal width. Vertebrae 38–41. Chromosome number 48 (Donahue and Loftus, 1974). Lateralis canals on head complete. Frenum absent. Gill membranes separate. Exposed scales cover body, including breast, belly, nape, cheeks, and dorsal portions of opercles. Opercular spine present. Preoperculum with serrate posterior border. Teeth present on vomer and palatines. Swimbladder well developed. The dorsum is brownish, bronze, or olivaceous, with six to nine dorsal saddles that extend well down the yellow sides and narrow to a point ventrally. A prominent blotch is usually present in the posterior membranes of the spinous dorsal fin. Caudal fin and remainder of dorsal fin dusky. Pectoral, pelvic, and anal fins pale yellow to orange. Breeding tubercles are lacking.

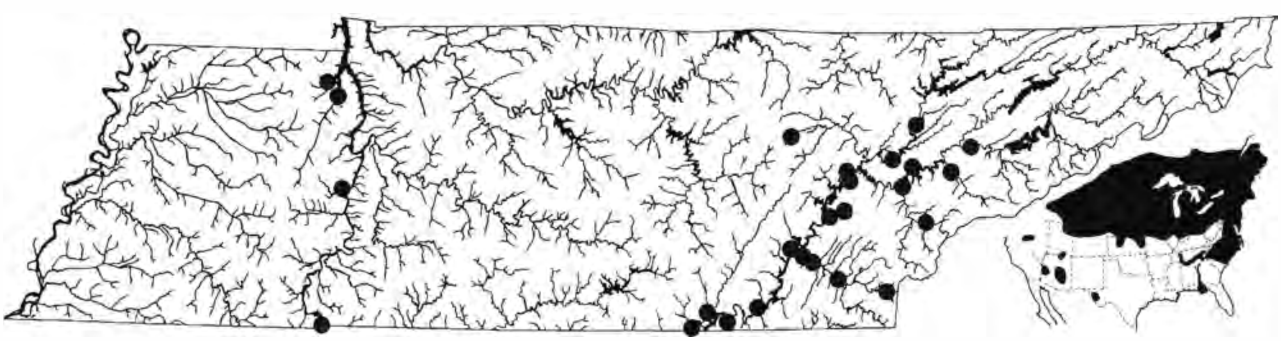
Biology: The yellow perch is an inhabitant of streams and lakes, and prefers quiet water habitats. It also enters brackish water along the Atlantic seaboard. It is of-

Plate 271. *Perca flavescens*, yellow perch, 105 mm SL, lower Tennessee R. system, TN.

ten associated with rooted aquatic vegetation. Broad overviews of yellow perch biology are presented by Scott and Crossman (1973) and Ney (1978). Spawning occurs during March to May. Spawning sites are either vegetation, submerged brush, or sand and gravel shorelines. Males move to the spawning areas first and are later joined by the larger females. Females produce up to 100,000 or more eggs in larger specimens, although most females contain 15,000–25,000 (Dahlberg, 1971). As perch swarm to the spawning site, each female is attended by as many as 15–25 males which form up into columns behind the female and create considerable disturbance as they traverse the spawning habitat. Eggs are extruded in long gelatinous strands which are festooned over underwater objects (Harrington, 1947) and often are swept onto the shore by wave action. Eggs hatch in 8–25 or more days depending on water temperature. Larvae are 5–6 mm long at hatching. Shortly after yolk sac absorption, larvae move to deep water areas where they are pelagic, feed on zooplankton, and lack the distinctive pigmentation of larger specimens. After about 1 month, they attain a length of about 25 mm, develop their characteristic pigmentation, return to shallow water, and begin the more bottom-oriented behavior typical of adults (Whiteside et al., 1985). Small fish enter the diet in the following months; and, as adults, perch feed heavily on both small fish (including smaller perch) and insects, with seasonal shifts in emphasis based on availability of forage species such as young shad (Tharratt, 1959; Clady, 1974; Knight et al., 1984). In a southern reservoir, yellow perch averaged 77 mm TL after 1 year's growth and averaged 132, 184, 217, and 250 mm at the ends of their second through fifth years (Clugston et al., 1978). Jobes (1952) estimated faster average growth in a Lake Erie population: age 1, 90 mm TL; age 2, 165; age 3, 215; age 4, 233 with comparable lengths (255) reached at age 5. This contradicts the usual comparative growth relationship of northern and southern fish populations. Maximum life span is at least 8 years (Dahlberg, 1971).

In northern states, where abundant, yellow perch are important game and pan fish, and they are also fished commercially. They have received little attention thus far from Tennessee anglers, but their increasing abundance in Tennessee River main-channel reservoirs is resulting in their more frequent encounters with fishermen. A small sport fishery has persisted for some time in the lower Hiwassee River, and perch are occasionally taken there by trout fishermen. Perch bite readily on live bait such as minnows, crayfish, worms, and grubs and are easily taken on a variety of small artificial lures fished near the bottom. They do not provide much of a tussle when hooked, but are a most welcome addition to the pan. The flesh of yellow perch is firm, white, of mild flavor, and it is one of our most palatable food fishes. It remains speculative whether the recently established Tennessee River reservoir populations will reach sufficient abundance to provide a significant sport fishery. Many populations in northern areas are overcrowded, with individuals rarely reaching usable size. Hopefully their potential for overpopulation and potential negative impacts on other species will not be realized in Tennessee. The world record of 1.93 kg (4 lb 3 oz) was caught in New Jersey in 1965. Tennessee record is 0.80 kg (1 lb 12.25 oz), Hiwassee River, 1985, Allen Rhoades.

Distribution and Status: Yellow perch are native to the northern states east of the Rocky Mountains, and Atlantic Coastal drainages south to South Carolina. Yellow perch were native to Tennessee during cooler times, as their bones appear in late Pleistocene deposits (12,000–16,000 years ago) at Cheek Bend Cave, Duck River system, Maury County (Dickinson, 1986). They have been widely introduced elsewhere, often accidentally, as appears to be the case in Tennessee. They appeared



Range Map 262. *Perca flavescens*, yellow perch (native range extends off inset northwest to upper Mackenzie River drainage; disjunct areas in inset and southwestern portion of continuous distribution represent introductions).

in upstream reservoirs on the Hiwassee River in North Carolina as early as the 1950s, perhaps being accidentally introduced along with walleye (Messer, 1965; Timmons, 1975), and first appeared downstream in Tennessee in 1968 (Hitch and Etnier, 1974). They are now common in the lower Hiwassee River and have rapidly dispersed into impoundments along the main Tennessee River downstream as far as Pickwick Reservoir in 1987 and Big Sandy River in 1988, and upstream through Fort Loudon, Melton Hill, and presumably Tellico reservoirs (L. B. Starnes and P. A. Hackney, in litt.). Except for invasion of major tributaries, dispersal farther upstream in the Tennessee drainage (barring unauthorized introductions) should be prevented by impassable dams. Yellow perch are not currently highly abundant in Tennessee, but their potential for future increased abundance may be considerable.

Similar Sympatric Species: Sauger and walleye (*Stizostedion*) are slimmer, have enlarged canine teeth, are gray or brown rather than yellow, lack precise vertical dark bars on the sides, and have 11 or more anal fin rays. Logperch (*Percina caprodes*) are occasionally taken by anglers in reservoirs, and are similar in being yellowish with vertical dark bands on the sides. Logperch are much slimmer, have a piglike snout with a broad frenum attaching the upper lip to the snout, and have many more than nine vertical bars on the sides.

Systematics: Svetovidov and Dorofeeva (1963) and Thorpe (1977) considered *P. flavescens* and the Eurasian *P. fluviatilis* to be conspecific. Collette and Banarescu (1977) published a concurrent (with Thorpe) rebuttal to this conclusion based on minor but consistent osteological differences and retained *P. flavescens* as a distinct species; this usage is generally accepted (Robins et al., 1991).

Etymology: *Perca* = a perch, *flavescens* = yellowish.

Genus *Percina* Haldeman

The genus *Percina*, with about 40 species, contains most of the larger members of the darter tribe (Etheostomatini), although a few species are quite small. The majority of members of this genus tend to inhabit larger creeks and rivers, but some are relatively ubiquitous or migratory and are often encountered in small creeks. They occur in several different habitats ranging from shallow riffles to deeper runs and pools; a few species are tolerant of lakes and reservoirs. They exhibit generalized spawning behavior, with all species for which data are available spawning on gravel riffles and burying their eggs shallowly under the substrate (*P. caprodes* may spawn on the wave-swept gravel shores of lakes). Nest building and parental care of eggs are unknown in *Percina*.

Members of the genus *Percina*, morphologically and behaviorally the least derived of the darters, are characterized by the presence of modified midventral scales on the breast and belly. One or two larger stellate scales occur on the breast between the bases of the pelvic fins in both sexes (Fig. 135), and a midventral row may be present on the belly of males and occasional females of some species. These scales have systematic value and may aid in defining relationships within the genus. The condition of these scales varies seasonally, with a thicker fleshy covering and more prominent teeth becoming evident during the breeding season. They probably serve as contact organs during spawning. An excellent discussion of these structures appears in Page (1976a). In addition to modified scales, *Percina* is characterized by having a complete lateral line with relatively high scale counts, a complete cephalic sensory system, with a mode of 8 infraorbital canal pores and 10 preoperculomandibular pores, separate to moderately connected gill membranes, 6 (rarely 7 in subgenera *Percina* and *Swainia*) branchiostegal rays, and the occasional persistence of the swimbladder.

Etymology: *Percina* = a diminutive of *Perca*.

Members of the genus *Percina* are divided into nine subgenera, all of which occur in Tennessee. Subgeneric allocations within *Percina* have been discussed by Bailey and Gosline (1955), Collette (1965), Page (1974a, 1976a, 1977, 1983a), and Page and Whitt (1973a, b). The following treatments are largely modified from Page (1974a).

Subgenus *Alvordius* Girard

This is the largest and most diversified subgenus of *Percina*, containing eight described and one or two undescribed species. Members of *Alvordius* are characterized by a naked breast, a non-serrate preoperculum, separate gill membranes, highly modified midventral scales in males, a broad frenum, absence of discrete breeding tubercles, and the absence of bright colors (except in *P. roanoka*). Tuberculate ridges occur on rays of the anal and pelvic fins in the three Tennessee species. All species have a prominent midlateral dark stripe or a row of dark blotches. Habitats range from pools in small creeks (*P. maculata*) and rivers (*P. macrocephala*) to swift riffles in moderate creeks and rivers (*P. crassa*, *P. roanoka*). In addition to species occurring in Tennessee (*macrocephala*, *maculata*, and one undescribed species), the subgenus contains *P. crassa*, *P. notogramma*, and *P. peltata* of Atlantic Coastal drainages, *P. gymnocephala* of the New River system of North Carolina, Virginia, and West Virginia, *P. roanoka* of Atlantic drainages and the New River system, and *P. pantherina* of the Little River system of Arkansas and Oklahoma. Two rather distinctive undescribed forms occur in the upper Mobile Basin (one of these occurs in the Conasauga River in Tennessee), but they are currently considered to be distinct from each other at only the racial or perhaps subspecies level. *Alvordius* species may be very similar in appearance to members of the subgenus *Hadropterus*, and juveniles of *P. macrocephala* are virtually identical to juveniles of the two species of *Odontopholis*. Systematics treated in part by Raney and Hubbs (1948), Mayden and Page (1979) and Beckham (1980).

Subgenus *Cottogaster* Putnam

Containing the smallest member of *Percina*, *P. copelandi*, which in addition to small maximum size, is distinguished by low meristic values (within range of many *Etheostoma*), the absence or virtual absence of a frenum, and the presence of both breeding tubercles and a complete row of modified midventral scales in males. Chromatic breeding colors are absent, the preoperculum has a smooth margin, and gill membranes are separate. Typical habitats are coarse sand and fine gravel shoal areas in large rivers. One or more additional species, closely related to *P. copelandi*, may be recognized from Gulf Coastal drainages in the future.

Subgenus *Ericosma* Jordan

This small subgenus contains two brightly colored species, *P. evides* and *P. palmaris*, both occurring in Tennessee. In addition to bright coloration of adult males, strongly developed breeding tubercles or tuberculate ridges and well-developed modified belly scales are present. Frenum present, preoperculum with smooth margin, gill membranes separate. Both species occur in shoal areas in large creeks and rivers.

Subgenus *Hadropterus* Agassiz

This is the most generalized subgenus of *Percina*; it contains the largest darter species, *Percina lenticula*, with a recorded standard length of 168 mm (Douglas, 1968), or a total length of nearly 8 in. A unique, and perhaps primitive, character of the subgenus is the typical presence of serrations on the margin of the preoperculum as in the genera *Perca* and *Stizostedion*. Additional characters are a well-developed row of modified midventral scales, a broad frenum, moderately connected gill membranes, and a vertical row of three dark blotches at the base of the caudal fin (Richards and Knapp, 1964). Chromatic breeding colors are absent except for a faint orange to yellow submarginal band in the spinous dorsal fin of *P. aurolineata* and *P. sciera apristis*. Discrete nuptial tubercles are absent, but tuberculate ridges occur on anal and pelvic fin rays (we have not examined nuptial *P. lenticula*). Our fauna contains two (*nigrofasciata*, *sciera*) of the four species. *Percina lenticula* has been collected in the Conasauga River, Georgia, within a few kilometers of the Tennessee border (Bryant et al., 1979b), and may eventually be taken in the Tennessee portion of that river. *Percina aurolineata* occurs in the Coosawattee portion of the Coosa River system in the lower Blue Ridge of northern Georgia, but differences in habitat characteristics and faunal associates suggest that it will not be found in the Conasauga portion of that system. Habitats for members of the subgenus range from pools to riffles and deep runs in small creeks to large rivers.

Subgenus *Hypohomus* Cope

Percina aurantiaca of the upper Tennessee River drainage is the only species. It is characterized by the bright yellow to orange colors on the sides, and a row of discrete dark spots on each side above the dark lateral stripe. Gill membranes are separate, the preoperculum has a smooth border, the frenum is well developed, tuberculate ridges are present on anal and pelvic fin rays, and modified midventral scales are very weakly developed. *Hypohomus*, along with the subgenera *Percina* and *Swainia*, retains the presumably primitive principal caudal fin ray count of 17. Habitats are pools and deep runs of clear upland rivers and large streams.

Subgenus *Imostoma* Jordan

Five species comprise the subgenus, which is unique among *Percina* in the excessive elongation of the anal fin in adult males. Modified midventral scales are poorly developed, the frenum is narrow to absent, gill membranes are separate, chromatic breeding colors are absent except for yellowish hues along the sides and a faint orange submarginal band in the dorsal fin (*P. shumardi*); nuptial tubercles are well developed. All species have eyes dorsally placed and close together. Four of the five species are characterized by the presence of four widely spaced dorsal saddles that angle down and forward. *Percina uranidea* occurs in the Ozark region and formerly occurred in the lower Wabash River; the remaining four species (*antesella*, *shumardi*, *tanasi*, *vigil*) occur in Tennessee. All species are prone to feed on snails. Habitats are sand and fine gravel shoal areas, primarily in lowland large creeks and rivers.

Subgenus *Odontopholis* Page
The two highly similar species are characterized by the presence of a keel-like extension of the ventral caudal fin base in breeding males and the proliferation of scales with extremely long cteni on the ventral portion of the body, including the breast, belly, and lower caudal peduncle. Modified midventral scales are restricted to the area between the pelvic fin bases. Frenum well developed, gill membranes separate, nuptial tubercles and chromatic breeding colors absent, preoperculum with smooth border. The subgenus consists of the undescribed species occurring in the Barren and Green river systems of Kentucky and Tennessee and the Kentucky River in Kentucky, and *P. cymatotaenia* of the Osage and Gasconade river systems (lower Missouri River drainage) of southcentral Missouri. Both are pool inhabitants of medium to large creeks, and they tend to swim above the bottom much of the time.

Subgenus *Percina* Haldeman
This group contains large and distinctive members of the genus. They are characterized by the presence of a conical, "pig-like" snout and a "tiger-stripe" pattern of numerous dark, vertical bars on a yellowish background. Frenum very broad, gill membranes separate, border of preoperculum smooth, modified midventral scales well developed, males may develop orange submarginal bands in the spinous dorsal fin, nuptial tubercles present in the form of tuberculate ridges on anal and pelvic fin rays and/or hardened swellings on ventral scales. The curious snout development is an apparent adaptation to stone-flipping behavior, in which the snout is used to flip over rocks during feeding. Page (1974a) regarded logperches as the most highly derived of the *Percina* subgenera. Systematics of the group is difficult. Until recent decades only two species, the widespread *P. caprodes* and *P. rex* (Roanoke River drainage, Virginia), were recognized. *Percina macrolepida* Stevenson (1971) and *P. carbonaria* (Baird and Girard) (See Jenkins, 1976; Morris and Page, 1981) of southwestern United States, and *P. burtoni* Fowler of the Tennessee and Cumberland drainages have been elevated from the synonymy of *P. caprodes*. Thompson (1978) indicated that as many as four additional logperches of eastern Gulf Coastal drainages (two occur in Tennessee) would eventually be recognized as distinct species and subsequently (1985) described one of these (*P. jenkinsi*) from the Conasauga River. Habitats range from deep riffles to pool areas in large streams and rivers, with *P. caprodes* tolerant of reservoirs and lakes.

Subgenus *Swainia* Jordan and Evermann
The five species of this subgenus are characterized by their long to very long snouts, and the presence of an orange submarginal band in the spinous dorsal fin. The frenum is well developed, there are 17 principal caudal fin rays, gill membranes are moderately connected, branchiostegal rays occasionally 7, preoperculum with smooth border, modified midventral scales well developed, discrete nuptial tubercles absent but tuberculate ridges present on anal and pelvic fin rays. In addition to the two Tennessee species (*P. phoxocephala* and *P. squamata*), *P. nasuta* occurs in the Ozark uplands, an undescribed species occurs in the Ouachita region (Thompson, 1980; Robison and Buchanan, 1988), and *P. oxyrhynchus* occurs in southern tributaries of the Ohio River. Habitats are typically swift gravel riffles or boulder runs of small to medium rivers, but *P. phoxocephala* occasionally occurs in smaller streams.

KEY TO THE TENNESSEE SPECIES

1. Total dorsal fin elements 30 or more; dorsum traversed by 15 or more narrow saddles; snout conical and "pig-like", with a whitish pad at the tip: subgenus *Percina*, the logperches 2
   Total dorsal fin elements 29 or fewer (rarely 30 in *aurantiaca* and *macrocephala*); dorsal saddles 12 or fewer or absent; snout pointed to blunt, but not "pig-like" with a padded tip 5
2. Spinous dorsal fin with a submarginal orange band (yellowish in juveniles, clear in preserved specimens) . . 3
   Spinous dorsal fin without clear or orange submarginal band 4

3. Dorsal saddles continuing on sides as vertical lateral bars extending near to or below lateral line; lateral blotches centered below lateral line (Pl. 290); nape completely scaled; Conasauga River . . . . *P.* (*Percina*) sp. p.593

Dorsal saddles giving way to dorsolateral reticulations or vermiculations; lateral blotches centered on lateral line (Pl. 274); nape partially naked; Tennessee and Cumberland drainages . . . . . . *P. burtoni* p.568

4. Total saddles anterior to dorsal fin usually 3, occasionally 4; total dorsal fin spines plus anal fin soft rays usually 25–26; secondary (narrower) dorsal saddles forming mostly uninterrupted bars laterally (Pl. 275); Tennessee drainage and northward, and Mississippi River . . . . *P. caprodes* p.569

Total saddles anterior to dorsal fin 5–6; total of dorsal fin spines and anal fin soft rays usually 27–29; secondary dorsal saddles mostly interrupted laterally (Pl. 278); Conasauga River . . . . . . *P. jenkinsi* p.574

5. Distance from tip of snout to gill juncture exceeding distance from gill juncture to pelvic fin base (Fig. 141a) 6

Distance from tip of snout to gill juncture equal to or less than distance from gill juncture to pelvic fin base (Fig. 141b) 7

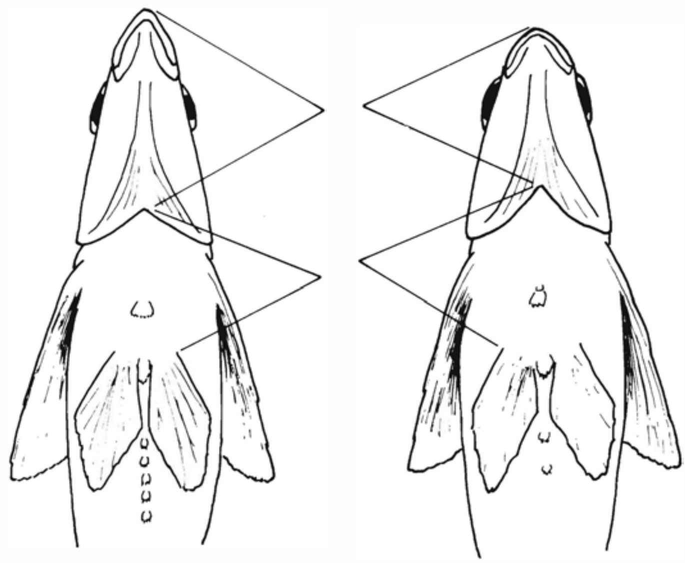


Figure 141. Comparison of snout to gill-juncture distances in *Percina* spp.: a) *P. phoxocephala* and *P. squamata*; b) other *Percina* spp.

6. Lateral-line scales usually fewer than 72; snout length about equal to eye diameter; lower Tennessee and Cumberland drainages and northward . . . . *P. phoxocephala* p.582

Lateral-line scales usually more than 72; snout length definitely exceeding eye diameter; upper Tennessee and upper Cumberland drainages . . . . *P. squamata* p.585

7. Premaxillary frenum (Fig. 14) absent or very weakly developed 8

Premaxillary frenum well developed 12

8. Dorsum with 4 or 5 prominent saddles (occasionally indistinct and represented by outlines) 9

Dorsum with 7 or more often ill defined saddles, specks or blotches 11

9. Anteriormost dorsal saddle entirely anterior to dorsal fin; Conasauga River . . . . *P. antesella* p.565

Anteriormost dorsal saddle partially or wholly beneath dorsal fin 10

10. Posterior margin of fourth dorsal saddle in contact with dorsal insertion of caudal fin (Fig. 142a); fifth dorsal saddle absent; anal fin soft rays usually 11–12; Tennessee River drainage .... *P. tanasi* p.587
Posterior margin of fourth dorsal saddle well in advance of caudal fin insertion (Fig. 142b); a fifth dorsal saddle often apparent straddling caudal fin insertion; anal fin soft rays usually 10–11; Tennessee and Mississippi drainages .... *P. vigil* p.590

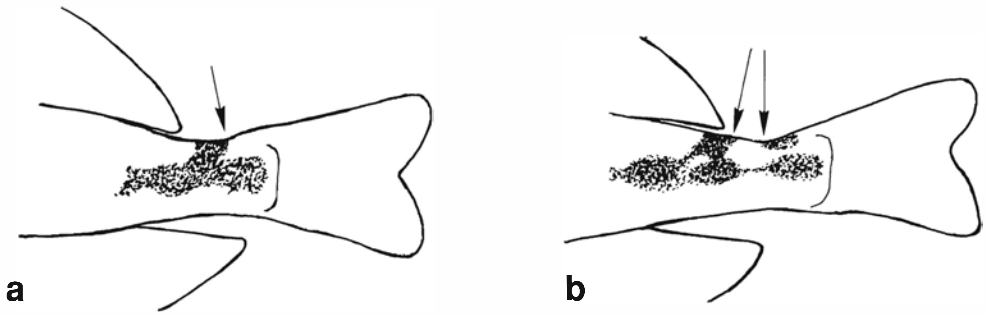


Figure 142. Positions of fourth dorsal saddle relative to caudal fin insertion in darters of subgenus *Imostoma*: a) *Percina tanasi*; b) *P. vigil*.

11. Anal fin soft rays 7–10; sides with blotches smaller than eye diameter (Pl. 276) .... *P. copelandi* p.571
Anal fin soft rays 11–13; sides with blotches larger than eye diameter (Pl. 285) .... *P. shumardi* p.584
12. Dorsum lacking saddles and usually with a row of small dark spots between dorsal fin and lateral blotches (Pl. 273); lateral-line scales 86 or more .... *P. aurantiaca* p.566
Dorsum with saddles or extensive dark markings; lateral-line scales usually 80 or fewer (occasionally more than 80 in *macrocephala*) 13
13. Sides with 12 or more, usually vertically elongate, dark blotches (Pl. 281); Conasauga River .... *Percina nigrofasciata* p.579
Sides with 11 or fewer dark blotches 14
14. Height of lateral blotches on anterior half of body exceeding their width (variable in *evides* and *sciera*) .. 15
Height of lateral blotches on anterior half of body not exceeding their width (blotches may be discrete, or confluent and forming an irregular lateral stripe) 17
15. Suborbital bar present (Pl. 277); males with orange belly; Tennessee drainage and northward .... *P. evides* (in part, see couplet 20) p.572
Suborbital bar absent (rarely present in *sciera*) 16
16. Three distinct vertically arranged dark basicaudal spots present (Pl. 284), the dorsal one isolated and the lower two often coalesced; lateral blotches usually black, oval, somewhat confluent, and not in contact with any dorsal saddles; Tennessee and Mississippi drainages and northward (*P. lenticula*, if present in Conasauga R., may key here) .... *P. sciera* (in part, see couplet 14) p.583
Basicaudal spots small, vague, and isolated by two conspicuous pale areas (Pl. 282); lateral blotches brownish or greenish, quadrate, and discrete, some usually contiguous with dorsal saddles; Conasauga River .... *P. palmaris* p.580
17. Three equally distinct, vertically arranged dark basicaudal spots present (Pls. 284, 289), the dorsal one isolated and the lower two often coalesced 18
Basicaudal spot single, median, and distinct, or indistinct from preceding lateral blotch (if three spots are present, the dorsal one is vague except in occasional specimens of *P.* (*Alvordius*) sp.) 19
18. Lateral-line scales 57–69; large lateral blotches usually nine or more; spinous dorsal fin never with bands (Pl. 284); Tennessee and Mississippi drainages and northward .... *P. sciera* (in part, see couplet 14) p.583
Lateral-line scales 66–73; large lateral blotches seven to eight; spinous dorsal fin of larger specimens with dusky bands (Pl. 289); Conasauga River .... *P.* (*Alvordius*) sp. (in part, see couplet 17) p.591

19. Lateral blotches discrete or narrowly confluent 20
Lateral blotches usually broadly confluent, at least anteriorly, forming a broad lateral stripe (sometimes narrowly joined in *P.* (*Alvordius*) sp.) 21
20. Spinous dorsal fin with dark basal blotch anteriorly; caudal spot distinct; conspicuous pale basicaudal areas lacking (Pl. 280); snout pointed; Tennessee and Mississippi drainages and northward . . . . *P. maculata* p.577
Spinous dorsal fin uniformly pigmented basally; caudal spot little distinct from posterior lateral blotch; two conspicuous pale basicaudal areas present (Pl. 277); snout blunt; males with orange bellies; Tennessee drainage and northward . . . . *P. evides* (in part, see couplet 13)
21. Row of enlarged, modified midventral scales lacking on belly (1 or 2 present between pelvic fin bases); males with a rounded keel ventrally at caudal fin base; cheeks completely scaled; Barren River system . . . . *P.* (*Odontopholis*) sp. p.594
Row of enlarged, modified midventral scales present (may be absent in specimens less than 45 mm SL); males lacking caudal keel; cheek scales present or absent 22
22. Cheeks mostly naked; total dorsal fin elements usually 27 or more; Tennessee drainage and northward . . . . *P. macrocephala* p.575
Cheeks well scaled; total dorsal fin elements usually 26 or fewer; Conasauga River . . . . *P.* (*Alvordius*) sp. (in part, see couplet 17) p. 591

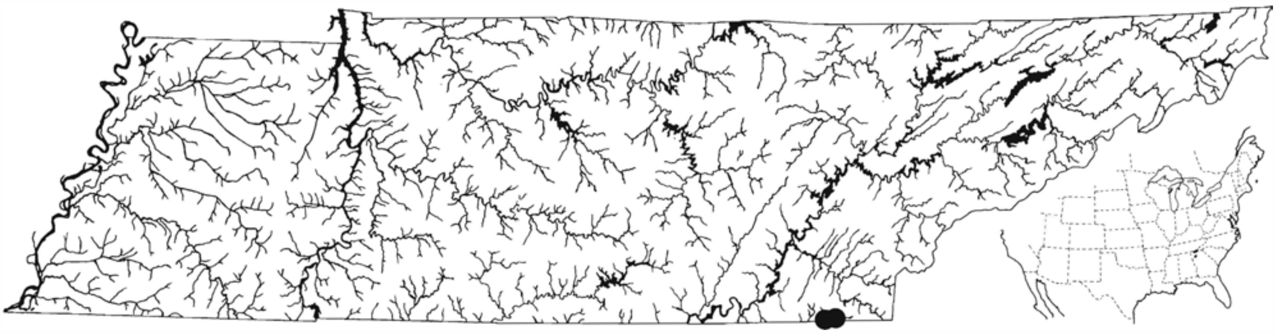
Percina antesella Williams and Etnier.

Amber darter

Plate 272. *Percina antesella*, amber darter, 57 mm SL, Etowah R., GA.

Characters: Lateral-line scales 54–65 (51–66). Dorsal fin with 10–11 (9–11) spines and 13–14 (12–15) soft rays. Anal fin soft rays 9–10 (8–10). Pectoral fin rays 13–15. Principal caudal fin rays 15–17. Gill rakers 13–15, length of longest rakers about 3–4 times their basal width. Vertebrae 38–40. Premaxillary frenum usually absent. Gill membranes barely connected. Opercles partially scaled; cheeks, anterior nape area, and belly naked; breast naked or with a few embedded scales. Modified midventral scales are restricted to the posterior portion of the belly in males. Color golden brown dorsally and pale below, with four distinctive dark dorsal saddles that angle down and forward; the most anterior dorsal saddle is completely anterior to the origin of the dorsal fin. Dark subocular bar well developed. Rays of all fins except anal and pelvics are speckled. Basal and marginal dark bands weakly developed on spinous dorsal fin of some specimens. As in other members of the subgenus *Imostoma*, the anal fin of males is much longer than that of females. Unlike other *Imostoma*, male amber darters have a ventral flange at the base of the caudal fin that is formed by modified procurrent rays. Nuptial tubercles develop on this flange as well as on rays of anal and pelvic fins and distal portions of pectoral fin rays; weak tuberculation develops on scales of belly and lower caudal peduncle.

Biology: In Tennessee the amber darter is restricted to the main channel of the Conasauga River where it occurs in flowing pool areas and deeper runs with clean substrates of sand and fine gravel with scattered boulders. Freeman (1983) found it associated with vegetation in riffle areas in midsummer. As is typical of the subgenus, spawning occurs early in the year, during late winter and early spring. At this time nuptial specimens may be collected from swift gravel shoal areas where spawning probably occurs. Gravid females have been collected as late as April. Males flowing milt have been taken as early as November, but this phenomenon has also been observed in *P. tanasi* several months before actual spawning (Starnes, 1977). As in other *Imostoma*, the amber darter is prone to feed on snails and limpets as evidenced by a small number of stomachs examined; these stomachs also contained some immature aquatic insects, particularly caddisfly larvae and mayfly nymphs (our data and Freeman, 1983). Length classes of specimens in our collection indicate that young reach about 45 mm after 1 year, 50–60 mm after 2 years, and may live to be about 4 years old. Sexual maturity is probably attained by some specimens after slightly over 1 year's growth, and all are mature at 2 years. Maximum total length 80 mm (3.15 in).



Range Map 263. *Percina antesella*, amber darter.

Distribution and Status: The amber darter is an upper Coosa River endemic known only from a few miles of the Conasauga River in southeastern Tennessee and adjacent Georgia (Bryant et al., 1979b; Freeman, 1983) and the Etowah River system farther to the south in Georgia. Prior to 1980, it was known in the Etowah system only from three specimens from Shoal Creek, a major tributary in Cherokee County, Georgia, collected in 1948. Shoal Creek was subsequently innundated by Alatoona Reservoir. A few specimens taken from the Etowah River above Alatoona Reservoir since 1980 indicate that it has persisted in low numbers in that portion of the river (Etnier et al., 1981; R. T. Bryant and B. J. Freeman, pers. comm.). In the Conasauga River, specimens have been taken only from the main channel from near the Polk-Bradley County line, Tennessee, downstream to Tibbs Bridge (Murray County Road 109), a distance of only about 60 river kilometers. The amber darter was federally listed as an Endangered Species in 1985 and a recovery plan (Biggins, 1986) was subsequently devised for its protection. The population remains healthy and should remain so as long as the Conasauga ecosystem is protected.

Similar Sympatric Species: The trispot darter, *Etheostoma trisella*, is superficially similar in having a low number of pronounced dorsal saddles. It has only three saddles, is gray rather than golden brown, develops red and green breeding colors, inhabits slackwater areas when present in the main channel, and differs in a number of counts and morphological characters.

Systematics: Subgenus *Imostoma*; interrelationships with other members of subgenus unclear (Williams and Etnier, 1977).

Etymology: *antesella* = anterior saddle, in reference to the diagnostic position of that saddle.

Percina aurantiaca (Cope).

Tangerine darter

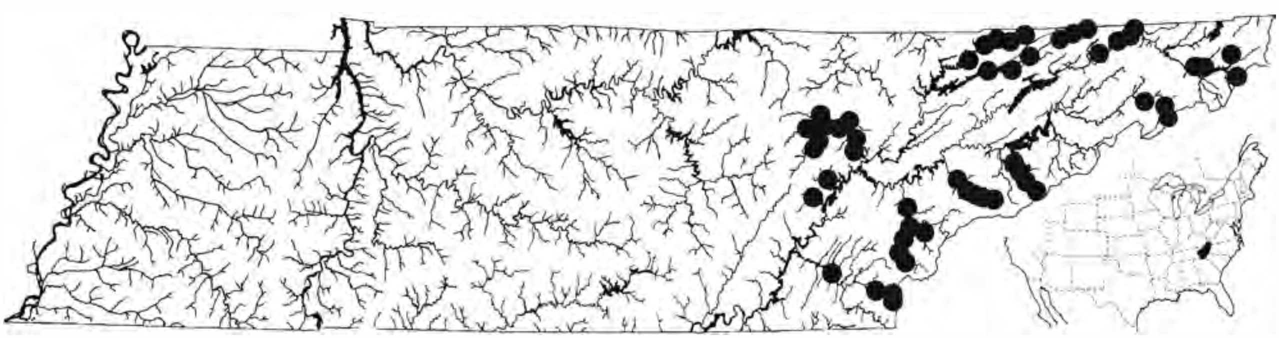
Characters: Lateral-line scales 84–94 (82–99). Dorsal fin with 14–16 (13–16) spines and 13–15 (12–15) soft rays. Anal fin soft rays 10–11 (9–12). Pectoral fin rays 14–15 (13–16). Principal caudal fin rays 17 (16–17). Gill rakers 11–15, length of longest rakers 3 (young) to 5 (adults) times their basal width. Vertebrae 43–46. Premaxillary frenum present. Gill membranes barely connected or separate. Breast naked anteriad; belly, opercles, cheeks, and nape scaled. Modified midventral scales poorly to moderately developed in nuptial males, but apparent only between pelvic bases in juveniles, females, and non-nuptial males. Adult males are among our most strikingly colored fishes. Females and juveniles are less brilliantly hued. Dorsum straw yellow to olivaceous and belly and lower head vary from pale yellow in juveniles, females, and subnuptial males to brilliant orange in breeding males. The row of small black spots in the dorsolateral area above the wide black lateral stripe is unique to this species. Dorsal fin of nuptial males bright orange, that of females pale yellow. Dusky ventral fins become blackened in nuptial males and have iridescent blue highlights. Discrete tubercles do not develop, but nuptial males have elevated tuberculate ridges on anal fin rays and spines, and on ventral surface of the pelvic fin rays and spine; epidermal tissues also proliferate dorsally on caudal peduncle of nuptial males and may completely conceal scales in that area (Thompson, 1977).

Biology: The tangerine darter is an inhabitant of clearer portions of large to moderate sized headwater tributaries to the Tennessee River. Altitude of these habitats ranges from about 260 to 550 m. It frequents deeper riffles and runs with boulders, large rubble, and bedrock substrates most of the year but moves into deeper pools in winter.

Plate 273. *Percina aurantiaca*, tangerine darter, male, 104 mm SL, Little Tennessee R. system, NC.

Juveniles often occur in pool areas with silty sand substrates. Biology has been studied by Howell (1971). Spawning occurs on gravel riffles primarily during May and June, with 3- and 4-year-olds comprising the bulk of the spawners. Females produce 400–1100 ova, with maturation of immature ova occurring during the spawning season as mature ones are expended. Howell felt that water temperature keyed the onset of spawning. He observed that a male dominance pattern developed, with the dominant male exhibiting the most intense coloration and participating in spawning most often, but territories were not defended. During the spawning act, the male rests upon the female's back, straddling her nape with his pelvic fins and positioning his peduncle along the female's such that the genital openings are in proximity. Eggs are extruded onto the gravel and into interstices by the female and fertilized by milt from the male, at which time both participants exhibit quivering behavior and rapid respiration. This general behavior, with minor variations, has been displayed by all members of *Percina* that have been observed spawning. Total lengths at the end of the first 4 years are 50–60, 85–90, 105–120, and 130 mm or more, respectively. Maximum life span is a little over 4 years. Diet studies and feeding observations indicated that food is procured primarily from riverweed (*Podostemum*) growths, a relatively close-cropped aquatic plant which is attached to rocks in areas having moderate to fast current. Juveniles feed principally on mayfly and dipteran larvae, while the adult diet is dominated by caddisfly larvae. Newly hatched *P. aurantiaca* were found to feed on microcrustacea such as copepods and cladocerans, and tiny mayfly larvae. Adult tangerine darters, sometimes termed "river slicks" by mountain folk, are occasionally taken by anglers using small baited hooks or small artificial flies. This is one of our largest darters, reaching 172 mm (6.75 in) total length.

Distribution and Status: Confined to the upper Tennessee River drainage. Today, the tangerine darter reaches maximum abundance in smaller rivers tributary to the upper Tennessee, such as the Emory, Little, Little Pigeon, Tellico, and Hiwassee rivers. Its distribution has been fragmented by the many storage reservoirs on those tributaries, but it continues to be reasonably widespread and abundant. It may have occurred in the main channel of the Tennessee River prior to impoundments. It was formerly thought to be quite rare, but this idea was certainly influenced by the difficulty of effectively seining in its preferred habitat, where it can be common



Range Map 264. *Percina aurantiaca*, tangerine darter.

based on snorkeling observations. Adults are much easier to capture with small dipnets while snorkeling than by seining. It is treated as a Species of Special Concern by the Tennessee Heritage Program.

Similar Sympatric Species: Superficially resembles the longhead darter, *Percina macrocephala*, which has a similar wide black lateral stripe but has a much sharper snout, lacks bright colors, and lacks the row of small black spots in the dorsolateral area.

Systematics: The only member of the subgenus *Hypohomus*. Systematics have been reviewed by Thompson (1977) who did not hypothesize relationships.

Etymology: *aurantiaca* = orange-colored.

Percina burtoni Fowler.

Blotchside logperch

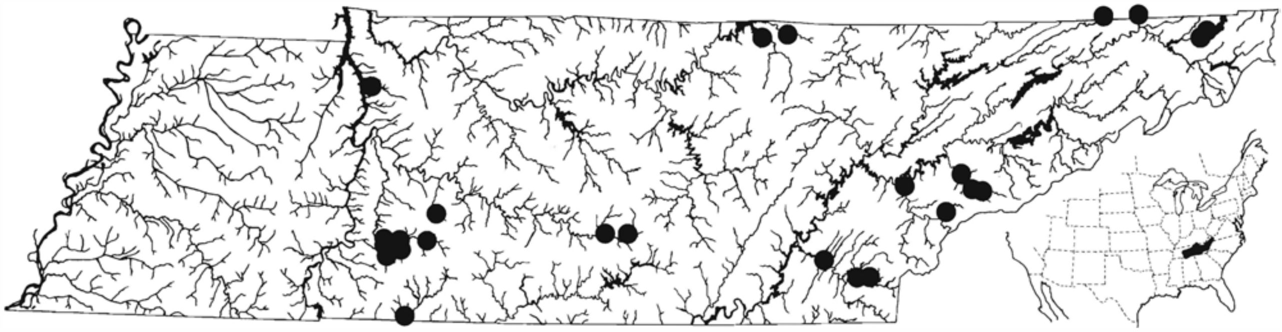
Plate 274a. *Percina burtoni*, blotchside logperch, adult, 95 mm SL, Little R., TN.

Plate 274b. *Percina burtoni*, blotchside logperch, juvenile, 63 mm SL, Little R., TN.

Characters: Lateral-line scales 79–94. Dorsal fin with 15–18 spines and 14–16 soft rays. Anal fin soft rays 11–13. Pectoral fin rays 14–15. Principal caudal fin rays 16–17. Gill rakers 15–17, length of longest rakers about 4 (adults) to 6 (young) times their basal width. Premaxillary frenum present. Gill membranes separate. Nape partially naked, cheeks and opercles scaled, breast naked except for modified scales in middle, belly partially naked to fully scaled, prepectoral area usually with a few scales. Modified midventral scales well developed. Ground color of body and fins pale yellowish green. Dorsum with about 11 quadrate saddles interspersed with narrow lines and vermiculations. Vermiculations in the dorsolateral area vary in intensity as do the eight or so lateral blotches and suborbital bar. A distinct caudal spot is usually present. Spinous dorsal fin with dark lower half or scattered dark spots, and an orange submarginal band most evident in breeding males. Soft dorsal and caudal fin speckled with dark pigment, mostly on the rays. Other fins typically immaculate. The cheeks and sides of the body of nuptial males are iridescent blue-green. Nuptial tubercles (R. E. Jenkins, pers. comm.) are essentially as described for *P. caprodes*.

Biology: Available biological information is restricted to a few observations. *Percina burtoni* is an inhabitant of large creeks and small to medium rivers with low turbidity. Preferred habitat seems to be areas of large gravel and small cobble substrates with moderate current and usually a half meter or more in depth. Spawning probably occurs in April and May, with spawning behavior presumably similar to that described for *P. caprodes*. As in other logperches, feeding is conducted by flipping over stones with the padded snout and dining on the larval aquatic insects thus revealed. Diet includes mayfly, caddisfly, stonefly, midge, and blackfly larvae and adult and larval riffle beetles. Noel Burkhead (pers. comm.) filmed a blotchside logperch while it held the stone case of a caddisfly larva (*Glossosoma*) in its mouth, smashed it against a rock with lateral movements of its head, and then consumed the larva. Gilt darters (*P. evides*) have been observed to feed with this logperch, following them about and dashing in to steal morsels as stones are turned over. Length distributions of specimens in our collections indicate that growth is quite rapid, with young reaching total lengths of about 60–70 mm after 1 year. At 2 years lengths are about 100 mm, and most specimens probably are not sexually mature until age 3. Maximum total length 160 mm (6.3 in) recorded from a Copper Creek, Virginia, specimen (R. E. Jenkins, pers. comm.), and a Little River specimen (R. D. Suttkus, pers. comm.).

Distribution and Status: The blotchside logperch is a Tennessee and Cumberland river drainage endemic that persists only in better quality creeks and rivers. Although it continues to be fairly widespread throughout the Tennessee drainage, it is usually quite rare and localized. Consistently collected in portions of the Little and Duck rivers in Tennessee, and the North Fork Holston and Copper Creek in Virginia. We are unaware of any recent records from the Cumberland River drainage, but earlier records are available from the Little



Range Map 265. *Percina burtoni*, blotchside logperch.

South Fork and from the Wolf and Obey rivers. It may be extirpated from the entire Cumberland River drainage, and it no longer occurs in several Tennessee River drainage streams from which earlier records are available. It is not an easy species to capture, and both abundance and total distribution may be slightly greater than records indicate. It is included in Tennessee's list of rare vertebrates as a Species of Special Concern (Starnes and Etnier, 1980).

Similar Sympatric Species: The logperch, *Percina caprodes*, is broadly sympatric and usually much more common than *P. burtoni*. Sympatric *P. caprodes* lack an orange band in the spinous dorsal fin, large lateral blotches, and dorsolateral vermiculations, and have a completely scaled nape.

Systematics: Subgenus *Percina*. This distinctive species was regarded as a subspecies, *P. caprodes burtoni*, by its author (Fowler, 1945). Most similar to the Roanoke logperch, *P. rex*.

Etymology: *burtoni* is a patronym for E. Milby Burton, former noted naturalist at the Charleston Museum (S.C.) who collected the type.

Percina caprodes (Rafinesque).

Logperch

Characters: Lateral-line scales 82–92 in our area (extremes throughout range 67–100). Dorsal fin with 14–16 (12–17) spines and 15–17 (14–18) soft rays. Anal fin soft rays 9–12 (8–13). Pectoral fin rays 14–15 (12–16). Principal caudal fin rays 17. Gill rakers 15–17, length of longest rakers 5–7 times their basal width. Vertebrae 40–46. Premaxillary frenum present. Gill membranes separate. Breast (except for modified scales) and prepectoral area naked, belly naked anteriad to naked along entire midline except for median row of modified scales. Cheeks, opercles, and nape scaled. Modified midventral scales well developed. Ground color pale yellowish traversed by thin dark dorsal saddles that extend well down the sides and give the distinctive "tiger stripe" appearance. The 8–12 primary saddles (usually darker) extend well below the lateral line, and their lower ends may expand slightly to form small blotches. The 7–14 intervening secondary saddles extend only to or above the lateral line. At times, especially in specimens collected at night, large dorsal blotches are present anterior to the spinous dorsal fin, at its posterior base, and posterior to the soft dorsal fin. In aquaria we have noted logperch to develop this color pattern and then completely bury themselves in the gravel substrate when aggravated. Spinous dorsal fin dusky basally and marginally, with submarginal clear band. Soft dorsal and caudal fins have dark marks on the rays which may be arranged in bands. Other fins clear, or pectoral and pelvic fins may have lightly speckled rays. The yellowish color of males may brighten somewhat during the breeding season. Breeding tubercles occur on scales of ventral portions of body and caudal peduncle, including modified midventral scales. Tuberculate ridges develop on all spines and rays of anal and pelvic fins, and lower rays of pectoral and caudal fins.

Biology: Due to the widespread and common occurrence of the logperch, it is one of the most studied darters. In Tennessee, it occurs in larger creeks and rivers, and also in the lower reaches of small tributaries as well as in reservoirs. It is less common in small streams, and its presence in these may be somewhat seasonal and related to spawning. Spawning occurs in late spring and early summer in gravel runs. Lake populations in northern United States spawn on wave-swept beaches, but our reservoir populations probably migrate into tributaries to spawn; logperch are notably abundant in small

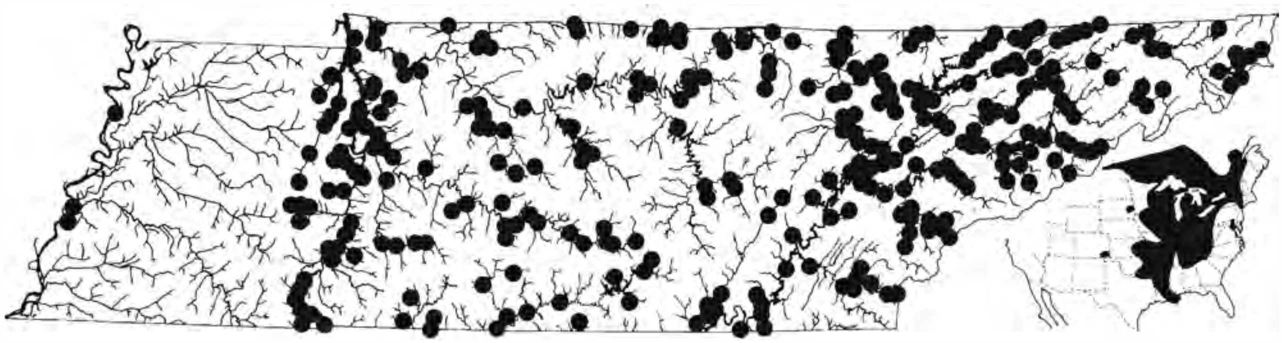
Plate 275. *Percina caprodes*, logperch, 115 mm SL, Stones R. system, TN.

tributaries to reservoirs during the spawning season. Logperch are known to occasionally hybridize with other darters (e.g., *P. maculata* [Page, 1976b]). Our collection contains hybrids of *P. caprodes* with *P. aurantiaca*, *P. macrocephala*, *P. maculata*, *P. phoxocephala*, *P. shumardi*, *Etheostoma rufilineatum*, and *E. zonale*. Spawning behavior of *P. caprodes* has been described in detail by Reighard (1913) and Winn (1958a,b). Spawning migrations definitely occur, and aggregations of logperch gather at favored gravel shoals or runs. Males are nonterritorial and several may follow a single female until she submits to mounting. A male mounts the female by straddling her dorsum with his pelvic fins and bending his caudal region beneath the female's. Both sexes vibrate vigorously as eggs and milt are extruded and partially buried in the substrate. Exposed eggs are usually eaten by the other males. Fecundity of females is high, ranging from about 1,000 to 3,000 ova per year (Winn, 1958b). Eggs are adhesive and demersal (heavier than water), thus allowing them to remain in the substrate. Early development has been described by Cooper (1978) and Simon (1985a). Hatching requires about 200 hours at 16.5 C, 120–144 hours at 22 C. Larvae are 4.5–5.7 mm long at hatching and transform to juveniles between 18 and 24 mm. Logperches grow to about 70 mm during the first year. Two-year-olds average 100 mm or so, and length is about 120 mm at the end of 3 years (Thomas, 1970). Logperch feed on a variety of invertebrates which they often obtain in characteristic manner by flipping over small stones with their padded snout and eating the organisms living beneath. This procedure makes available to them a wide range of organisms including larvae of midges, mayflies, caddisflies (especially hydropsychids), riffle beetles, stoneflies, limpets, and fish eggs (Turner, 1921; Thomas, 1970; Starnes, 1977). Reservoir populations have been reported to feed on bottom-dwelling midge larvae and burrowing ephemerid mayflies (Mullan et al., 1968). Young feed on microcrustacea. Logperch are occasionally seined along with minnows and used as bait by anglers, and are locally known as "jacks". Larger specimens may surprise anglers fishing with small baited hooks or small lures. Maximum total length about 165 mm (6.5 in).

Distribution and Status: The logperch is widespread in eastern and central North America in the Great Lakes and several Atlantic coastal drainages and the Mississippi River basin. It is common throughout the Ohio, Tennessee, and Cumberland drainages except in higher-elevation tributaries. It occurs in the Cumberland drainage above Cumberland Falls. It is uncommon in the main channel of the Mississippi River and is apparently absent from its eastern tributaries in Tennessee, perhaps due to the lack of gravel substrates in these streams.

Similar Sympatric Species: *Percina burtoni* is broadly sympatric with *P. caprodes* in portions of the Tennessee and Cumberland drainages but is much more rare, being restricted to clearer rivers. See comments under *P. burtoni* regarding characters. The slenderhead darter (*P. phoxocephala*) of middle Tennessee and olive darter (*P. squamata*) of east Tennessee resemble the logperch in snout shape, body form, and coloration, but have dorsal vermiculations rather than saddles, an orange dorsal fin band, and lower scale and fin ray counts.

Systematics: Subgenus *Percina*. Morris and Page (1981) regarded *caprodes* forms occurring in the Tennessee drainage and northward through the Ohio basin as the nominate subspecies, *P. c. caprodes*. They described a new subspecies, *P. c. fulvitaenia*, from the Ozark region and regarded logperches occurring in the main channel of the Mississippi River in west Ten-



Range Map 266. *Percina caprodes*, logperch (range extends north and west off inset to southern Hudson Bay and to central Manitoba).

nessee as intergrades between these two subspecies. A third subspecies, *P. c. semifasciata* DeKay, occupies the more northerly portions of the range from northern Illinois northward. The systematics of logperches is highly complex and future revisions may result in different species concepts.

Etymology: *caprodes* = pig-like, doubtless in reference to the snout shape.

Percina copelandi (Jordan).

Channel darter

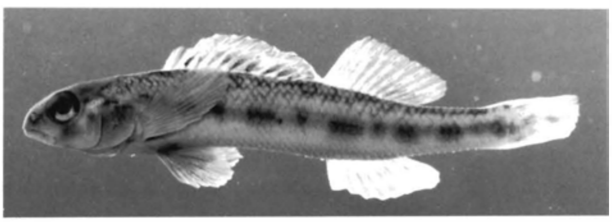
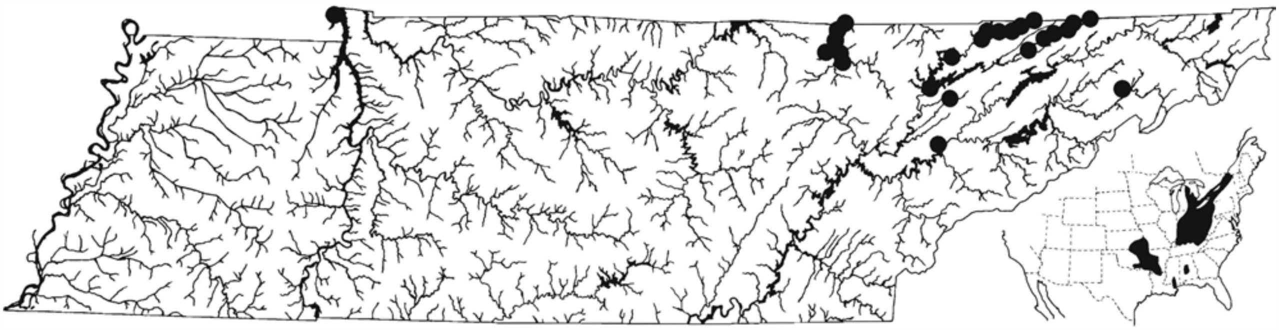


Plate 276. *Percina copelandi*, channel darter, preserved specimen, 41 mm SL, Elk R., WV.

Characters: Lateral-line scales 43–61 (46–56 in 54 Tennessee specimens). Dorsal fin with 9–12 (9–11 in 42 Tennessee specimens) spines and 10–14 (11–12 in 41 of 42 Tennessee specimens) soft rays. Anal fin soft rays 7–10 (8–9 in Tennessee). Pectoral fin rays 13–15 (13–14 in Tennessee). Principal caudal fin rays 16 (15–17). Gill rakers 12–15, length of longest rakers about 4 times basal width. Premaxillary frenum absent. Gill membranes separate. Vertebrae 37–40. Tennessee specimens have small naked areas at the anterior portion of the nape and belly. Cheeks and opercles scaled. Breast (except for 1–2 modified scales in middle) and prepectoral area naked. Modified midventral scales large and in a nearly continuous row in males. Ground color grayish to olivaceous, usually light brown. Dorsal markings consist of speckling and seven to eight dorsal saddles, which may be poorly defined. Fin membranes clear except for weak basal and submarginal dark bands in spinous dorsal fin and scattered dark speckling on rays of other fins. In breeding males, the nine to ten lateral blotches become enlarged and fused and have a faint iridescent blue color, as does the darkened breast. Pelvic and anal fins also blacken and dark bands in the spinous dorsal fin intensify. Nuptial tubercles in specimens we have examined are restricted to tuberculate ridges on spines and rays of anal and pelvic fins. Denoncourt (1976) noted similar tubercle development.

Biology: The diminutive channel darter is chiefly an inhabitant of rivers, where it occurs in sandy areas and gravel shoals. Northern populations occur along the margins of some larger lakes. In Michigan, spawning occurs in July (Winn, 1953), but in our area specimens from late May appear to be in spawning condition, and Oklahoma populations apparently spawn in June (Hubbs and Bryan, 1975). Spawning sites, to which migrations occur, are in areas of swift current over gravel and sand. Males are reportedly somewhat territorial, maintaining areas less than 1 m in diameter, usually with a large rock for cover. Females move in from deeper water from time to time and traverse the spawning territories, promiscuously mating with several males (Winn, 1953, 1958a). Mating procedure is essentially as described for *P. caprodes*. Eggs are buried in the substrate, and some incidental protection is afforded by the male's maintaining the surrounding territory for a time. Fecundity of females averaged about 400 ova at age 1 and 700 at age 2. At 15–20 C, hatching requires 6–10 days (Hubbs and Bryan, 1975). Except for a description based on a single supposed larval specimen (Fish, 1932), other aspects of early development or age and growth have not been published to our knowledge.



Range Map 267. *Percina copelandi*, channel darter.

None of our collections contains more than two distinct size groups, and life span is probably no more than 2.5 to 3.5 years; lengths of 35–40 mm are apparently reached after 1 year's growth, and these specimens are presumably sexually mature. Two-year-olds are about 50–55 mm long in our area. Turner (1921) and Winn (1953) summarized food data based on small numbers of midwestern specimens. Principal food was midge larvae, with small numbers of mayfly and caddisfly immatures also consumed. Small prey size may reflect the small size of the channel darter or be related to the predominance of these smaller organisms in the finer substrates which it frequents. Channel darters in our area apparently retreat to pool areas during winter months. Maximum total length about 60 mm (2.4 in) for our form, but we have a 70 mm specimen from the Pascagoula River drainage.

Distribution and Status: Channel darters occur in the lower Great Lakes drainage and Ohio River basin, and west of the Mississippi River in upland portions of the Red and Arkansas river drainages. In Tennessee, the channel darter is currently restricted, so far as is known, to the Big South Fork of the Cumberland and the Clinch and Powell rivers (Tennessee drainage) above Norris Reservoir. Preimpoundment records are available from the Knoxville area and the lower Tennessee River, and three specimens were collected from College Creek, a small tributary to the Nolichucky River at Tusculum, Greene County, Tennessee, in February 1947, by Mike Wright (Univ. Mich. Mus. Zool. 157290). It may be seasonally common, but apparent fluctuations in abundance are extreme. In the Clinch River it is often one of the most abundant darters in spring and summer, but our annual fall collecting trips (usually late October) to the same area rarely produce any specimens. The few October specimens we have are from silty pool areas, suggesting a very different winter habitat. It is also possible that life span is even shorter than previously suggested and that few individuals live past their second summer.

Similar Sympatric Species: The channel darter, especially females, would most likely be confused with members of the genus *Etheostoma* rather than other *Percina* species. In Tennessee it occurs with *E. stigmaeum* in the Clinch and Powell rivers; this species, as well as *E. nigrum* and *E. chlorosomum*, with which the channel darter is sympatric outside of Tennessee, have somewhat similar pigmentation. All of these lack the modified midventral scales that are diagnostic for males of the genus *Percina* and tend to have W-shaped rather than round lateral blotches.

Systematics: Subgenus *Cottogaster*. R. D. Suttkus, who is studying the systematics of the group, indicates (pers. comm.) that one or more eastern Gulf drainage forms may eventually be recognized as distinct species.

Etymology: *copelandi* is a patronym for H. E. Copeland, who discovered the species.

Percina evides (Jordan and Copeland).

Gilt darter

Characters: Lateral-line scales 54–69 (51–76). Dorsal fin with 11–13 (10–14) spines and 11–13 (10–14) soft rays. Anal fin soft rays 7–9 (5–10). Pectoral fin rays 13–15 (11–16). Principal caudal fin rays 17. Gill rakers 15–17, length of longest rakers 4 times their basal width. Vertebrae 37–42. Premaxillary frenum present. Gill membranes barely connected or separate. Scales few or absent on cheeks. Opercles and nape scaled. Breast and belly (except for modified midventral scales) and prepectoral area naked. Modified midventral scales well developed in males and occasionally present in females. Dorsal pigmentation consists of about seven dorsal saddles that become less conspicuous with age. Subadults and mature females are olivaceous dorsally and pale yellowish below with five to seven black, rectangular lateral blotches. Suborbital bar usually prominent, and two pale basicaudal areas are characteristic. Dark basal and submarginal bands present in spinous dorsal fin, and dusky pigment present in membranes of the soft dorsal fin and basal portions of anal fin membranes. Caudal fin clear to distinctly banded, pectoral and pelvic fins dusky (mature males) to clear. Adult males, particularly nuptial specimens, are among the most brilliantly colored darters. Lateral blotches become diffuse and highly iridescent blue-green while the belly, lower head, and spinous dorsal fin are brilliant orange with gold highlights. Nuptial females actually become less yellowish on the venter. Tuberculation of breeding males is the most highly developed of any species of darter. Tubercles occur over much of ventral surface of the body including belly and caudal peduncle scales as well as on rays of pelvic and anal fins and lower caudal fin rays. It was the conspicuous tuberculation of *P. evides* that first caught the eye of early ichthyologists (Jordan, 1877b) and brought to attention the existence of these structures in the family Percidae (Collette, 1965).

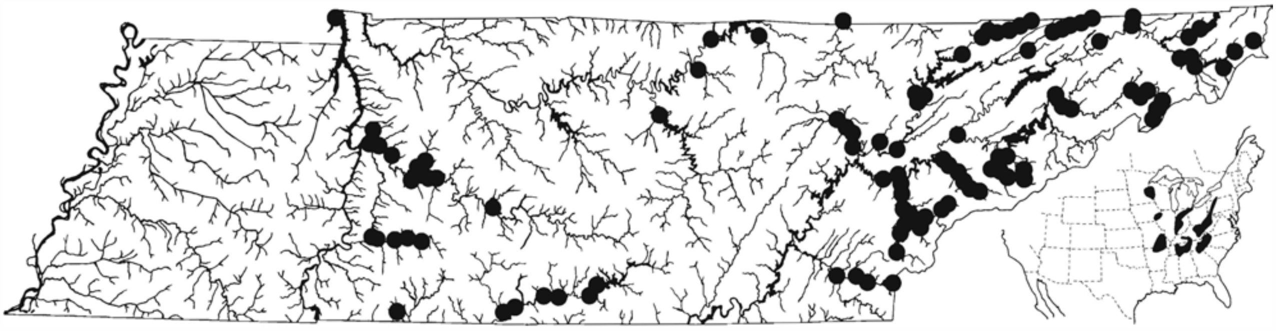
Biology: The gilt darter is an inhabitant of upland rivers where it occurs in shoal areas having moderate to fast current and substrates of gravel, sand, and scattered

Plate 277a. *Percina evides*, gilt darter, female, 42 mm SL, Clinch R., TN.

rubble free of vegetation. Habitat streams are usually clear or only slightly turbid and typically free of excessive silt. Gilt darters move to deeper portions of riffles in winter (Hatch, 1982; 1986). The breeding season extends from April through early July. Breeding behavior (Page et al., 1982) was observed in Little River, Tennessee, from 2 June through 9 July at water temperature of 17–20 C in the upper portions of riffles with sand and gravel substrates interspersed with larger cobbles and boulders. Hatch (1982) observed males to establish specific territories unlike other species of *Percina*. The spawning act differs little from that described for *P. caprodes*. According to Hatch, fecundity of females ranges from about 130–400 mature ova, and egg and larval stages are completed in 2 weeks. Denoncourt (1969) stated that *P. evides* attained a standard length of 34–40 mm at 3 months and averaged about 50 mm SL at 1 year. Total lengths of apparent age classes in several of our larger fall collections from the Duck, Little Tennessee, and Nolichucky rivers ranged from 45–50 mm for young-of-the-year, 60–70 mm for yearlings, and about 80 mm for specimens apparently ending their third summer. Males grow faster and to larger size than females (Hatch, 1982). Dietary information is available for gilt darters from the Little Tennessee River (Starnes, 1977; Hickman and Fitz, 1978), where food consisted of larvae of hydropsychid caddisflies, midges, mayflies, and (especially during warmer months) blackflies. We have observed gilt darters feeding in association with logperches (*P. caprodes* and *P. burtoni*), following them about as they engage in their stone-flipping behavior and rushing in to "steal" the food items revealed beneath. Maximum length 94 mm (3.7 in) from Ozark region (Denoncourt, 1969). Our largest specimens, from the Duck River, are 77 mm (3 in) total length.

Distribution and Status: Widespread in upland portions of Mississippi Basin from New York to Minnesota

Plate 277b. *Percina evides*, gilt darter, male, 62 mm SL, Little Tennessee R. system, NC.



Range Map 268. *Percina evides*, gilt darter.

south to White River system of Arkansas and the Tennessee River; avoids Coastal Plain. The gilt darter continues to be reasonably widespread in Tennessee, and it is often common in our better quality rivers. It is apparently subject to extirpation in degraded streams and has disappeared from much of its former range in the Midwest (Page, 1983a).

Similar Sympatric Species: Females and young of the gilt darter, with their black lateral blotches and somber coloration, resemble members of the *Percina* subgenus *Alvordius*, including *P. macrocephala* and *P. maculata*, and smaller specimens of *Hadropterus* such as *P. sciera*. They are distinguishable from these by their more robust bodies, blunter snouts, darker suborbital bar, larger and more conspicuous dorsal saddles, and absence or virtual absence of scales on the cheeks.

Systematics: Subgenus *Ericosma*. Denoncourt (1969), in his unpublished dissertation, described *P. evides* forms from the upper French Broad system southwestward through the Hiwassee River as a new subspecies having completely naked cheeks and distinctly banded soft dorsal and caudal fins. He did not treat material from the intervening but lower elevation Little River system. Our material from there appears to correspond to that form. The remainder of the gilt darter's range in Tennessee is inhabited by the nominate subspecies. Denoncourt recognized Ozarkian populations as representing a distinct subspecies. He also discussed a distinctive form from the Barren River system in Kentucky, based on one specimen collected in 1952. This specimen has been reidentified as *P. maculata* by L. M. Page (pers. comm.).

Etymology: *evides* = comely or beautiful.

Percina jenkinsi Thompson.

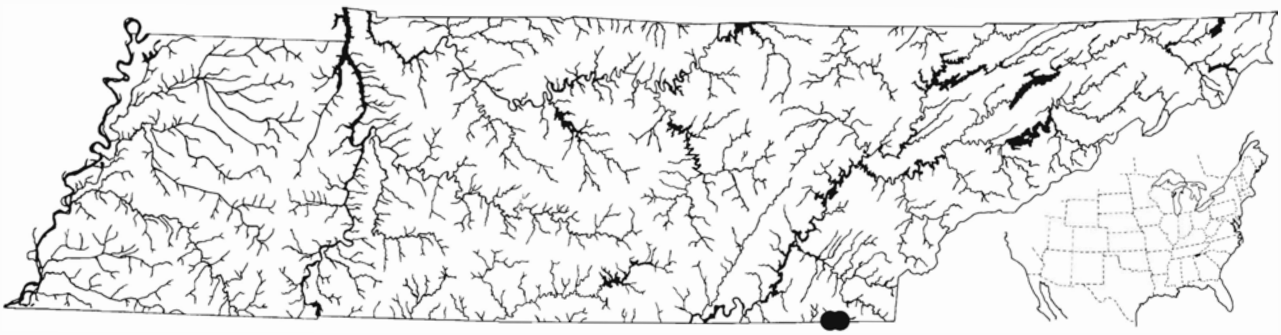
Conasauga logperch

Characters: Lateral-line scales 87–97. Dorsal fin with 16–17 (15–18) spines and 14–16 (13–17) soft rays. Anal fin soft rays 10–11 (9–12). Pectoral fin rays 14–15. Gill rakers 13–14 (three specimens). Vertebrae 45–47. Premaxillary frenum present. Gill membranes separate. Scalation and ground coloration like that of *P. caprodes*. Dorsal saddle pigmentation highly irregular, having only eight or nine primary saddles reaching well below lateral line, with the remaining (secondary) saddles broken up into interrupted bars and vermiculations. Nape area and cheeks notably vermiculate. Fin coloration like that of *P. caprodes*. Nuptial tubercles are as described for *P. caprodes*.

Biology: The Conasauga logperch is most often encountered in deep gravel runs or pools with small stones and sandy bottoms. Apparent spawning individuals have been taken from shallow gravel shoal areas with fast current during late April. Little else is known of its biology, but reproduction, growth, and feeding characteristics are probably very similar to that of other logperches. Maximum size (Thompson, 1985) 116 mm SL (about 133 mm TL, = 5.25 in).

Distribution and Status: Restricted to a small (18 km) portion of the Conasauga River from about 5 km above the US Highway 411 bridge, Polk County, Tennessee to about the Georgia Highway 2 bridge, Murray and Whitfield Counties, Georgia (Freeman, 1983). Fewer than 50 specimens have been taken, and this logperch qualifies as one of our rarest darters. It was listed as an Endangered Species by the U.S. Fish and Wildlife Service in 1985. A federal recovery plan for protection of the Conasauga logperch and sympatric amber darter was subsequently devised (Biggins, 1986). The population

Plate 278. *Percina jenkinsi*, Conasauga logperch, 88 mm SL, Conasauga R., TN.



Range Map 269. *Percina jenkinsi*, Conasauga logperch.

would appear secure for the foreseeable future as long as the excellent quality of the Conasauga River habitat is maintained.

Similar Sympatric Species: The undescribed Mobile logperch is more common and widespread in the Conasauga River; it has a persistent orange band in the spinous dorsal fin, more primary dorsal saddles, well-defined and regularly spaced secondary saddles, and lacks vermiculations on the cheeks.

Systematics: Subgenus *Percina*. Thompson (1985) hypothesized *jenkinsi* to be derived from *P. caprodes* which entered the Conasauga system from the adjacent Hiwassee system of the Tennessee drainage.

Etymology: *jenkinsi* is a patronym for R. E. Jenkins, ichthyologist at Roanoke College, Salem, Virginia.

Percina macrocephala (Cope).

Longhead darter

Characters: Lateral-line scales 70–87 (69–90). Dorsal fin with 13–15 (11–16) spines and 12–13 (11–14) soft rays. Anal fin soft rays 8–11 (8–12). Pectoral fin rays 12–15. Principal caudal fin rays 15–17. Gill rakers 15–17, length of longest rakers about 3 times their basal width, but many rakers on lower limb vestigial. Vertebrae 44–45. Premaxillary frenum present. Gill membranes barely connected or separate. Scales absent from anterior belly and breast except for modified midventral scales. Cheeks and opercles typically with a few tiny, embedded scales near dorsal margin, but frequently naked, and occasionally (one Duck River specimen) fully scaled. Nape typically with small naked area anteriad. Modified midventral scales well developed in both sexes, but more prominent in males. Dorsal ground color brown to olivaceous, belly white to pale yellow. Vague dark saddles (up to 15) may be present on the dorsum. Lateral line conspicuously depigmented amid the 8–14 fused lateral blotches. The single median ba-

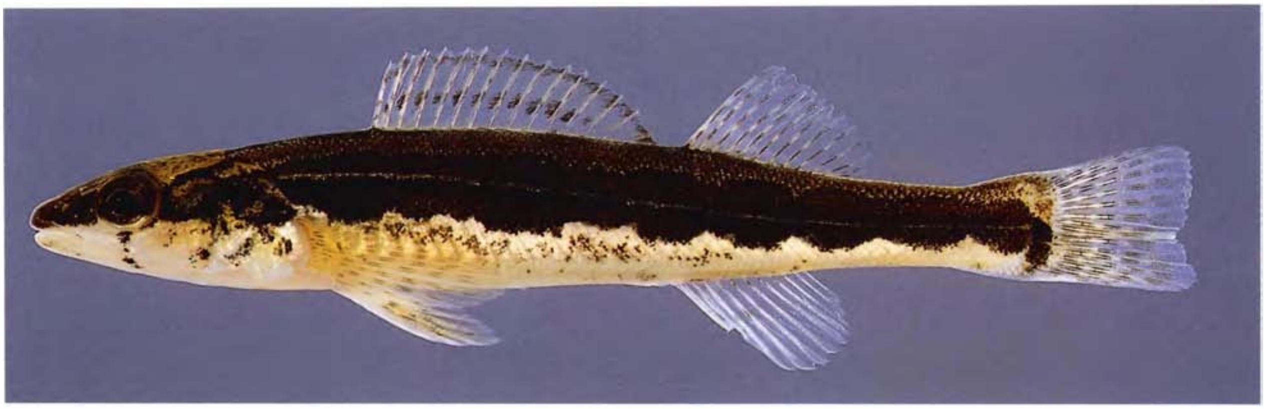


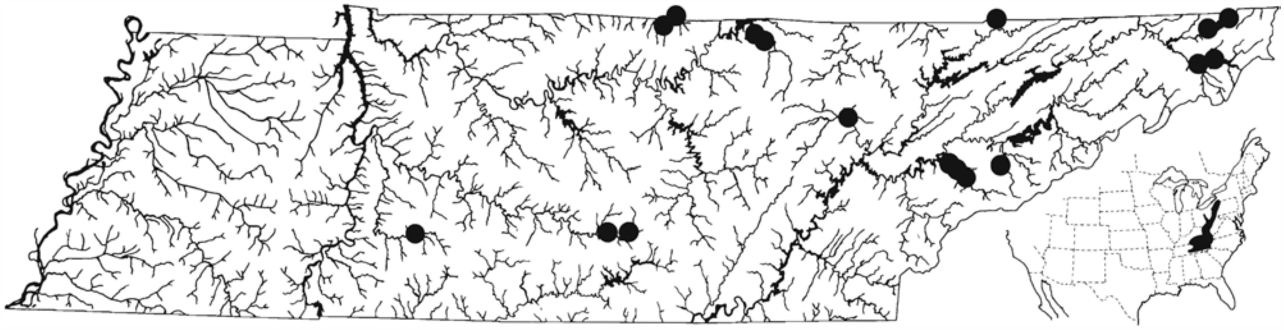
Plate 279. *Percina macrocephala*, longhead darter, 52 mm SL, Little R., TN.

sicaudal spot is very dark and has a gray linear "shadow" extending vertically from the spot to the ventral margin of the caudal fin. Spinous dorsal fin with black marginal band (may have narrow clear border), a broad median clear band, and a broad black band below extending nearly to the base of the fin. Remaining fins with rays darkly speckled. Reported to lack breeding tubercles, but three males from Duck River, 22 March, are similar to *P. caprodes* in having tuberculate ridges on rays and spines of the anal and pelvic fins and in having the modified midventral scales and scales adjacent to the anal fin base with prominent, hardened swellings.

Biology: The longhead darter is an inhabitant of chiefly larger upland creeks and small to medium rivers. Preferred streams have good water quality, with little turbidity and negligible siltation. It occurs most of the year in pools a meter or so in depth with gentle current and clean sand-detritus or bedrock-boulder substrates. It is most often encountered near the cover of brush, vegetation such as water willow, or boulders. This darter spends much of its time in the water column, often hovering a few centimeters above the bottom. Biology of this species in Little River has been studied in part by W. C. and L. B. Starnes. During winter the longhead darter moves into the deepest pool areas of the river. In early spring (March in 1980) it migrates to shallow gravel shoal areas to spawn. At an average water temperature of about 10 C (50 F), eggs hatched in 27 days with larvae emerging at a length of 10 mm. The larvae are very active and, after surviving several days on yolk sac nutrients, presumably feed on microinvertebrates. The UT collection contains several hybrids between *P. macrocephala* and *P. caprodes*. Page (1978), based on specimens from the Green River, Kentucky, estimated that *P. macrocephala* grew to about 50–60 mm SL the first year. From his data it appears that 2-year-olds probably average about 75 mm SL, with 3- and 4-year-olds exceeding 90 mm SL. Little River specimens appear to have similar growth. Specimens examined by Page had fed on small crayfishes and mayfly nymphs. In Little River, we have observed them feeding in a delicate manner, deftly plucking food items from the surfaces of stones and other underwater objects while swimming above the bottom. Maximum size (Page, 1978) 102 mm SL (= about 120 mm, or 4.7 in).

Distribution and Status: The longhead darter is a widespread but rare species of the Ohio River basin. It is common in some years in localized portions of Little River, Blount County, Tennessee. It is rare to extirpated in other tributaries to the Tennessee River, and has not been collected from the Cumberland River since 1891 (Page, 1978). It is known from recent records in the Barren River system in Kentucky very near Tennessee and may occur rarely in the Tennessee portion of that system. It is apparently intolerant of siltation as is often the situation with darters which spend much of their time in pool habitats. Little River populations appear to have experienced at least a temporary decline in recent years. It probably warrants Threatened status throughout its range, and is listed thusly in Tennessee (Starnes and Etnier, 1980).

Similar Sympatric Species: Occurs with the very similar appearing, undescribed frecklebelly darter in the Barren River system, but may not be syntopic in the Tennessee portion of that system; the latter has well scaled cheeks and opercles and a fully scaled belly. Also may occur with other black-sided species, *P. maculata* and *P. sciera*, both of which have completely scaled cheeks, differ in other key characters, and have differently patterned lateral blotching.



Range Map 270. *Percina macrocephala*, longhead darter.

Systematics: Page (1974a) regarded *P. macrocephala* as a member of the subgenus *Alvordius*. It differs from other members of the subgenus (except *P.* [*Alvordius*] sp. of Conasauga R.) in overall physiognamy, habits, and habitat, and in the presence of modified midventral scales in both sexes. Infraspecific variation is treated by Page (1978). Two puzzling, poorly preserved specimens from the Emory River system (upper Tennessee drainage) deserve comment. They have low scale counts (but not out of the range of Little River specimens), well-scaled opercles, and pigmentation that, to us, is rather typical of *P. macrocephala*. Page identified one of these as *P. maculata* and the other as *P. macrocephala*. We remain convinced that the two specimens are conspecific and that they conform more closely to *P. macrocephala* than to *P. maculata*. The 1971 and 1975 collection dates suggest that this form persists in the Emory system. Additional specimens might allow clarification of this problem.

Etymology: *macrocephala* = long head.

Percina maculata (Girard).

Blackside darter

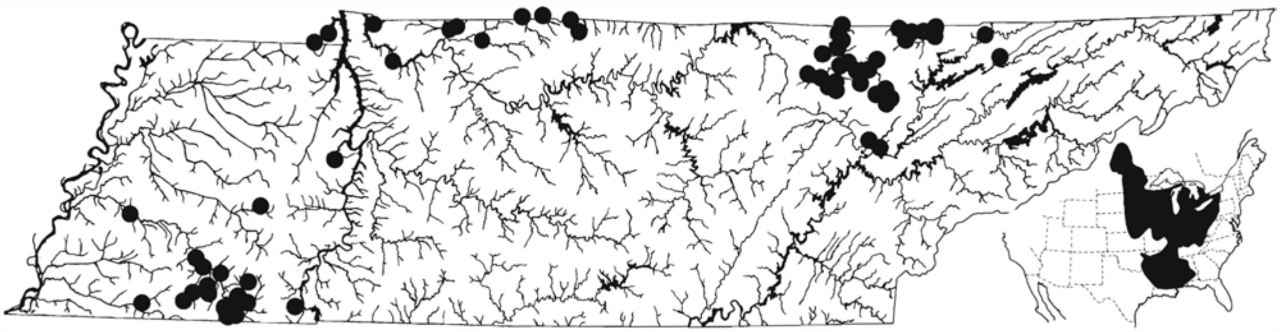
Characters: Lateral-line scales usually 60–71 (53–81). Dorsal fin usually with 13–15 (12–17) spines and 12–13 (10–15) soft rays. Anal fin soft rays usually 8–9 (7–13). Pectoral fin rays usually 13–14 (11–16). Principal caudal fin rays modally 17 (14–17). Vertebrae usually 42–43 (40–44). Above data from Beckham (1986) and our data. Gill rakers 14–15 (13–17), length of longest rakers about 3 times their basal width. Premaxillary frenum present. Gill membranes barely connected or separate. Scalation shows as much variation as above meristic characters. Cheeks and opercles scaled. Nape with shiny appearance, either naked or with tiny embedded scales. Breast and prepectoral area naked to al-

Plate 280a. *Percina maculata*, blackside darter, female, 74 mm SL, Barren R. system, TN.

Plate 280b. *Percina maculata*, blackside darter, breeding male, 76 mm SL, Barren R. system, TN.

most fully scaled. Modified midventral scales well developed on males on breast and posterior half of belly. Dorsal coloration straw yellow to olivaceous with seven to ten dark saddles or middorsal spots which are interconnected to the eight or so lateral blotches by a reticulate pattern. Caudal spot single, large, and darker than lateral blotches. Suborbital bar usually well developed. Spinous dorsal fin with a dark spot basally between the first 3 spines. Other fins light dusky to clear, but very dark in nuptial males. Nuptial males with tuberculate ridges on rays and spines of anal and pelvic fins and with exposed portion of modified midventral scales with hardened swellings.

Biology: The biology of the widespread blackside darter has been relatively well studied. It is an inhabitant of small creeks as well as small to medium rivers. It occurs mostly in pools with substrates ranging from sand to detritus, silt, boulders, and rubble. It also frequents undercut banks and brush piles. *Percina maculata* tends



Range Map 271. *Percina maculata*, blackside darter.

to be migratory, moving into smaller tributaries and headwaters during spring (Winn, 1958a,b; Thomas, 1970). Spawning occurs during March through June in sand-gravel runs with moderate current. Hybrids are known with *Etheostoma gracile*, *Percina caprodes* and *P. phoxocephala* (Page, 1976b). Petravicz (1938) has described the breeding behavior of the blackside darter in some detail: The female "nervously" swims to suitable depressions in the substrate, where she is followed by males. Upon coming to rest, she is mounted by one of the males who straddles her nape with his pelvic fins and drops his caudal peduncle down to the substrate so that the genital openings are in proximity. Both sexes vibrate vigorously as eggs and milt are extruded, kicking up a cloud of sand and thus creating a depression for the eggs. Just prior to and during spawning the male undergoes striking color changes, with dark markings intensifying and a green-gold cast covering the body. All fins blacken and the iris of the eye becomes intense gold (also noted in spawning *P. tanasi*, Starnes, 1977). After spawning, eggs are left unattended in the substrate. Sexual maturity is reached at age 1. Fecundity ranged from about 600 ova in yearlings to nearly 2,000 in older females (Thomas, 1970). Young hatch after an incubation period of 142 hours or more and are 6 mm long at hatching (Petravicz, 1938); larvae live in the water column for up to 3 weeks, perhaps subjecting them to considerable downstream drift as noted in the snail darter (Starnes, 1977; Hickman and Fitz, 1978). The diet of *P. maculata* is dominated by dipterans such as midge and blackfly larvae; mayfly nymphs (baetids, heptageniids) are second in importance, followed by caddisfly larvae (Turner, 1921; Karr, 1963; Thomas, 1970). Blackside darters average about 40 mm at age 1, 65 at age 2, 75 at age 3, and attain lengths of over 80 mm as they approach age 4 (Karr, 1963, Thomas, 1970). Maximum SL 95 mm (about 110 mm TL or 4.4 in) reported by Beckham (1986).

Distribution and Status: One of our most widespread darters, occurring throughout much of the Mobile Basin, eastern and central portions of the Mississippi Basin, Great Lakes drainages, and portions of the Hudson Bay drainage. The blackside darter seems to be tolerant of considerable siltation, based on its persistence in good numbers in agricultural areas of the Midwest and in the upper Cumberland drainage, which has been ravaged by siltation from surface mining runoff. It is of sporadic occurrence in small to medium streams in west Tennessee but is apparently absent from the Obion River system and is known in the Forked Deer River system from a single specimen. This distributional pattern suggests that it may be one of several species involved in the dispersal crossroads encompassing the headwaters of the Hatchie River of the Mississippi drainage and the Tombigbee River of the Mobile Basin, as well as southwestern tributaries to the lower Tennessee River (Starnes, 1973). Elsewhere in the state, it is uncommon to rare except in the Big South Fork and upper Cumberland drainage, where it is common. Very rare in the upper Tennessee drainage, being substantiated only by older specimens from the Emory and Powell river systems (Univ. Mich. Mus. Zool.).

Similar Sympatric Species: Occurs in portions of range with the similar appearing (especially when young) dusky darter, *P. sciera*, which is separable by the three vertically arranged caudal spots and more continuous lateral blotches. See also comments under *P. macrocephala*.

Systematics: Subgenus *Alvordius*.

Etymology: *maculata* = spotted.

Percina nigrofasciata (Agassiz).

Blackbanded darter

Characters: Lateral-line scales 46–71 (54–66 in Conasauga River). Dorsal fin with 9–15 (11–13, usually 12 in Conasauga) spines and 12–13 (10–14) soft rays. Anal fin soft rays 7–11 (usually 10 in Conasauga). Pectoral fin rays 14–15 (13–15). Principal caudal fin rays 15–16 (14–17). Gill rakers 10–13, length of longest rakers 2.5–3 times their basal width. Vertebrae 40–42. Premaxillary frenum present. Gill membranes moderately connected. Scales present on nape, cheeks, opercles, and prepectoral area. Belly occasionally with small naked area anteriad (mostly naked in Apalachicola race). Breast usually fully scaled but mostly naked in Apalachicola race. Modified midventral scales variable in number and development but usually weaker than in other members of subgenus *Hadropterus*. Pigmentation highly variable. Ground color of dorsum ranges from grayish brown to olivaceous. Adults have about 11 vertically elongate lateral blotches which range from concise, intense, black zebra-like markings to diffuse and gray; in young, lateral blotches are much less vertically developed. There are seven or eight dorsal saddles which tend to disappear with age. Three vertically arranged basicaudal spots with lower two coalescing with age are characteristic. Suborbital bar variable and occasionally absent. Belly plain to highly mottled. Fins of females and juveniles with speckled rays and, often, speckled membranes; those of mature males more uniform with dark basal bands in dorsal and anal fins, and caudal fin dark with a central clear band. Nuptial males darken overall and assume a blue-green cast with lateral markings becoming obscure. Nuptial tubercles lacking, but our highest April males have ridge-like swellings on rays and spines of anal and pelvic fins that are probably homologous to "tuberculate ridges" mentioned for several other *Percina* species.

Biology: *Percina nigrofasciata* is an abundant and nearly ubiquitous inhabitant of streams of all dimensions in both the Coastal Plain and upland areas of much of southeastern United States. It is generalized in its habitat preferences, apparently requiring only the presence of at least a moderate amount of current. It frequents debris strewn areas, vegetation, rocky areas, bank cover, and even occurs on open sandy or gravel substrate. Mathur (1973a) studied the biology of this darter in the Chattahoochee River system of eastern Alabama where spawning occurred in May and June. We have several 19–23 mm specimens collected in May that were certainly spawned that year, probably in early April or earlier. Suttkus and Ramsey (1967) reported blackbanded darters spawning in sand and gravel runs as early as February. Fecundity estimates for females were low, ranging from only 40 eggs in young to about 250 in the largest females. Age and growth were not determined in Mathur's study. Several larger collections from throughout the Southeast suggest that lengths are 36–68 mm at age 1, about 70–80 mm at age 2, and about 85–95 mm at age 3. Since length-frequency analysis failed to show discrete size groups and there is an apparent wide range of sizes at age 1, the spawning season may be relatively long. Mathur (1973b) reported a diet dominated by dipterans (midge and blackfly larvae) and mayfly and caddisfly larvae, with daily feeding peaks in the early morning and late afternoon. Seasonal feeding peaked during late spring and early fall at water temperatures of 15–23 C. Suttkus and Ramsey (1967) discussed natural hybrids of *P. nigrofasciata* x *P. sciera*, and the UT collection contains hybrids of *nigrofasciata* with *P. shumardi* and the undescribed "Mobile logperch." Maximum total length 111 mm SL (4.4 in).

Distribution and Status: Occurs both above and below the Fall Line in Atlantic and Gulf Coastal drainages

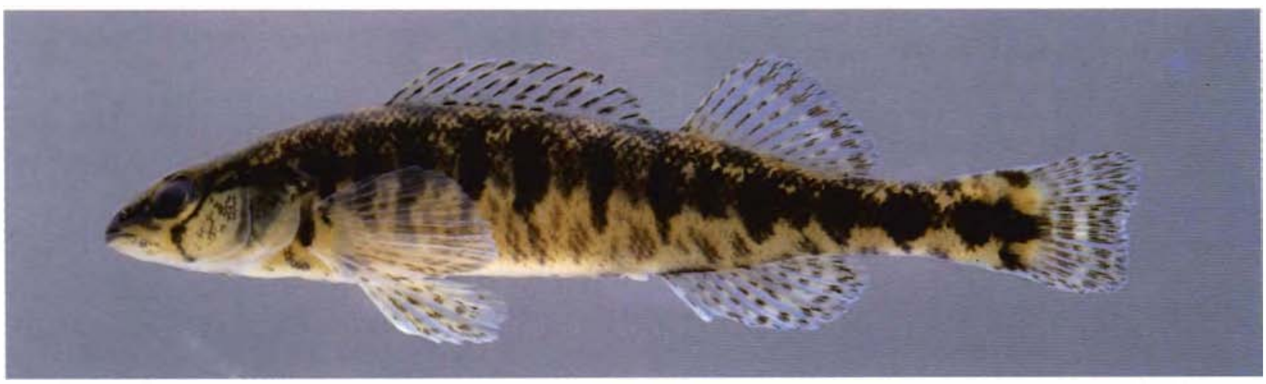
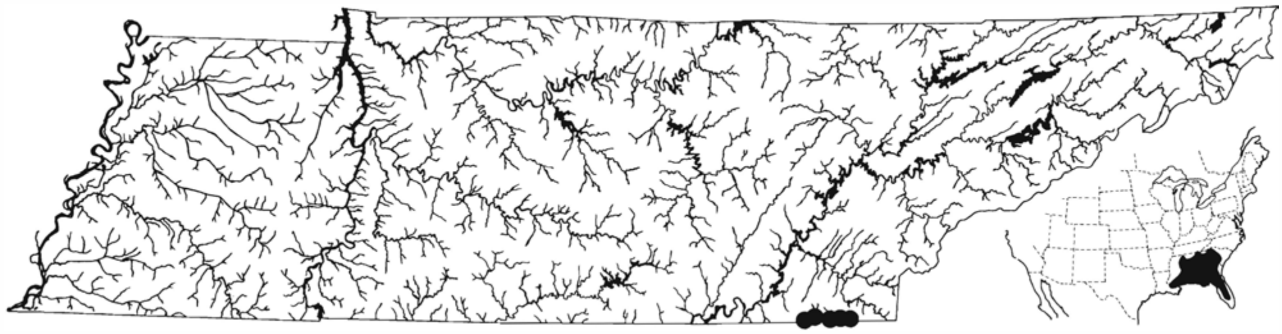


Plate 281. *Percina nigrofasciata*, blackbanded darter, 60 mm SL, Conasauga R., TN.



Range Map 272. *Percina nigrofasciata*, blackbanded darter.

from Edisto River, South Carolina, through eastern tributaries to Mississippi River in southwestern Mississippi. It is often the most common darter in streams of this area.

Similar Sympatric Species: In Tennessee, the blackbanded darter is restricted to the Conasauga River system where it occurs with the somewhat similar appearing but undescribed bridled darter (see comments under that species). *Percina palmaris* is also common in the Conasauga River and is somewhat similar in appearance to *nigrofasciata*. It differs from *nigrofasciata* in having separate or only slightly connected gill membranes, a mostly to completely naked breast, and scales on the operculum are much smaller than body scales (subequal in *nigrofasciata*), in addition to characters listed in the key. *Percina lenticula*, *P. sciera*, and *P. aurolineata* are additional Gulf Coast members of subgenus *Hadropterus* which are sympatric with the blackbanded darter extralimital to Tennessee. Vertically elongate lateral blotches are shared by *lenticula* and *nigrofasciata*, but *lenticula* has 77–93 lateral-line scales. Both *sciera* and *aurolineata* have round to oval lateral blotches little if any deeper than long.

Systematics: Subgenus *Hadropterus*. Crawford (1956) recognized two subspecies, *P. n. raneyi* of the upper Savannah River drainage, and *P. n. nigrofasciata* from the lower Mississippi drainage eastward with intergrades occurring in the lower Savannah and Altamaha region. A distinctively pigmented form, with quadrate lateral blotches, accorded only racial status by Crawford, occurs in the Apalachicola drainage in Georgia and Alabama.

Etymology: *nigrofasciata* = black banded.

Percina palmaris (Bailey).

Bronze darter

Characters: Lateral-line scales 57–73. Dorsal fin with 11–15 spines (usually 13–14 in Conasauga River) and 10–14 soft rays (usually 13 in Conasauga). Anal fin soft rays 8–9 (7–10). Pectoral fin rays 13–16. Principal caudal fin rays 16–17. Gill rakers 13–16, length of longest rakers about 3 times their basal width. Vertebrae 40–42. Premaxillary frenum present. Gill membranes barely connected or separate. Cheeks, opercles, nape, and belly scaled, breast and prepectoral area mostly naked. Modified midventral scales well developed in males but usually occurring in an incomplete row. Ground color of dorsum brownish to straw yellow or green with nine to ten dorsal saddles which are often interconnected by dorsolateral reticulations to, or directly confluent with, 9–11 quadrate lateral blotches. Three vertically arranged basicaudal spots are interspersed by two conspicuous pale areas. Suborbital bar usually lacking. Rays of all fins speckled. Spinous dorsal fin of adult males with pale margin, wide, dusky orange median band, and pale orange basal band; soft dorsal fin dusky orange. Nuptial males brighten, with dorsal fin coloration intensifying and body color becoming bright bronze. Head region, lateral blotches, and pelvic and anal fins become iridescent blue-green. Nuptial tubercles develop on ventral scales of the caudal peduncle and some belly scales including modified midventral scales, and tuberculate ridges are conspicuous on anal spines, distal half of anal rays, on spine and rays of pelvic fin, and on lower pectoral fin rays (Denoncourt, 1976, and our observations).

Biology: The bronze darter is an inhabitant of small upland rivers where it occurs in swift, rocky riffles and is often associated with, but not restricted to, areas of rooted vegetation, especially riverweed (*Podostemum*).

Specimens collected from vegetated riffles are often greenish in color, thus matching their surroundings. Based on tuberculation, spawning probably occurs from mid-March to June (Wieland, 1982), principally during May in Tennessee (our data). Although Denoncourt (1976) discussed sexual dimorphism, other aspects of reproductive biology or age and growth were not considered. Apparent young-of-year specimens in one of our larger September collections from the Conasauga River ranged from about 32–50 mm; subsequent length classes averaged 55–65 and 70–75 mm. Tallapoosa River specimens were 40–50 mm at age 1 (May), and did not appear to be in spawning condition, suggesting that spawning does not occur until age 2. Wieland (1982) reported fecundity of 37–404 ova per female, and comparable growth at age 1. Stomachs of specimens we examined contained a preponderance of blackfly larvae and pupae, and hydropsychid (*Cheumatopsyche*) caddis larvae, both of which are abundant among rocks laced with riverweed. Wieland (1982) found blackfly, baetid and siphlonurid mayfly, and midge larvae to be dominant foods. Maximum total length 100 mm (4 in).

Distribution and Status: Restricted to the upper Mobile Basin, primarily in the Coosa and Tallapoosa river systems, where it is often common. In Tennessee it occurs only in the main channel of the Conasauga River, where it is locally common.

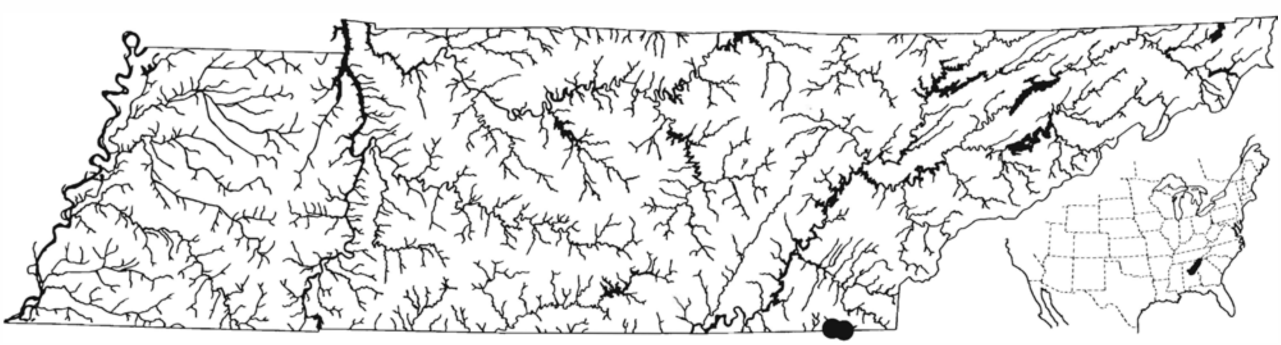
Similar Sympatric Species: Certain of the color phases exhibited by the variable *P. nigrofasciata* are somewhat similar to the bronze darter. The many characters separating these two common species are discussed under *P. nigrofasciata* and included in the key.

Systematics: Subgenus *Ericosma*. Bailey (1940), Crawford (1954), and Denoncourt (1976) have studied the systematics of *P. palmaris*; Denoncourt noted marked sexual dimorphism in meristics and fin morphology, and geographic variation between Coosa and Tallapoosa river system populations.

Etymology: *palmaris* = a prize.

Plate 282a. *Percina palmaris*, bronze darter, female, 63 mm SL, Tallapoosa R. system, GA.

Plate 282b. *Percina palmaris*, bronze darter, male, 66 mm SL, Tallapoosa R. system, GA.



Range Map 273. *Percina palmaris*, bronze darter.

Percina phoxocephala (Nelson).

Slenderhead darter

Plate 283. *Percina phoxocephala*, slenderhead darter, male, 49 mm SL, Red R., TN.

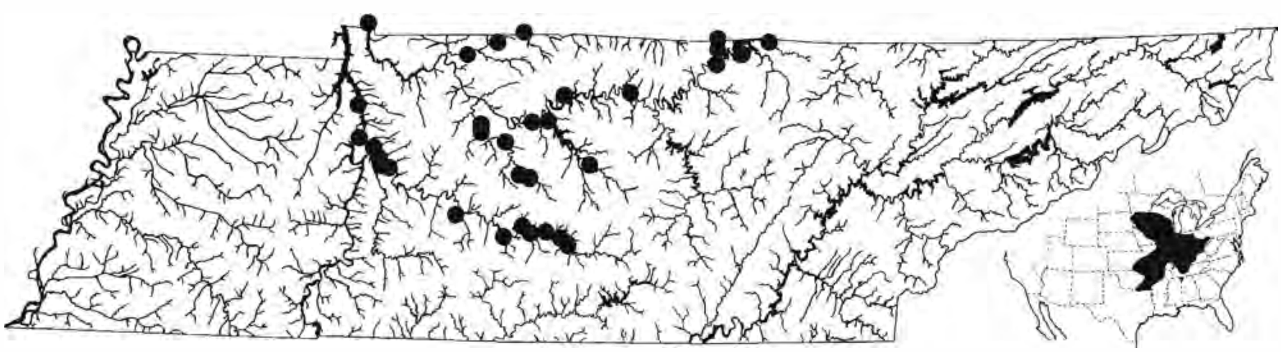
Characters: Lateral-line scales 56–79 (60–72 in Tennessee). Dorsal fin with 11–13 (10–14) spines and 12–14 (11–15) soft rays. Anal fin soft rays 8–10 (7–11). Pectoral fin rays 13–15. Principal caudal fin rays 17 in 50 of 56 specimens. Gill rakers 12–16, length of longest rakers about 2–2.5 times their basal width. Vertebrae 39–41 (38–43). Premaxillary frenum present. Gill membranes moderately connected. Cheeks, opercles, and nape scaled. Belly with naked areas anteriad. Breast with modified scale in center, otherwise naked or having embedded scales posteriad and near bases of pectoral fins. Modified midventral scales well developed on males. Dorsum straw yellow with brown vermiculations. Median caudal spot small but prominent. Suborbital bar lacking. The 14 or so lateral spots range from vague to distinct. Spinous dorsal fin with a narrow clear border, a narrow submarginal dark band best developed posteriad, a broad median orange (males) to yellow (females) band, and a dark basal band. Soft dorsal and caudal fins speckled with brown and yellowish pigment on rays. Lower fins usually clear but anal and pelvic fins often becoming dusky in nuptial males, which also have weak tuberculate ridges on anal spines, distal half of anal rays, and on pelvic spine and adjacent one or two pelvic rays.

Biology: The slenderhead darter is an inhabitant of small to large rivers of moderate gradient where it frequents gravel shoal areas having moderate to swift current. In winter, most individuals move into deeper water. Spawning peaks during May in our area, but has been reported to occur from late March through mid-July (Thompson, 1977). Spawning occurs over swift gravel riffles. *Percina phoxocephala* is known to hybridize with *P. maculata* (Page, 1976b) and *P. caprodes* (our data). Fecundity of females ranges from fewer than 100 ova per female to 750 or more, depending on size (age) (Karr, 1963; Page and Smith, 1971). Males move to the spawning riffles first and are later joined by the females. Hatching requires about 2 weeks, and larvae reach a length of about 20 mm at 2–3 weeks of age. Young grow to about 45–50 mm at age 1 and are sexually mature at these sizes. Lengths at age 2 and 3 are about 60 and 68 mm, respectively. Maximum lifespan is probably 4 years. The diet is dominated by smaller food items such as mayfly nymphs (baetids, heptageniids), midge larvae, and hydropsychid caddisfly larvae (Karr, 1963; Thomas, 1970). Maximum size 80 mm SL (92 mm total length, or 3.6 in) reported by Page (1983a).

Distribution and Status: Widespread in upper and middle portions of Mississippi River basin from Minnesota south through Tennessee River, and Red River of Oklahoma and Texas. One record from Great Lakes drainage of Lake Michigan and one questionable record from Yazoo River system of northwestern Mississippi (Thompson, 1977). Virtually all recent Tennessee records are from the Duck River (Tennessee drainage) and the Stones, Harpeth, and Red rivers of the Cumberland drainage. Sporadically taken in main channel samples from both the Tennessee and Cumberland rivers.

Similar Sympatric Species: None.

Systematics: Subgenus *Swainia*. Thompson (1977) studied systematics of the subgenus and considered



Range Map 274. *Percina phoxocephala*, slenderhead darter.

phoxocephala the most primitive member as did Mayden (1985).

Etymology: *phoxo* = tapering, *cephala* = head.

Percina sciera (Swain).

Dusky darter

Plate 284a. *Percina sciera*, dusky darter, 73 mm SL, Red R., TN.

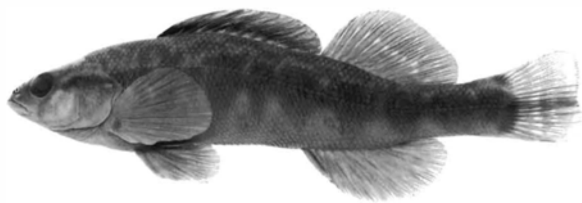


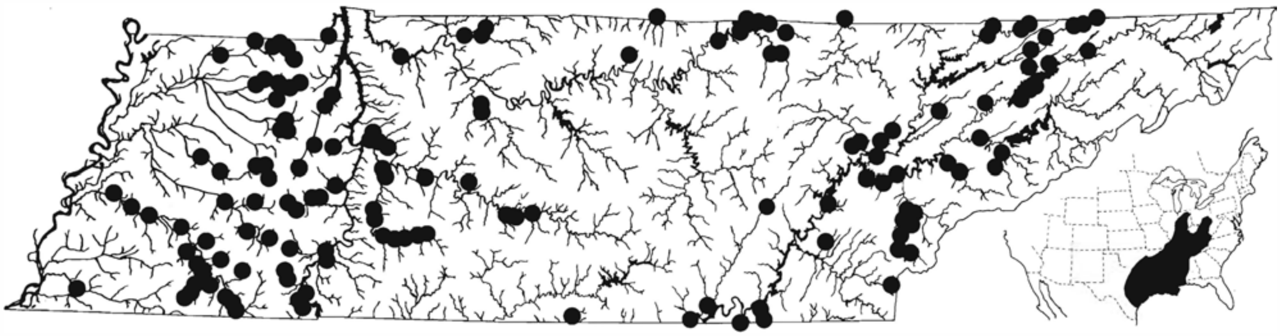
Plate 284b. *Percina sciera*, dusky darter, preserved breeding male specimen, 84 mm SL, Tennessee R. system, AL.

Characters: Lateral-line scales 55–78 (55–69 in Tennessee). Dorsal fin with 12–13 (10–14) spines and 12–14 (10–14) soft rays. Anal fin soft rays 9–10 (7–11). Pectoral fin rays 13–15 (12–15). Principal caudal fin rays 15–17. Gill rakers 13–15 (11–16), length of longest rakers about 4–6 times their basal width. (Fin ray and gill raker counts are from 60 Tennessee specimens, with range-wide extremes listed in parentheses.) Vertebrae 39–42. Premaxillary frenum present. Gill membranes moderately connected. Cheeks, opercles, and nape scaled. Belly often naked anteriad. Prepectoral area and posterior half and lateral margins of breast usually scaled; anterior portion of breast typically naked but may be fully scaled in males. Modified midventral scales well developed in males. Coloration of dorsum grayish with seven to nine dark dorsal saddles which may be distinct, vague, or essentially absent. Dorsolateral reticulations interlie dorsal saddles and the eight or so oval lateral blotches. In large individuals (80 mm or more), particularly nuptial males, lateral blotches and dorsal markings give way to an overall charcoal gray color. Three vertically arranged basicaudal spots are present, with lower two usually partially coalesced. Suborbital bar rarely present. Rays of median fins speckled except in nuptial males which have uniformly gray fins. Spinous dorsal fin of nuptial males may show a vague submarginal clear band; in subspecies *P. s. apristis* of the Edwards Plateau, Texas, this band is pale orange. What probably represent tuberculate ridges occur as thickenings on middle portions of anal fin rays of males and less prominently on anal fin spines and the pelvic spine and adjacent rays.

Biology: The dusky darter is most common in larger creeks and rivers ranging from Coastal Plain streams to upland rivers. It frequents areas having moderate current and is associated with debris-strewn areas, undercut banks, vegetation, and brush. Substrates are generally sandy and silty. Overwintering occurs in deeper waters and some dusky darters migrate into smaller tributaries during spring and summer (Page and Smith, 1970). Spawning occurs during late spring and early summer, presumably in riffles. Suttkus and Ramsey (1967) reported spawning over sand and gravel bars in the Pearl River, Louisiana, along with *P. nigrofasciata*, with hybrids occurring between them. Page and Smith (1970) reported fecundity ranging from 80 to nearly 200 ova per female. Eggs hatched in about 4 days and larvae were 5.5 mm long at hatching. Hubbs (1961) found that *P. sciera* eggs do not survive well to hatching below 22 C. In the Embarras River, Illinois, dusky darters grew to about 70 mm in 1 year and added about 10–12 mm per year the next 2 years according to Page and Smith. Maximum lifespan was reported at over 4 years, at which times lengths may exceed 120 mm; most large specimens are males. The diet of juveniles is dominated by small prey items such as midge and blackfly larvae; adults utilize larger organisms such as caddisfly and mayfly larvae (Page and Smith, 1970; Miller, 1983). Maximum size 110 mm SL (about 130 mm total length, or 5.1 in) reported by Page (1983a).

Distribution and Status: Gulf Coastal drainages from the Tombigbee River portion of Mobile Basin west through the Guadalupe River, Texas, and extending up the Mississippi River basin to northern Indiana and central Ohio. Widespread throughout much of Tennessee, but most common on the Coastal Plain and in more sluggish tributaries to the Tennessee River. We have only two specimens from the Cumberland River drainage, and the apparent scarcity of *P. sciera* in that drainage can hardly be explained as a collecting artifact.

Similar Sympatric Species: In Tennessee, the dusky darter is sympatric with the similar appearing *P. mac-*



Range Map 275. *Percina sciera*, dusky darter.

ulata, *P. macrocephala*, and undescribed frecklebelly darter. See comments under these species regarding separation from *P. sciera*.

Systematics: Subgenus *Hadropterus*. Hubbs (1954) partially analyzed the systematics of *P. sciera* and recognized populations from the Guadalupe River system, Texas, as a distinct subspecies, *P. s. apristis*. It differs in serration of the preoperculum and in having smaller scales, an orange or yellow band in the spinous dorsal fin, and several other characters. Additional information appears in Hubbs and Black (1954) and Suttkus and Ramsey (1967).

Etymology: *sciera* = dusky.

Percina shumardi (Girard).

River darter

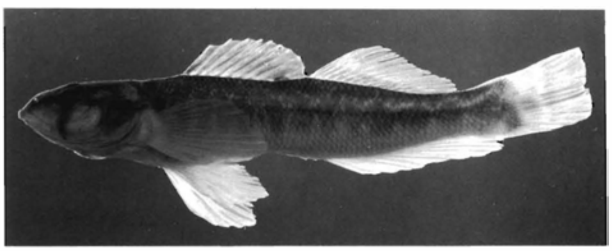
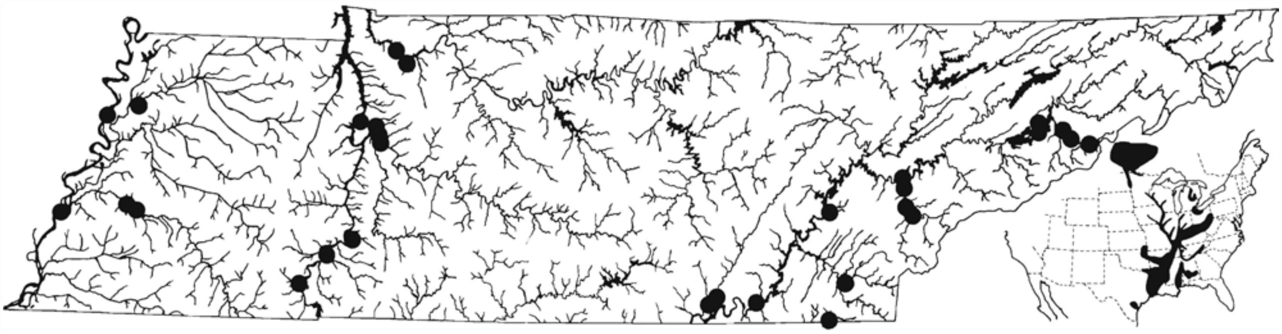


Plate 285. *Percina shumardi*, river darter, preserved male specimen, 58 mm SL, Flint R., AL.

Characters: Lateral-line scales 46–63. Dorsal fin with 10–11 (9–12) spines and 14–16 (11–17) soft rays. Anal fin soft rays 11–13 (10–14). Pectoral fin rays 13–14 (13–15). Principal caudal fin rays modally 16 (14–17). Gill rakers 15–17 (12–17), length of longest rakers about 2.5–3 times their basal width. Vertebrae 37–40. Premaxillary frenum absent or weakly developed. Gill membranes separate. Cheek scaled in Mississippi River drainage, but with only a few scales behind eye in more easterly Gulf drainages. Opercle scaled. Nape variable, but typically with naked areas. Breast and much of belly naked except for modified midventral scales which are weakly developed. Dorsum olivaceous to gray with five to seven dark, irregular saddles often present, less distinct anteriad. Sides may be uniform gray, but more often with 8–15 diffuse, vertically elongate, lateral blotches which may have an iridescent blue-green sheen. Areas of blue-green iridescence may also occur on the head, especially in nuptial males. Suborbital bar well developed. Spinous dorsal fin with characteristic prominent basal dark blotches anteriorly and posteriorly, dusky elsewhere. Soft dorsal and anal fin rays speckled or banded with dark pigment, and membranes of these fins often dusky. Pigment, on caudal, pectoral, and pelvic fins, if present, restricted to rays. Breeding tubercles develop on rays of characteristically elongate anal fin rays of males, which extend past caudal fin base. Tubercles also occur on pelvic and lower caudal fin rays, and weak tubercles develop on ventral body scales and on lower cheeks and opercles. Chromatic breeding colors have not been reported, but we have noted prominent orange submarginal bands in spinous and soft dorsal fin and orange on caudal fin membranes of spring males from the Coosa and Cahaba river systems.

Biology: As the name suggests, the river darter is mostly an inhabitant of larger rivers, although it occasionally occurs in smaller streams, especially during the winter and early spring breeding season. *Percina shumardi* is also tolerant of "flow-through" reservoir environments and is occasionally taken in collections from main stream impoundments of the Tennessee River. Thomas (1970) studied river darter biology in the Kaskaskia River, Illinois, where spawning occurred during April and May. Spawning may be as early as February in Tennessee, based on ripe specimens taken in the



Range Map 276. *Percina shumardi*, river darter.

lower Little Tennessee River prior to impoundment (Starnes, 1977). In the upper Mississippi River (Simon, 1985a) spawning occurs at 10 C (April–May). Larvae hatch in 144–168 hours at 22 C and presumably require much longer at spawning temperatures. Newly hatched larvae are about 4 mm TL. During daylight hours larvae are active and are known to drift downstream near the surface. Transformation to juveniles is at about 12–15 mm. These early juveniles inhabit moderate current areas with sand and gravel substrates. There may be some capacity for reproduction in current-swept areas of impoundments, or reservoir populations may be dependent on tributaries for reproduction. Our collection contains specimens identified as hybrids between this species and both *P. caprodes* and *P. nigrofasciata*. Thomas (1970) reported the diet of both young and adults from Illinois as being dominated by midge and hydropsychid caddis larvae, with microcrustaceans also important in the juvenile diet. Three apparent year classes in the Kaskaskia River averaged 48, 62 and 72 mm. Maximum total length 84 mm (3.3 in) attained by specimens in Gulf drainages east of the Mississippi River.

Distribution and Status: Gulf Coastal drainages from San Antonio Bay, Texas, and eastward through Mobile Basin. Extending up Mississippi and Ohio rivers to southern Minnesota and western Pennsylvania, respectively. Also occurs in southern Great Lakes tributaries and in the Hudson Bay drainage of western Minnesota, Manitoba, and Ontario. The river darter's rarity in collections from Tennessee probably reflects the difficulty of sampling its big-river habitats more than actual rarity. Occurs throughout the Tennessee River and its major tributaries to slightly above Knoxville, in the main channel of the Mississippi River, and in larger portions of its direct tributaries.

Similar Sympatric Species: The river darter, when lateral blotches are distinct, most closely resembles more somberly colored specimens of the gilt darter, *Percina evides*, from which it is separable by the greater number of lateral blotches (usually nine or more vs. five to seven, and the presence of anterior and posterior basal dark blotches in the spinous dorsal fin.

Systematics: Subgenus *Imostoma*. A rangewide systematic treatment is not available. Gulf Coast populations from drainages east of the Mississippi River are distinctive in their reduced cheek squamation, higher lateral-line scale counts, and orange-banded dorsal fin in nuptial males. They probably warrant taxonomic recognition. We have not examined specimens from Gulf tributaries west of the Mississippi River. The lack of the presumably derived dorsal saddle pattern shared by the other four members of *Imostoma* suggests that *shumardi* forms the sister lineage to that group.

Etymology: *shumardi* is a patronym for Dr. G. C. Shumard, surgeon for the U.S. Pacific Railroad Survey and discoverer of the species.

Percina squamata (Gilbert and Swain).

Olive darter

Characters: Lateral-line scales 71–86 (68–89). Dorsal fin with 13–14 (12–15) spines and 12–13 (11–14) soft rays. Anal fin soft rays 7–9 (7–10). Pectoral fin rays 12–15. Principal caudal fin rays 17. Gill rakers 14–16, length of longest rakers about twice their basal width. Vertebrae 42–45. Premaxillary frenum present. Gill membranes moderately connected. Snout exceptionally sharp in this species, as in other members of the subgenus *Swainia*, perhaps exceeding all other *Percina* in this character with the exception of the closely related *P. nasuta* and *P. oxyrhynchus*. Cheeks, opercles, nape,

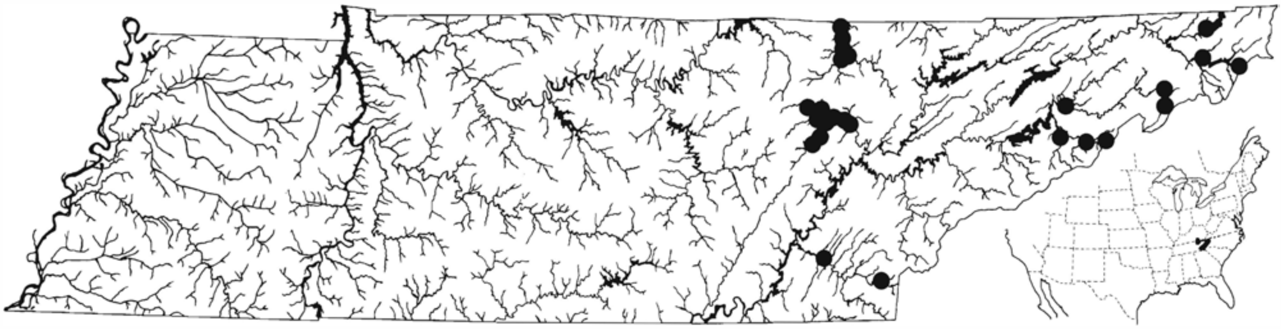
Plate 286. *Percina squamata*, olive darter, 98 mm SL, Nolichucky R., TN.

prepectoral area, breast, and belly well scaled. Modified midventral scales well developed in males. Color of dorsum uniformly olivaceous to having some darker vermiculations. Juveniles have 13–15 small saddles which disappear with age. Lateral blotches small and ten or more in juveniles, and often fusing to form a broad, irregular lateral stripe in larger specimens. Distinct caudal spot present, suborbital bar absent or poorly developed. Spinous dorsal fin with submarginal orange band and dark marginal and medial bands. Rays of soft dorsal and caudal fins speckled. Nuptial males develop tuberculate ridges on rays and spines of anal fin and on pectoral spine and adjacent two or so rays.

Biology: The olive darter is strictly an inhabitant of higher gradient upland rivers where it resides in boulder and bedrock chutes having moderate to torrential current. It is probably common where it occurs, but the nature of its preferred habitat makes effective seining for the olive darter extremely difficult. It is often taken in large numbers when such habitats are sampled with ichthyocides. Thompson (1977) suggested a prolonged spawning period from mid-May through mid or late July, based on sexual condition of adults and seasonal occurrence of very small young-of-year specimens. The UT collection contains a presumed hybrid with *E. rufilineatum* from Pigeon River, Cocke County. Examination of stomachs from Big South Fork specimens revealed a diet composed mainly of hydropsychid caddis larvae and heptageniid mayfly nymphs. Life span is probably 4 years, with young attaining lengths of over 50 mm the first year. Lengths of subsequent age groups were given by Thompson (1977), but were not accompanied by a collection date. Our largest available collections are from the Big South Fork during July, during which young-of-year were already 46–49 mm; specimens presumably representing the 1+, 2+, and 3+ age groups averaged 80, 100, and 115 mm, respectively. Maximum size (Thompson, 1977) 108 mm SL, or about 131 mm TL (= 5.2 in).

Distribution and Status: Restricted to upland rivers primarily in the Blue Ridge and Cumberland Plateau portions of the upper Tennessee and Cumberland river drainages. Cumberland drainage records are available only from the Rockcastle River, Kentucky, and the Big South Fork in Tennessee. Current range in the Tennessee drainage extends from the Holston River system (Watauga River) downstream through the Hiwassee River system, including the Emory River. Range has probably been reduced considerably by storage reservoirs, especially in the Tennessee drainage, but it seems unlikely that its recent distribution extended below the Hiwassee River system. The presence of this and several other species only in the upper portions of the adjacent Tennessee and Cumberland drainages has led to speculation concerning former major stream piracies in this region. It seems virtually certain that these distributions represent relicts of what were formerly much more widespread distributions throughout the two drainages, and that populations inhabiting lower reaches of the two drainages gradually disappeared in response to river maturation (decreased gradient, increased siltation, reduced substrate size, warming) and were replaced by species more tolerant of these more mature habitats (Starnes and Etnier, 1986). Although the olive darter is not well represented in collections, it is often a very abundant and successful species in localized suitable habitats.

Similar Sympatric Species: The elongate body and excessively produced snout of the olive darter are not approached by any darter with which it occurs. The somewhat similar logperches (*P. burtoni* and *P.*



Range Map 277. *Percina squamata*, olive darter.

caprodes) and tangerine darter (*P. aurantiaca*) with which it occurs are easily separable based on their yellow to orange (vs. gray green pigment) and completely different snout shapes.

Systematics: Subgenus *Swainia*. Closely related to *P. oxyrhynchus* of southern tributaries to the Ohio River (Mayden, 1985). Thompson (1977) recognized separate races of *P. squamata* in the Big South Fork and Tennessee systems based on differences in meristics and coloration, with Big South Fork populations having higher average scale counts and more somber coloration.

Etymology: *squamata* = scaly.

Percina tanasi Etnier.

Snail darter

Characters: Lateral-line scales 48–56 (47–60). Dorsal fin with 10–11 (9–12) spines and 14–16 (13–17) soft rays. Anal fin soft rays 11–12 (10–13). Pectoral fin rays 13–15. Principal caudal fin rays 15–17. Gill rakers 15–17, length of longest rakers about 2.5 times their basal width. Vertebrae 39–41. Premaxillary frenum absent or weakly developed. Gill membranes separate. Opercles and nape fully scaled. Cheeks typically with a few scales behind eye, but ranging from apparently naked (juveniles) to almost fully scaled in some adults. Breast and prepectoral area naked in juveniles, but these areas usually with embedded scales in adults and occasionally with exposed scales. Belly with naked area adjacent to modified midventral scales, which are weakly developed in females and moderately developed in males. Body brownish to brownish gray with traces of green. Back with four distinct, dark brown saddles which extend down and forward to contact the series of ten or so lateral blotches along lateral line. Dark

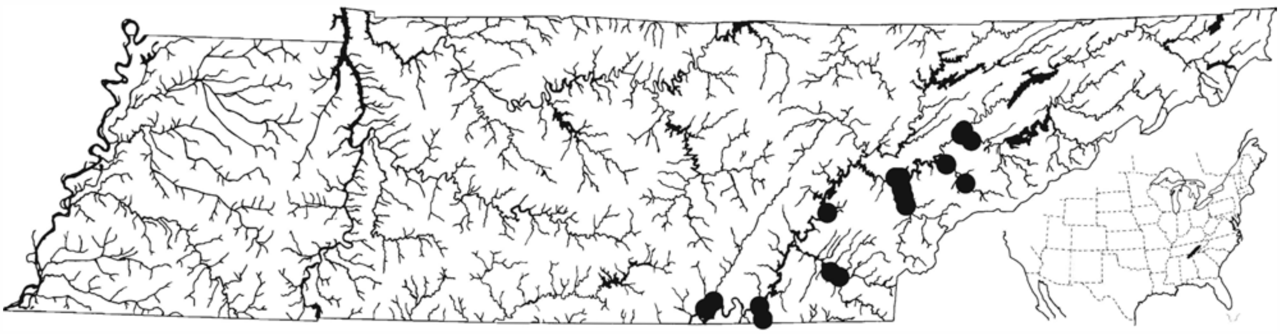
Plate 287. *Percina tanasi*, snail darter, male, 63 mm SL, Holston R., TN.

suborbital bar usually prominent. Rays of all fins are usually speckled, but pelvic and anal fins occasionally immaculate. Nuptial males develop iridescent blue-green coloration on sides and venter and on the branchiostegal membranes and breast region. Gold flecks appear ventrolaterally at pectoral fin bases, cheeks, and opercles, and the iris is bright gold. Females have some similar gold coloration but generally are much more subdued during spawning, with the usually prominent dorsal saddles becoming virtually invisible in some specimens. Prominent breeding tubercles develop on rays of elongate anal fin of males as well as on ventral surfaces of median pelvic rays, lower caudal fin rays, and branchiostegal rays. Scales of cheeks, breast, and ventral portion of the body also bear tubercles.

Biology: The snail darter has been the center of world-renowned controversy due to its presumed Endangered status and the construction of Tellico Dam on the Little Tennessee River which inundated much of the habitat, and all of the reproductive habitat, it was known to occupy at that time. Consequently, the snail darter became almost a household word, and in current usage the term "snail darter types" is approximately synonymous with "ultraliberal environmental activists." Stemming from this controversy, which ultimately ascended to the Supreme Court of the United States and finally resulted in congressional action exempting the Tellico project from all federal law, were numerous biological studies on the snail darter. Consequently, the biology of this species, which was not discovered until 1973, has probably been the most intensely studied of any non-game fish. Studies have been published (Starnes, 1977; Hickman and Fitz, 1978), which together with ongoing studies by Tennessee Valley Authority and U.S. Fish and Wildlife Service biologists and members of the federally appointed Snail Darter Recovery Team, have constituted a considerable compilation of knowledge concerning the ecology and life history of the snail darter.

The snail darter is an inhabitant of larger creeks where it frequents sand and gravel shoal areas; it also occurs in deeper portions of rivers and reservoirs where current is present. The dorsal color pattern of alternating dark saddles and pale brown areas serves as highly effective camouflage against the snail darter's preferred substrate of sand and scattered gravel. It also has the capacity to burrow beneath the substrate, similar to the behavior exhibited by the sand darters of the genus *Ammocrypta*, perhaps serving both as concealment and an energy-conservation measure. Spawning occurs early in the year, extending from February to about mid April. Males move to shoal areas in early February and are joined by more and more females as the season progresses. Males court females by following them along the bottom and butting them on the caudal peduncle with their heads and stroking the females' backs with their pectoral fins. Although actual spawning has not been observed, spawning behavior probably approximates that described for *P. caprodes* and other members of the genus. Females contain an average of about 600 mature eggs and probably mate with several males over the course of the season. Hatching requires 15–20 days depending on water temperature. Newly hatched larvae are about 7 mm long. During their early development, which is extended by cooler water temperatures, snail darter larvae drift considerable distances downstream to deeper areas. The larvae survive by first absorbing nutrients from the yolk sac and then probably feed on zooplankton. By late summer, young snail darters attain lengths approaching 40 mm or so and many have begun to migrate upstream toward the spawning habitat. Sexual maturity is apparently reached by some individuals at age 1, at lengths averaging 55 mm. At age 2, lengths are 65–70 mm, and 3-year-olds are 80 mm or more. A few individuals may survive into a 4th year. Larvae are very phototaxic (attracted to light), a phenomenon also noted in larval walleye by Bulkowski and Meade (1983). This phenomenon may have implications regarding diurnal movements in the water column or depth maintenance. The dietary preference of the snail darter gave it its name. *Percina tanasi* specializes on small pleurocerid river snails, mostly *Leptoxis* (= *Anculosa*) and *Lithasia*, as well as some physid snails and limpets. This preference is exhibited to some degree by all members of the subgenus *Imostoma*. The gape (mouth size) of *Imostoma* species exceeds that of other *Percina* and is perhaps an adaptation to feeding on these relatively large particles. Snails comprised 60% of the overall annual diet of Little Tennessee River snail darters, but there was considerable utilization of caddisfly larvae (*Glossosoma*, *Hydropsyche*, *Brachycentrus*), midge and blackfly larvae, and a few mayfly nymphs. Maximum total length 90 mm (3.55 in).

Distribution and Status: It is generally felt that the snail darter inhabited the main channel of the upper Tennessee River and the lower reaches of major tributaries. Impoundments have fragmented much of this range. After its discovery in the lower Little Tennessee River in 1973 by D. A. Etnier and R. A. Stiles, the snail darter was thought to be restricted to that habitat, with stragglers from that population dispersing into the adjacent headwaters of Watts Bar Reservoir below Fort



Range Map 278. *Percina tanasi*, snail darter.

Loudon Dam. In 1976 it was transplanted to the lower Hiwassee River by TVA biologists in an attempt to preserve the species prior to impoundment of the Little Tennessee River by Tellico Dam, which ultimately occurred in 1979. A population estimated at about 2,500 persists in the Hiwassee River. A smaller transplant to the Nolichucky River was also attempted by TVA in 1975, but was curtailed when surveys there revealed a population of another federally jeopardized fish, the sharphead darter (*Etheostoma acuticeps*). The Nolichucky transplant, and 1979–1980 transplant attempts in the lower Holston and middle Elk rivers may have been unsuccessful, but the 1988 and 1989 collections of snail darters from the lower French Broad and lower Holston rivers, respectively (C. F. Saylor, pers. comm.), may represent progeny of snail darters transplanted into the lower Holston. Neither the numerous fish collections from the Tennessee River drainage dating back into the late 1800s nor the massive effort to locate additional populations conducted by TVA during the 1970s revealed any snail darters besides the population in the lower Little Tennessee River, unless those from upper Watts Bar could be demonstrated to represent a breeding population not dependent on the Little Tennessee River for spawning habitat. Reproduction apparently does not occur in upper Watts Bar, as considerable effort by TVA biologists subsequent to impoundment of Tellico Reservoir revealed only large adults persisting for a few years post-impoundment.

In 1978, a recovery team for the snail darter was appointed by the director of the U.S. Fish and Wildlife Service consisting of the authors of this book plus biologists from the Fish and Wildlife Service, TVA, and Tennessee Wildlife Resources Agency. Various recovery plans were devised (e.g., Biggins and Eager, 1983) over the succeeding years to identify objectives for preservation. In 1980, the future of the snail darter brightened considerably when W. C. Dickinson, D. A. Etnier, A. G. Haines, and G. J. Kaufmann discovered an additional population in South Chickamauga Creek in Chattanooga. This discovery prompted the recovery team to search for additional populations in similar habitats, the lower reaches of larger tributary streams of the Tennessee River. These searches and more recent general collections resulted in the discovery of a substantial population of snail darters in the lower portion of Big Sewee Creek in Meigs County and apparently smaller populations (represented by only one or a few specimens) from lower Sequatchie River in Marion County, Little River in Blount County, lower French Broad River in Sevier County, and lower Paint Rock River in Madison County, Alabama. The population in South Chickamauga Creek extends upstream a short distance into north Georgia. These new discoveries prompted the Snail Darter Recovery Team to suggest reclassification of the snail darter from Endangered to Threatened, an action accomplished in July 1984 by the U.S. Office of Endangered Species.

Similar Sympatric Species: Occurs with the related saddleback darter (*P. vigil*) in the lower Paint Rock River in Alabama, and perhaps additional sites of sympatry will be discovered near the lower bend of the Tennessee River. See comments under *P. vigil.* Also occurs with the blenny darter (*Etheostoma blennius*) in the Sequatchie River. In the blenny darter, the most anterior of the four dorsal saddles is entirely in advance of the dorsal fin, and modified midventral scales are lacking on the completely scaled belly.

Systematics: Subgenus *Imostoma*. Systematics presented by Etnier (1976). Intimately related to the stargazing darter, *P. uranidea*, of the White and Ouachita river systems of Missouri and Arkansas and formerly of the lower Wabash River, Illinois and Indiana.

Etymology: *Tanasi* is the former capital of the Cherokee Nation, which was located on the Little Tennessee

River, the type locality of the snail darter. A derivation of this Cherokee place name is "Tennessee."

Percina vigil (Hay).

Saddleback darter

Plate 288a. *Percina vigil*, saddleback darter (saddles indistinct), male, 51 mm SL, Big Sandy R. system, TN.

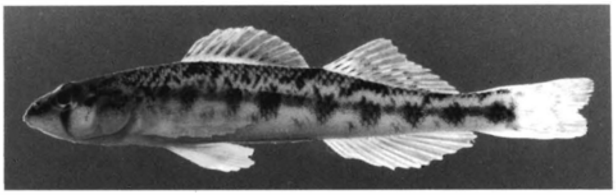


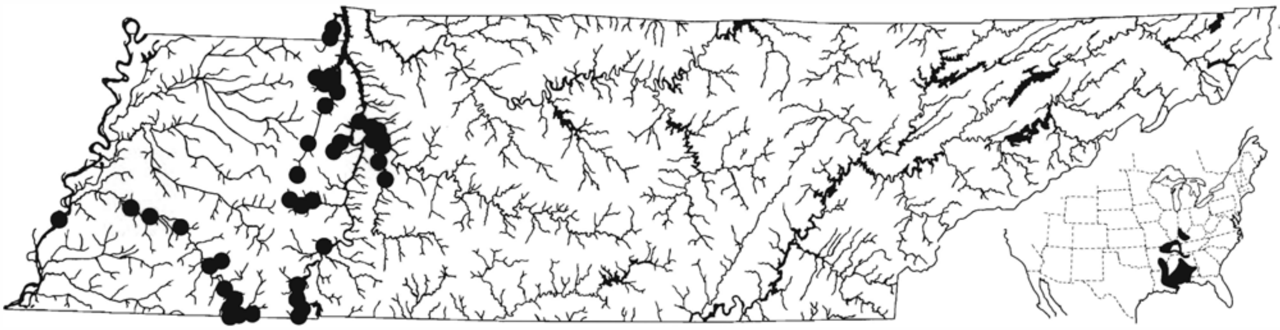
Plate 288b. *Percina vigil*, saddleback darter, preserved specimen with well developed dorsal saddles, 43 mm SL, Hatchie R., TN.

Characters: Lateral-line scales 46–62. Dorsal fin with 10–11 (9–12) spines and 13–15 (12–16) soft rays. Anal fin soft rays 10–11 (9–12). Pectoral fin rays 14–15 (13–16). Principal caudal fin rays 15–17 (14–17). Gill rakers 13–16, length of longest rakers about 4 times their basal width, even most ventral gill rakers well developed. Vertebrae 38–40. Premaxillary frenum absent or weak. Gill membranes separate. Cheeks naked in most Gulf Coast populations to well scaled elsewhere. Opercles and nape scaled. Breast and prepectoral area naked. Belly with naked areas anteriad and along midline, except for weakly to moderately developed modified midventral scales on posterior portion of belly. Dorsum straw colored with four broad, dark saddles which are often indistinct in specimens from turbid water; a fifth saddle sometimes apparent over the caudal fin insertion. Lateral blotches eight or nine. Suborbital bar well developed. Spinous dorsal fin with narrow dark marginal and broader basal dark bands separated by clear area (more conspicuous in males). Soft dorsal and caudal fins with brown markings on rays, other fins clear. As characteristic of the subgenus *Imostoma*, the anal fin of males is much longer than that of females. Extensive breeding tubercles develop over ventral half of body, on anal fin soft rays, ventral surface of pelvic fin rays, and ventral caudal fin rays. Small tubercles also develop on cheeks, opercles, and lower jaw.

Biology: The saddleback darter is an inhabitant of larger creeks and rivers and, occasionally, small streams, where it frequents shoal areas having sand and/or gravel substrates. As with other *Imostoma*, spawning may occur early in the year, during late winter, but it probably extends at least into April. Collette (1965) reported maximum tubercle development during February in Mississippi populations. Thompson (1977) postulated an April to June spawning season. Early life history information is not available. Length-frequency distribution of specimens in our collection indicates that lengths of about 35–50 mm are reached after 1 year's growth, and many of these are sexually mature. Lengths of about 55–60 mm are reached at age 2, and apparently few individuals survive through their third winter. Members of *Imostoma* seem predisposed to feed on snails when available, and this was found to be true in Duck River specimens of saddleback darters which had fed on pleurocerid (*Leptoxis*) river snails (Starnes, 1977). A variety of aquatic insects including hydropsychid caddisfly larvae, midge larvae, and small mayfly nymphs, such as baetids, is also utilized (Thompson, 1974; Miller, 1983). Maximum total length 65 mm (2.5 in).

Distribution and Status: Widespread but of sporadic occurrence in low-gradient creeks and rivers, mostly below the Fall Line, along Gulf Coastal drainages from the Escambia River westward to the Mississippi River, and continuing up both sides of the Mississippi (and in the main channel) to southeastern Missouri, and lower reaches of the Ohio and Tennessee rivers. Lower Ohio River populations are apparently extirpated, but *P. vigil* continues to be fairly common in suitable habitats in lower Tennessee and Mississippi River tributaries in west Tennessee.

Similar Sympatric Species: Occurs with the snail darter, *P. tanasi*, in the lower Paint Rock River in Alabama. In *P. vigil* the posterior border of the fourth dorsal saddle (Fig. 142b) is well in advance of the anterior dorsal insertion of the caudal fin (visible as a median white line); in the snail darter (Fig. 142a) the posterior border of this saddle contacts the anterior caudal fin insertion. May also be occasionally sympatric with *Etheostoma blennius*, a more upland species, which also has four conspicuous dorsal saddles that are similarly placed. In *blennius* the gill membranes are broadly connected, there is a reddish marginal band on the spinous dorsal



Range Map 279. *Percina vigil*, saddleback darter.

fin, the belly is completely covered with unmodified scales, and the most anterior dorsal saddle is entirely in front of the dorsal fin.

Systematics: Subgenus *Imostoma*. It appears that this species will have been known under three different names within a 10-year period. Hubbs and Black (1940b) incorrectly synonymized it with *P. uranidea* (Jordan and Gilbert), feeling that the nominal species *P. ouachitae* (Jordan and Gilbert) was identical. It was referred to as *P. uranidea* until Thompson and Cashner (1975), after examining types of these two nominal species, pointed out that both were distinct and still occurred sympatrically in the eastern Ozark area. It now appears that the use of *P. ouachitae* will be short lived. Suttkus (1985) has re-examined the type specimen of *Ioa vigil* Hay and presents convincing evidence that this juvenile specimen, synonymized with *P. shumardi* by Page (1983b), represents the same taxon as *P. ouachitae* (Jordan and Gilbert). Since *Ioa vigil* Hay (1883) has chronological priority over *Etheostoma ouachitae* Jordan and Gilbert (Gilbert, 1887), rules of zoological nomenclature mandate that the latter name be treated as a junior synonym of *Percina vigil* (Hay). Except for valid specimens from the lower Wabash River during the late 1800s, records of *P. uranidea* from east of the Mississippi River should be considered as representing *P. vigil*; many records of *P. uranidea* from west of the Mississippi River are also based on *P. vigil*.

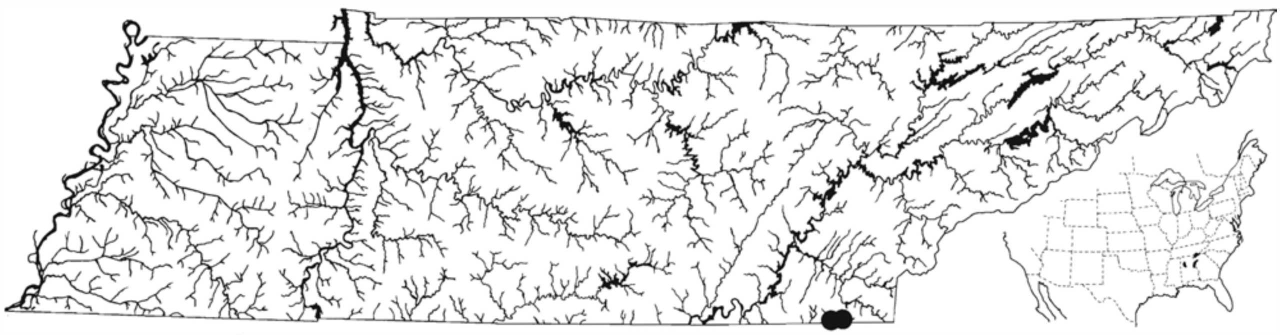
Etymology: *vigil* = wide awake.

Percina (*Alvordius*) sp.

"Bridled darter"

Plate 289. *Percina* (*Alvordius*) sp., "bridled darter," 62 mm SL, Conasauga R., TN.

Characters: (Based on 23 Conasauga River specimens.) Lateral-line scales 66–73 (65–77). Dorsal fin with 12–15 (11–15) spines and 10–12 soft rays. Anal fin soft rays 8–9 (8–10). Pectoral fin rays 13–14 (12–14). Principal caudal fin rays 15–16 (14–16). Gill rakers 12–14, longest rakers about 4 times their basal width. Premaxillary frenum present. Gill membranes barely connected or separate. Cheeks, opercles, prepectoral area, and nape scaled. Belly and breast fully scaled to naked anteriad. Modified midventral scales well developed in males. Dorsum pale brown, typically without conspicuous darker markings on midline but with an irregular, narrow, dark brown stripe above black lateral stripe. The eight or so lateral blotches vary from being completely fused into a lateral stripe to having some blotches discrete. Suborbital bar weak to absent. Posterior lateral blotch extends on base of caudal fin to form a caudal spot slightly below the midline and little if any darker than the lateral blotches. Fins with membranes clear and rays and spines with scattered brown pigment except in nuptial males which have marginal and basal dark bands around a clear median band in the spinous dorsal fin and darkly speckled membranes in anal and pelvic fins. Caudal fin with darkened membranes distally. Tuberculate ridges develop on rays and spines of anal fin, on pelvic spine, and possibly on pelvic fin rays.



Range Map 280. *Percina* (*Alvordius*) sp., "bridled darter."

Biology: The bridled darter is an inhabitant of small rivers having exceptional water quality. It spends much of its time in midwater, hovering about underwater objects such as boulders or large piles of debris rather than maintaining close contact with the substrate. Preferred habitats in the Conasauga River are flowing pool areas with sand and detritus substrates and/or bedrock. We have also collected this rare darter from the lower reaches of a small tributary, Minnewauga Creek, in both spring and fall. Its biology has received little attention. Presumably, it spawns on gravel shoals as do other *Percina*. The biology of a highly similar and presumably intimately related form has recently been studied by Wieland and Ramsey (1987) in the Tallapoosa system of Alabama, where spawning probably occurs from late March into May. In the Conasauga form, fully gravid females have been collected from late May through late June. Females have a low average fecundity of only about 75 mature ova. Actual spawning was not observed. Apparent length classes of bridled darters in our collections indicate that lengths of about 50, 65, and 75 mm are reached at ages 1–3. These correspond generally to lengths (converted from SL) for the Tallapoosa form reported by Wieland and Ramsey, except they found only the two smaller age classes and thus surmised a life span of 2+ years with sexual maturity reached at 1 year. We have observed bridled darters to feed in a delicate manner similar to that of the longhead darter, plucking food items from underwater objects and also feeding on drifting organisms while hovering downstream of rocks where turbulence thrusts these items upward. Stomachs of Conasauga specimens examined contained small prey items, primarily baetid mayfly nymphs and blackfly larvae. Wieland and Ramsey found similar prey items plus chironomid larvae and perlid stonefly nymphs to be dominant. Peak feeding was late in the day just before dusk. Maximum total length 75 mm (3 in).

Distribution and Status: The form occurring in Tennessee is restricted to the Conasauga River system in Tennessee and adjacent north Georgia (Bryant et al., 1979a). It is uncommon in the Conasauga River in the vicinity of the Georgia state line, but may be locally common in some years in areas a few kilometers upstream near Minnewauga Creek in Polk County. Although not currently afforded protected status under Tennessee or federal actions, it is certainly a candidate for such status. If, as we suspect to be the case, the form in the Conasauga River is recognized as being separable from similar undescribed forms in the Tallapoosa and Black Warrior river systems, it would warrant the same Threatened status conferred to other Conasauga endemics or virtual endemics such as the amber and trispot darters and the Conasauga logperch.

Similar Sympatric Species: Occurs with the abundant blackbanded darter, *P. nigrofasciata*, juveniles of which are similar in appearance to the bridled darter. The blackbanded darter has more (usually 12 or more) lateral blotches that are higher than wide, three basicaudal spots, 66 or fewer lateral-line scales, and tends to be deeper bodied.

Systematics: Page (1974a) has tentatively assigned this form to the subgenus *Alvordius*. Like the similar *P. macrocephala*, it is divergent from other *Alvordius* in being overall more attenuate and slender-snouted, and in having less benthic-oriented habits. Wieland and Ramsey (1987) treated the Conasauga form as conspecific with Tallapoosa and Black Warrior forms. We have seen very few specimens from the Black Warrior River system, but those from the Tallapoosa are much stockier, have a decidedly shorter snout, more dark markings on the dorsum, smaller lateral blotches, and lower (virtually nonoverlapping) lateral-line scale counts. Systematics of this complex have been under study by J. D. Williams and J. S. Ramsey.

Percina (*Percina*) sp.

"Mobile logperch"

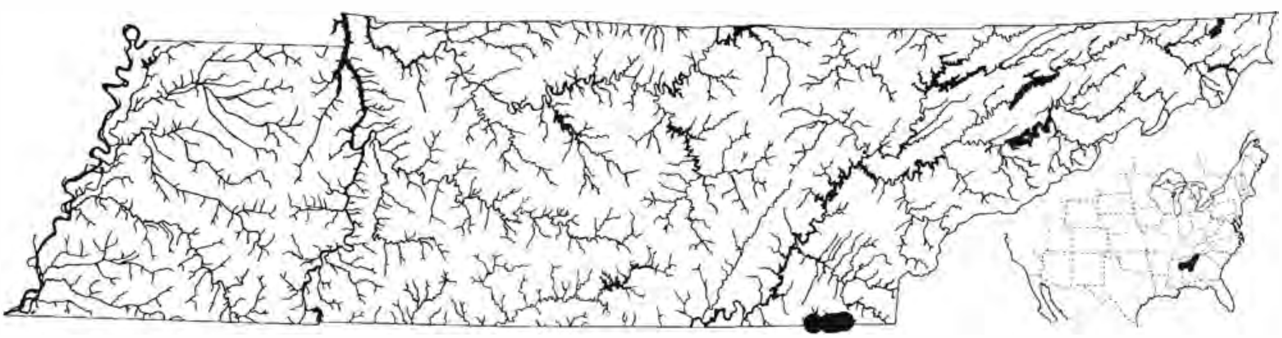
Characters: (Based on 50 specimens from upper Mobile Basin.) Lateral-line scales 86–95 (84–104). Dorsal fin with 15–17 (14–17) spines and 15–17 (14–17) soft rays. Anal fin soft rays usually 11 (10–12). Pectoral fin rays 14–15 (14–16). Principal caudal fin rays 17. Gill rakers 14–16 (14–18), length of longest rakers about 4 times their basal width. Premaxillary frenum present. Gill membranes separate. Anterior belly (except for modified midventral scales), breast, and prepectoral area naked. Nape, cheeks, and opercles scaled. Modified midventral scales well developed in males. Coloration similar to *P. caprodes* except for persistent orange submarginal band in spinous dorsal fin (bright red-orange in nuptial males) bordered by dark marginal and basal bands. Nuptial males with darkened pelvic and anal fins, and nuptial tubercles as described for *P. caprodes*.

Biology: The Mobile logperch occurs in a variety of habitats from pool areas to deep riffles and runs in rivers as well as smaller streams. Apparent spawning aggregations have been observed in late April over swift gravel riffles. Specimens appear to retain reproductive condition through at least mid-May. We have observed it to feed in typical logperch fashion, flipping over stones with the padded snout and feeding on the organisms beneath. One individual observed in the Conasauga River exhibited particularly interesting behavior, repeatedly rolling a live, medium-sized mussel along the river bottom. The UT collection contains a hybrid between this species and *P. nigrofasciata*. Other aspects of its biology are unstudied but are probably much like those of *P. caprodes*. Maximum total length 163 mm (6.5 in).

Distribution and Status: Widespread and abundant in Mobile Basin, mostly above the Fall Line. This is a common darter in the Conasauga River and some of its larger tributaries in Tennessee, but it occurs nowhere else in the state.

Similar Sympatric Species: See *P. jenkinsi*.

Plate 290. *Percina* (*Percina*) sp., "Mobile logperch," 114 mm SL, Conasauga R., TN.



Range Map 281. *Percina* (*Percina*) sp., "Mobile logperch."

Systematics: Subgenus *Percina*. According to Jenkins et al. (1977) and Thompson (1978, 1985) this species is part of a complex of eastern Gulf slope logperches closely allied to *Percina carbonaria* of the Edwards Plateau region of Texas (elevated from synonymy of *P. caprodes* by Jenkins, 1976, and Morris and Page, 1981). The complex reportedly consists of the Mobile logperch plus a second form restricted to below the Fall Line in the Mobile through Pearl drainages; a third form is found east of Mobile Basin in southern Alabama and the Florida panhandle eastward to the Choctawhatchee River (Thompson, 1980, 1985).

Percina (*Odontopholis*) sp.

"Frecklebelly darter"

Characters: Lateral-line scales 56–71. Dorsal fin with 11–15 spines and 11–13 soft rays. Anal fin soft rays 9–10 (8–11). Pectoral fin rays 12–13 (10–13). Principal caudal fin rays 15–16 (6 specimens); Thompson (1977) reported a consistent count of 17 in this species and *P. cymatotaenia*. Gill rakers 12–16, longest rakers about 4 times their basal width (seven specimens). Vertebrae 42–45. Premaxillary frenum present. Gill membranes barely connected or separate. Nape, cheeks, opercles, breast, prepectoral area, and belly completely covered with exposed ctenoid scales. Modified midventral scales lacking except for 1 or 2 between the pelvic fin bases. Dorsum brownish with about 11 small saddles, anterior ones forming a continuous predorsal streak. Dorsolateral area with a wavy brown stripe. Lateral line conspicuously depigmented within the wide, black lateral stripe. Lower head and body with profuse brown mottling which may form irregular horizontal stripes along belly. Suborbital bar weakly to moderately developed. Single median caudal spot much darker than lateral band. Spinous dorsal fin with marginal and broader basal black band separated by a clear band about the same width as the marginal band (base of fin and extreme anterior margin clear). Rays of other fins flecked with brown. Nuptial males with dark gular area and a keeled flange with highly modified ctenoid scales at ventral base of caudal fin. Nuptial tubercles and bright breeding colors absent.

Biology: Biology of the undescribed "frecklebelly darter" is poorly known. It occurs in small rivers and larger creeks where it generally frequents pool areas with moderate to sluggish current and vegetational cover, such as water willow and riverweed, steep banks with brush and roots, as well as submerged leaf litter. It spends much of its time in midwater well above the substrate and occasionally perches on suspended objects such as roots or debris. We have observed both this species and the highly similar bluestripe darter (*P. cymatotaenia*) of Missouri hovering among current-swept vegetation where the wavy lateral pigmentation blends well with the undulating background of broken stalks and willowy leaves. Peak breeding season is from mid-March to mid-April (Thompson, 1977). Pflieger (1982) has studied the biology of the highly similar *P. cymatotaenia* in Missouri. He found spawning to occur on fine gravel with eggs buried in the substrate. Larger males have intensified coloration and are aggressive towards other males. Receptive females are followed and mounted by the males; the pair then vibrate together creating a depression in the substrate into which their caudal regions are buried during the release of ova and milt. Females contained about 100–300 mature ova depending on their size. Hatching of eggs required about 10 days and larvae were about 8.5 mm TL at hatching. Growth was estimated to average 45 mm SL at age 1, 63 at 2, 68 at 3, and 72 at 4 with a life span of over 4

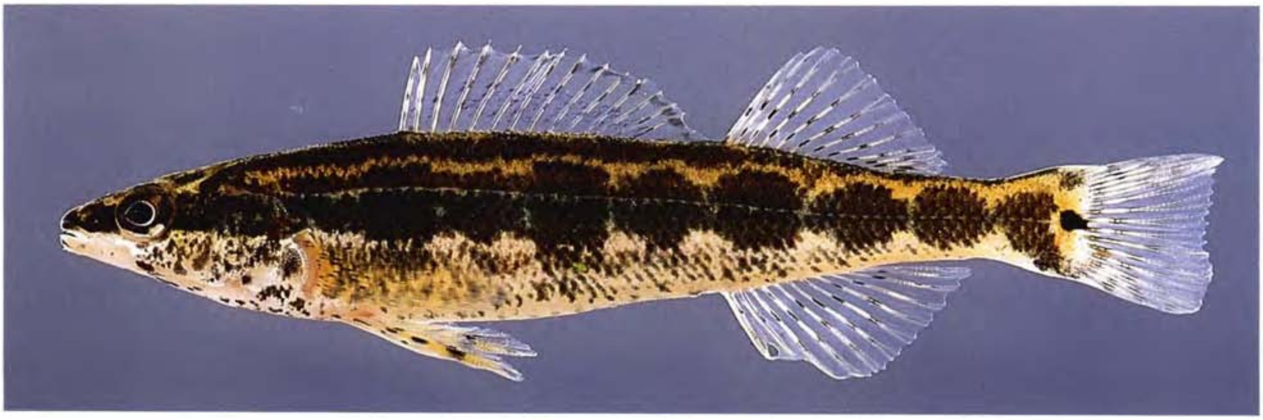
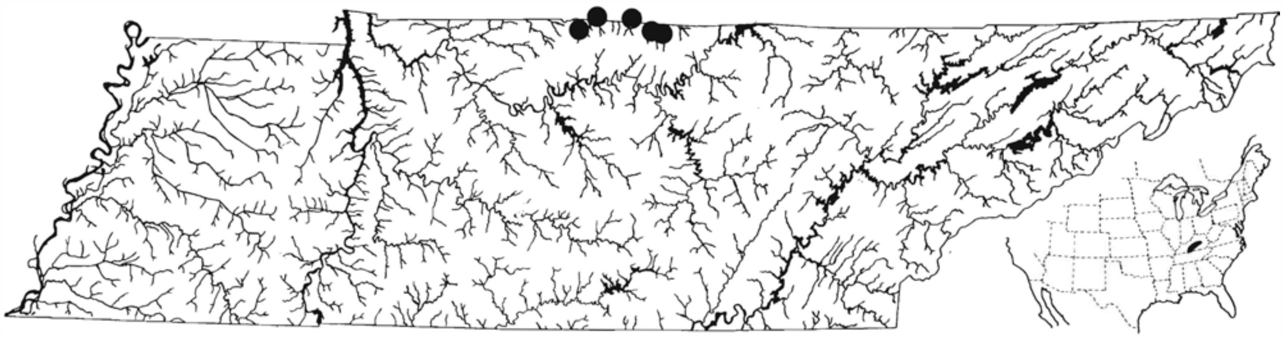


Plate 291. *Percina* (*Odontopholis*) sp., "frecklebelly darter," 59 mm SL, Trammel Fork, KY.



Range Map 282. *Percina* (*Odontopholis*) sp., "frecklebelly darter."

years indicated. Chief prey items were midge larvae, mayfly and stonefly nymphs, microcrustaceans, and amphipods. Maximum size 68.6 mm SL, or about 81 mm TL (3.2 in) (Thompson, 1977).

Distribution and Status: Restricted to the middle and upper Green River system and portions of the upper Kentucky River system. Usually rare, but not uncommon in some Kentucky localities. In Tennessee restricted to the Barren River system. Rarely collected in Tennessee, with records from West Fork Drakes Creek, Sumner County (Thompson, 1977) and Salt Lick Creek, Macon County (Clay, 1975). Its rarity in Tennessee results from the peripheral nature of its distribution rather than any identifiable, immediate threats. It is included in Tennessee's list of rare vertebrates as a Species of Special Concern (Starnes and Etnier, 1980).

Similar Sympatric Species: The frecklebelly darter is sympatric with three similar appearing *Percina* species, *P. macrocephala*, *P. maculata*, and *P. sciera*. Most similar to *P. macrocephala*, which differs in lacking a complete covering of exposed ctenoid scales on the gill cover and breast, and has the belly naked along the midline or this area is occupied by modified midventral scales. The dark shadow under the caudal spot (*P. macrocephala*) is lacking in the frecklebelly darter. The other two species are somewhat less similar and are easily separable on characters given in the key.

Systematics: Subgenus *Odontopholis*. Systematics were treated by Thompson (1977). Highly similar to the only other *Odontopholis*, *P. cymatotaenia*, of south-central Missouri. Thompson hypothesizes *Odontopholis* to be most closely related to subgenus *Alvordius*.

Genus *Stizostedion* Rafinesque
The Pikeperches

In addition to the two North American species, the pikeperches include *Stizostedion lucioperca*, *S. marinum*, and *S. volgense* of western Eurasia. Svetovidov and Dorofeeva (1963), Marshall (1977), Collette and Banarescu (1977), and Collette et al. (1977) provided information on the systematics and biology of the genus. All are piscivores with enlarged canine teeth on both jaws and the prevomer and palatine bones. Other generic characters include a strongly serrate preoperculum and dorsal margin of the supracleithrum, complete head canals, protractile premaxillae, 7 branchiostegal rays, 17 principal caudal fin rays, separate gill membranes, a well-developed swimbladder, and the absence of nuptial tubercles. Pikeperches are by far the largest of the percids and are highly esteemed game and food fishes. Meat is white, firm, flaky, mild flavored, and superb table fare. Although they tend to be unspectacular as fighters, occasional large fish can display impressive speed, power, and stamina when hooked.

Etymology: *Stizostedion*, of Greek origin is transliterated to "pungent throat" according to Rafinesque (1820). The name presumably refers to the proliferation of large canine teeth on the jaws and roof of the mouth.

KEY TO THE NORTH AMERICAN SPECIES

1. Spinous dorsal fin with horizontal rows of discrete black spots; 4 dark saddles and two midlateral blotches conspicuous against paler background; longest gill rakers shorter than diameter of pupil; pyloric caecae 4 or more; soft dorsal fin rays (exclusive of 1–2 short, spine-like anterior elements) usually 19 or fewer . . . . *S. canadense*

   Spinous dorsal fin lacking discrete black spots except large one at posterior base; dark dorsal saddles and lateral blotches absent or inconspicuous; longest gill rakers equal to or longer than diameter of pupil; pyloric caecae 3; soft dorsal fin rays often 20 or more . . . . *S. vitreum* p.599

Stizostedion canadense (Griffith and Smith).

Sauger

Characters: Lateral line complete with 75–88 scales (higher counts in Northwest), with additional pored scales extending onto hypural plate. Spines in first dorsal fin 12–13 (10–14), 13–15 in Northwest. Second dorsal fin with 1–2 short, anterior, spine-like rays and 17–19 (16–21) soft rays. Anal fin with 2 slender spines and 11–13 (10–14) soft rays. Pectoral fin rays 14–16 (13–16), 12–14 in Northwest. Gill rakers (rudiments shorter than basal width excluded) 7–11, longest rakers shorter than (about 2/3) diameter of pupil. Vertebrae 43–45. Pyloric caecae 4–8 (3–9). Scales present on opercle, subopercle, cheek, breast, nape, and top of head forward to interorbital region. Opercular scales exposed, ctenoid, and as large as anterior lateral-line scales in our area, but may be reduced or absent in Northwest. Sauger are strikingly patterned, with dark brown saddles and blotches on a tan (dorsal) to white (ventral) background. Four dark saddles located under anterior third of spinous dorsal fin, between dorsal fins, under posterior middle of soft dorsal fin, and anterior to caudal fin insertion. Spinous dorsal fin with three hori-

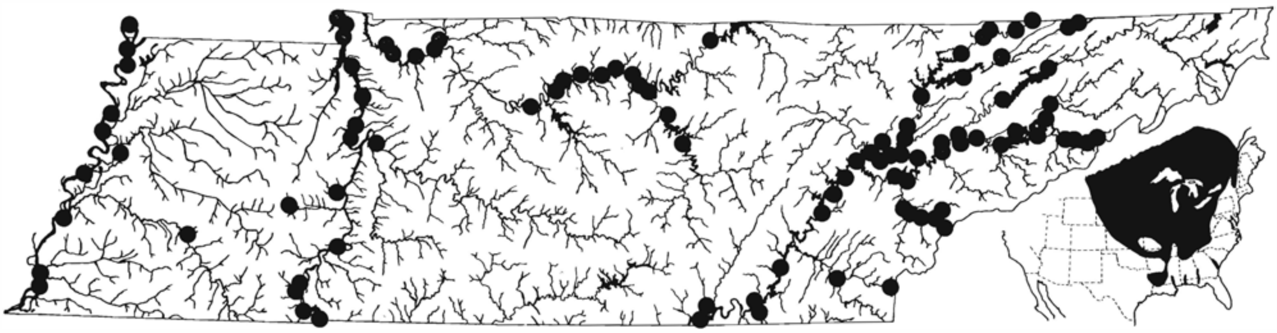
Plate 292a. *Stizostedion canadense*, sauger, 260 mm SL, Mississippi R., TN.

Plate 292b. *Stizostedion canadense* x *S. vitreum* hybrid, "saugeye," 290 mm SL, French Broad R., TN.

zontal rows of discrete black spots on anterior half of each membrane and often a large black spot at its posterior base. Soft dorsal and caudal fins darkly mottled on rays and membranes. Anal and pelvic fins immaculate or nearly so. A dark blotch occurs at pectoral fin base and extends onto proximal portion of the fin; distal portion of fin is weakly mottled. Side of head and jaws darkly mottled, with suborbital bar extending posterioventrad. Breast and lower surface of head immaculate.

Biology: Sauger typically inhabit large, often turbid rivers and have been successful in many reservoirs. A light-reflective coating behind the retina (*tapetum lucidum*) gives the eyes an eerie glow and is an adaptation to feeding at night and in dim light (Ali and Anctil, 1977; Ali et al., 1977; Ryder, 1977). Sauger are more tolerant of turbidity than are walleye, and where both species occur, one is typically far more abundant (Fitz and Holbrook, 1978). Biological information is summarized from Scott and Crossman (1973) and Becker (1983) unless otherwise indicated. A large bibliography on sauger biology was compended by Ebbers et al. (1988). During late winter sauger begin congregating near spawning areas, at which time they are most vulnerable to anglers (Eschmeyer and Haslbauer, 1946; Haslbauer and Manges, 1947). Spawning activity begins in late April as water temperatures approach 43 F in northern portions of their range. Spawning migrations may cover considerable distances. For instance, a sauger tagged at Kentucky Dam subsequently negotiated two dams and was recaptured 11 days later at Wheeler Dam in Alabama 380 km upstream (Clay, 1975). In our area (Muench, 1966; Byerly and Ridley, 1980) spawning begins earlier (late March) but at higher water temperatures (52 F), and is slightly later than, but overlapping with, walleye spawning; natural hybrids between the two are not uncommon (Stroud, 1948b). Spawning occurs at night and extends over a 2-week period. Nest construction and parental care are absent. Typically, several males attend each spawning female. Successful spawning requires firm substrates. In our area, most spawning probably occurs over rubble and gravel in tailwaters, but sauger runs into large unimpounded streams and rivers also occur. Larger females may produce over 100,000 eggs annually, but most produce 20,000–60,000 (Hassler, 1958). The mature eggs, 1.3 mm in diameter, are slightly smaller than those of walleye. Eggs are adhesive immediately after spawning, but shortly become non-adhesive and may be widely dispersed by currents. Hatching, which requires 21 days at water temperature of 47 F, probably occurs after about 2 weeks in our area. The 5 mm TL larvae soon begin feeding on cladocera, copepods, and midge larvae, but, as juveniles, switch to a diet of almost exclusively fishes (Vanicek, 1964; Priegel, 1969; McGee and Griffith, 1977; McBride and Tarter, 1983). Small gizzard and threadfin shad are the primary prey locally, with emerald shiners and burrowing mayfly nymphs important food where abundant. Adults disperse to deeper waters after spawning. Young-of-year sauger, like walleye and yellow perch, are pelagic during the early part of their first summer (Nelson, 1968a). In general, southeastern sauger initially grow much faster than those studied in the north, but have a shorter life span. Sauger in Tennessee reservoirs (Hassler, 1957; Fitz, 1968; Hackney and Holbrook, 1978; Arnold Woodward, in litt.) are 8.4–10.6 cm TL at age 1, 12.6–15.6 at age 2, 15.0–17.4 at age 3, 17–18 at age 4, and 19–20 at age 5. Except for greater growth in the 1st year, lengths of various age classes in Tennessee are comparable to those reported for South Dakota populations (Vanicek, 1964). Strictly riverine populations, such as in the Mississippi, may have a much slower growth rate (Vasey, 1967), possibly due to less concentrated forage fishes. Females average slightly longer than males at all ages. Most of our sauger are sexually mature at age 2, and maximum life span is about 7 years, but up to 13 years in the north (Hassler, 1958). Growth of sauger-walleye hybrids through the first 4 years (Cherokee Reservoir, Arnold Woodward, in litt.) is greater at 11.6, 17.4, 20.8, and 23.7 in TL. Favored angling method is to fish slowly near the bottom with leadhead jigs dressed with hair, a plastic grub, or a live minnow. Sauger congregate below dams in early spring, and these are favored fishing areas. They are probably underharvested during the rest of the year when less concentrated (Eschmeyer and Haslbauer, 1946). The flesh is firm and white and of a mild flavor. Although there is a possibility that record-size saugers represent sauger x walleye hybrids, the following are reported: Tennessee, 7 lbs 6 oz, Pickwick tailwater, 19 Feb. 1973, Rayford Voss; world record 8 lbs 12 oz, North Dakota, 1971. Sauger X walleye hybrids (saugeyes) get larger, with the Tennessee record of 9 lbs 15 oz (Ft. Loudoun tailwater, 15 Mar. 1983, Jerry Windle) approaching the world record of 10 lbs 6 oz (North Dakota, 1975).

Distribution and Status: Sauger are native to much of central North America from the Mississippi and Missouri river basins, the Great Lakes drainage, and Hudson Bay drainage of southern Canada from Quebec west to Alberta. Successful introductions have been made in larger Gulf Coast and Atlantic Slope drainages. Sauger disappeared from Cherokee Reservoir several years af-



Range Map 283. *Stizostedion canadense*, sauger (range extends north off inset to latitude of James Bay and west to Alberta; disjunct southern populations represent introductions).

ter impoundment (Hackney and Holbrook, 1978), perhaps due to blockage of spawning runs by John Sevier dam farther up the Holston River. Hatchery reared sauger x walleye have been stocked in several localities by the Tennessee Wildlife Resources Agency (TWRA).

Similar Sympatric Species: With the exception of pigmentation, there are surprisingly few characters that allow consistent separation of sauger and walleye. Pigmentation of the spinous dorsal fin and body are the most reliable characters, but juvenile sauger lack the characteristic pigmentation of adults. Fish (1932), Nelson (1968b), and Priegel (1969) discuss characters useful in separating young sauger and walleye up to 27 mm long. At 35–40 mm SL, dorsal saddles and lateral blotches are well developed, but spinous dorsal pigment and scales on the gill cover may not be. Relative gill raker length and dorsal soft ray counts are reliable characters, but some overlap occurs in the latter. Counts of pyloric caecae (3 in walleye, 4 or more in sauger) appear to be reliable characters, but the value of relative length of these caecae (reported as long as stomach in walleye, shorter in sauger by Jordan and Evermann in 1896 and perpetrated by later workers) is difficult to evaluate since stomach length may vary by a factor of 3 or 4 dependent on food content. Our comparisons of longest pyloric caecum with a less variable measurement, head length, indicate considerable overlap between the two species. In spite of these problems, subadult and adult sauger and walleye are rarely misidentified by ichthyologists, fisheries workers, or fishermen.

Although it may not always be possible to identify sauger-walleye hybrids with certainty, a number of characters are useful. "Saugeye" have variable body pigmentation depending on sex of the parental species but generally resemble sauger, with the saddles and blotches somewhat subdued (Nelson, 1968b). The spinous dorsal fin membranes have interrupted to nearly continuous dark pigment on their anterior half, but discrete black spots are absent in hatchery-reared adults we examined. Pyloric caecae, finger-like projections extending posteriad along the ventral and occasionally lateral aspect of the stomach and often margined with fat, have their bases at the level of the anterior pelvic fin base. There are consistently 3 caecae in walleye, and 4 or more in 27 of 29 sauger examined. Of 32 saugeye, 30 had 3 and only 2 had 4 caecae. Longest gill rakers in saugeye are nearly equal to (.9–1.2 times) pupil diameter. Cheek squamation (always 75–100% scaled in sauger) is less extensive in saugeye. In 18 subadult saugeye, 12 had cheeks 0–25% scaled; 4 were 26–50% scaled, and 2 were 51–75% scaled. Sauger have the operculum well covered with exposed ctenoid scales as large as anterior lateral-line scales. In walleye the opercle is often totally to mostly naked, with scales tiny, cycloid, and embedded. There is considerable variation, however, in both walleye and saugeye. Only 4 of 18 saugeye had opercular scales ctenoid and as large as anterior lateral-line scales. Soft dorsal fin ray counts, of limited use in identifying individual saugeye, were 17(1), 18(9), 19(31), 20(13), and 21(1) in 55 saugeye; counts for 52 sauger were 17(6), 18(29), 19(24), and 20(3). Sculpturing of the frontal bone may be an additional useful character. The elevated ridges on the frontal are visible without dissection, and our impression is that in walleye the parallel ridges extending between the orbits are more numerous and extend farther forward than in sauger, while in sauger, the numerous ridges behind the orbits are more conspicuous, diverging from the midline and extending nearly to the posterior orbital rim. These diverging posterior ridges seem better developed in saugeye than in walleye, but are not as conspicuous as in sauger. This character may be useful, but we have not attempted quantification or critically studied ontogenetic or geographic variation. Our appreciation is extended to TVA and TWRA personnel for providing hatchery reared male sauger x female walleye specimens used in the above analysis.

In summary, saugeye visually resemble sauger but have pyloric caecae counts of walleye, longer gill rakers than sauger, lack discrete black spots in the spinous dorsal fin, and have reduced cheek and opercular squamation relative to sauger.

Systematics: Although rarely employed by recent workers, three subspecies names have sporadically appeared in the literature: *S. c. griseum* (DeKay) of the Great Lakes, *S. c. boreum* (Girard) of the upper Missouri River, and *S. c. canadense* elsewhere. Rangewide variation has not been thoroughly studied. As indicated earlier, some meristic differences exist between sauger from our area and those from the northern portion of its range.

Etymology: *canadense* = of Canada.

Stizostedion vitreum (Mitchill).

Walleye

Characters: Lateral line complete with 77–87 (up to 104) scales, and additional pored scales extending onto hypural plate. High counts from published data may reflect inclusion of pored hypural scales. Dorsal fin with 12–16 spines; soft dorsal fin with 1–2 short spine-like anterior rays and 18–21 (18–23) soft rays. Anal fin with 2 slender spines and 11–14 soft rays. Pectoral fin rays 13–16. Gill rakers (rudiments shorter than their basal width not counted) 9–12, longest rakers about 1.2 times pupil diameter. Vertebrae 44–48. Pyloric caecae 3. Cheek mostly to fully naked. Opercle and subopercle mostly naked to covered with small cycloid scales, occasionally covered with large ctenoid scales. Breast and nape fully scaled. Walleye are extremely variable in color, ranging from bluish gray to brown to bright yellow. Pigment pattern also variable, usually rather uniform, but occasional specimens, especially small fish from clear water, approach sauger in their lateral and dorsal blotching. Spinous dorsal fin with continuous dusky to black on anterior one-half to two-thirds of membranes, and a black blotch covering last 2 membranes. Soft dorsal and caudal fins with dark mottling on rays and membranes, lower tip of caudal fin distinctly white. Pectoral fin with or without dark blotch at base, if present less intense than in sauger; pectoral rays weakly mottled distally. Anal fin, pelvic fin, and entire ventral surface immaculate white to yellowish.

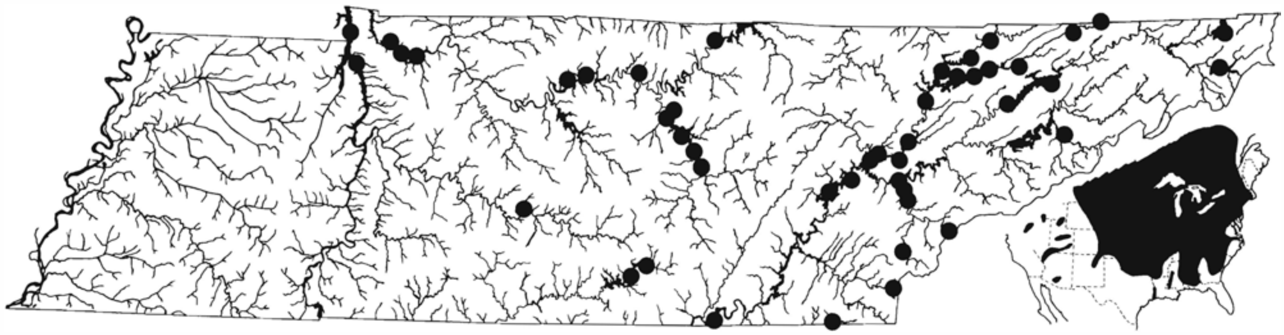
Biology: Walleye are abundant in cool, sandy-bottom lakes of glacial North America, occurred in larger rivers in our area, and continue to be common in some of our clearer tributary reservoirs. The common name stems from the large, luminous eye, which, like that of sauger, has a light-reflecting *tapetum lucidum* behind the retina. They are often incorrectly called "walleyed pike" but they are not at all related to the true pikes (Esocidae). Walleye tend to be less active than sauger in mid-day, and are primarily crepuscular feeders during cooler months and nocturnal during summer (Ager, 1976). They are prized by anglers for their large size and superb food qualities and are by far the favorite sport fish where abundant in the Midwest, where innovative angling techniques, fishing pressure, and contests rival similar interest in bass fishing in our area. Angling strategy is usually to fish slowly near the bottom. Live minnows on the tip of a leadhead, still-fished with a bobber, or trolled behind a spinner continue to be effective techniques. More recent techniques utilize night crawlers or leeches with "bait walkers," sinkers de-

Plate 293. *Stizostedion vitreum*, walleye, 190 mm SL, Norris Res., TN.

signed to avoid snagging and keep bait a precise distance from the bottom. Downriggers and depth sounders have been added to the trollers arsenal. Since walleye often associate in loose schools, locating one fish often signals a period of good fishing. At dusk and night, actively feeding walleye can be readily taken on artificial lures, with various moderate- to deep-running plugs the usual offering. Under these conditions, walleye, often extremely large ones, can be taken in shallow water over rocky reefs or near shore with large, shallow-running surface plugs using a rapid retrieve. In portions of the Midwest, ice-fishing for walleye is extremely popular, with virtual towns of fishing shanties (often including food and beverage vendors) developing on the more popular lakes. Favorite winter fishing technique continues to be a live minnow still-fished or jigged near the bottom. Hatchery culture of walleye provides fry and fingerlings for stocking primarily soft-bottomed lakes that lack suitable spawning habitat.

Except for their preference for clearer waters, walleye biology is probably very similar to that of sauger. It has been more thoroughly studied, and additional details are available for which parallels will likely be found in sauger. We summarize from the excellent reviews in Scott and Crossman (1973) and Becker (1983) unless otherwise indicated. A large bibliography on walleye biology was prepared by Ebbers et al. (1988). Like sauger, walleye are "potadromous," migrating up rivers to spawn. In northern North America, walleye begin spawning runs soon after or while lake ice cover is breaking up. Actual spawning occurs at night and peaks at water temperatures of 42–50 F. This corresponds to late April and early May in northern states and southern Canada, and is slightly earlier but broadly overlapping with sauger spawning. Spawning occurs from March to early April in Tennessee (Muench, 1966; Libbey, 1969). Where rivers are accessible, most spawning occurs there, but successful spawning also occurs in tailwaters, reefs or firm shorelines of lakes, and in flooded marshes. Spawning substrate varies from firm inorganic (boulder to sand) to flooded vegetation. In Tennessee rivers there can be considerable competition for spawning habitat with white bass and suckers (*Moxostoma*). Males precede females to the spawning grounds, and schooling by sexes occurs until the onset of spawning. Courtship and spawning have been observed to involve preliminary butting and pushing. During actual spawning, a female closely flanked by two smaller males makes a sudden rush toward the surface. Shortly thereafter the female turns or is pushed to her side, and eggs and sperm are released. Individual females spawn every 5 minutes or so, and may shed all their eggs in one night. Males spawn repeatedly throughout the 2-week reproductive period. Large females may produce over 600,000 eggs annually (70,000–230,000 more commonly), which are 1.5–2 mm in diameter and adhesive before water hardening, larger and non-adhesive after hardening. Eggs hatch in 12–18 days at normal spawning temperatures. Hatchlings are 6–8.6 mm TL, much larger than sauger larvae (Nelson, 1968b), and begin to feed on cladocera, copepods, and midge larvae before the yolk sac is completely absorbed (Houde, 1967). Larvae up to 30 mm are highly phototaxic (attracted to light), after which lighter areas are shunned (Bulkowski and Meade, 1983). This phenomenon has been previously observed in larvae of the percid genus *Percina* as well (Starnes, 1977). Like yellow perch and sauger, walleye are pelagic until they reach 25–30 mm TL, after which they live near the bottom in depths of 6 m or more until their second summer. Food shifts to small fishes during their pelagic period, and they continue to eat a wide variety of fishes the rest of their lives, supplemented with occasional frogs, crayfishes, and large insect larvae when available (Priegel, 1970; Swor, 1973; Scott, 1976). Knight et al. (1984) found seasonal shifts in forage species with minnows fed on most heavily in cooler months and the abundant juvenile shad fed on in summer. Tennessee walleye grow rapidly relative to those in the north, but may not live more than 8 years (up to 20 in the north). Moss et al. (1987) reported that overall growth in the Mobile Basin "strain" of walleye is slower than in those of other regions. Growth estimates for different reservoirs in the region are quite varied. Estimates for Norris (Stroud, 1949) and Center Hill (Scott, 1976) reservoirs are quite similar averaging about 265 mm TL at age 1, 420 at 2, 475 at 3, 505 at 4, 530 at 5, and diverging somewhat thereafter being, respectively, 533 and 559 at 6, 558 and 592 at 7, and 632 and 664 at 8. However, a wide range of growth estimates for other reservoirs is summarized in Hackney and Holbrook (1978). Some of this variation doubtless reflects difficulty in accurately aging length classes. Females average larger in age classes and grow to larger size.

Although walleye have never been as popular with anglers in Tennessee as they are in the Midwest, reservoir construction in the 1930s and 1940s was followed by the capture of huge walleye, especially in Norris Reservoir. Fish weighing 15 lbs or more were not unusual, and that was the minimum entry weight (10 lbs elsewhere) for a Tennessee walleye in the Field and Stream annual fishing contest for many years. The southern riverine strain of walleye apparently was genetically superior in growth potential to northern popu-



Range Map 284. *Stizostedion vitreum*, walleye (range extends off inset north to Hudson Bay and northwest throughout the Mackenzie River drainage; many populations in southern and southwestern portion of range represent introductions).

lations and, when forage fishes boomed following impoundments, were able to attain large size in a few years of growth (Muench, 1966; Hackney and Holbrook, 1978). However, these fish were unable to reproduce in reservoir environments or were genetically swamped and eventually supplanted by introduced northern walleyes. Walleye over 4.5 kg (10 lbs) are exceptional at present. Tennessee's record walleye, 25 lbs, is also the world record. It was taken by Mabry Harper in Old Hickory Reservoir in 1960.

Distribution and Status: Walleye have been so widely introduced that their native range is somewhat uncertain. They occur farther north than sauger, throughout the Great Lakes and Hudson Bay drainages and into the Arctic drainage in the Mackenzie River. In the United States, native range includes virtually the entire Mississippi and Missouri basins. Populations on the Atlantic Slope from Pennsylvania to North Carolina, and Gulf Coastal populations (Mobile Bay and Pearl River) may also be native (Brown, 1962; Hackney and Holbrook, 1978), but intermediate Atlantic and Gulf drainage populations and all Pacific Slope populations are introduced. Various "strains" of walleye have been stocked all over the continent including a Lake Erie strain and Hudson Bay drainage strain from Minnesota. As discussed above these introductions may have hastened the loss of a very valuable genetic resource in Tennessee rivers, a common result of the rather thoughtless widespread stockings practiced by early fisheries managers. Because of so many introductions in reservoirs, in some cases biologists have resorted to electrophoretic analysis of proteins to try to ascertain which strain they are managing (Murphy et al., 1980). Walleye wander considerably and can be expected to occur occasionally in all large waters in our state, including the Mississippi River. In the Mobile Basin, a single specimen is recorded from the Conasauga River in Tennessee. Favored fishing reservoirs include Norris, Watauga, Center Hill, and Dale Hollow.

Similar Sympatric Species: See account under sauger.

Systematics: Scott and Crossman (1973) discussed the systematics of the blue walleye, *Stizostedion vitreum glaucum* Hubbs, formerly abundant in lakes Erie and Ontario, but of questionable occurrence elsewhere. Although occasional blue-gray walleye occur in many areas, those of the Great Lakes had larger and more dorsally placed eyes, occurred in deeper waters, and were smaller than typical walleye. It has disappeared from the Great Lakes, and its taxonomic status remains uncertain (mere color morph, subspecies, or full species). Although considered by many to be extinct, blue walleye reports from Center Hill and Dale Hollow reservoirs may have some basis. Original stocking of these reservoirs were in part from Great Lakes populations, and may have included the true blue walleye. Though E. M. Scott (1976) concluded that present Center Hill stocks contained no influence of blue walleyes, subsequent photos secured by him show a typical walleye, and a blue walleye from the same gill net. The blue specimen in the photo is very different in color from the typical walleye, and appears to have larger eyes. Scott (pers. comm.) plans to investigate this situation further. The Gulf Coastal form is a smaller one (maximum known size 3.75 kg) which is intolerant of reservoirs but occurs in free flowing rivers, tailwaters, and even brackish waters (Hackney and Holbrook, 1978). This stock may eventually warrant taxonomic recognition.

Etymology: *vitreum* = glassy, referring to the luminous eye.

FAMILY SCIAENIDAE
The Drums

The sciaenids are a relatively large family of mostly marine fishes with a single freshwater representative in North America and several others in South America (e.g., genus *Plagioscion*) and other regions. The marine sciaenids are mostly shallow water forms associated with soft or sandy substrates, and several are familiar to those who have fished along our coasts. Common species are the spot (*Leiostomus xanthurus*), croaker (*Micropogonias undulatus*), kingfishes or "whiting" (*Menticirrhus*), seatrouts (*Cynoscion*), and red drum or channel bass (*Sciaenops ocellata*).

Sciaenids have two distinct dorsal fins, the second characteristically long-based and thus having high numbers of soft rays. The anal fin has 1 or 2 spines. Pelvic fins are positioned near the pectorals, and the caudal fin typically is broadly pointed or truncate and the lateral line extends on to it to near the tip. Scales are ctenoid. The sensory system of the head is characteristically cavernous and often conspicuous. A complex swimbladder with specialized musculature is capable of resonating deep sounds, giving rise to the drum family's common name. The widespread monotypic genus *Aplodinotus* Rafinesque occurs throughout central North America and south in the east coastal drainages of Mexico to Yucatan. Chao (1978) left this genus unassigned in his classification of western Atlantic region sciaenids. Sasaki (1989) has conducted a comprehensive study on the phylogeny of sciaenids. He hypothesized closest relatives of *Aplodinotus* to be among a group including marine genera, such as *Sciaenops* and *Roncador*, with the black drum, *Pogonias cromis*, of the Atlantic, as sister taxon. This group is phylogenetically remote from that containing South American freshwater genera.

Aplodinotus grunniens Rafinesque.

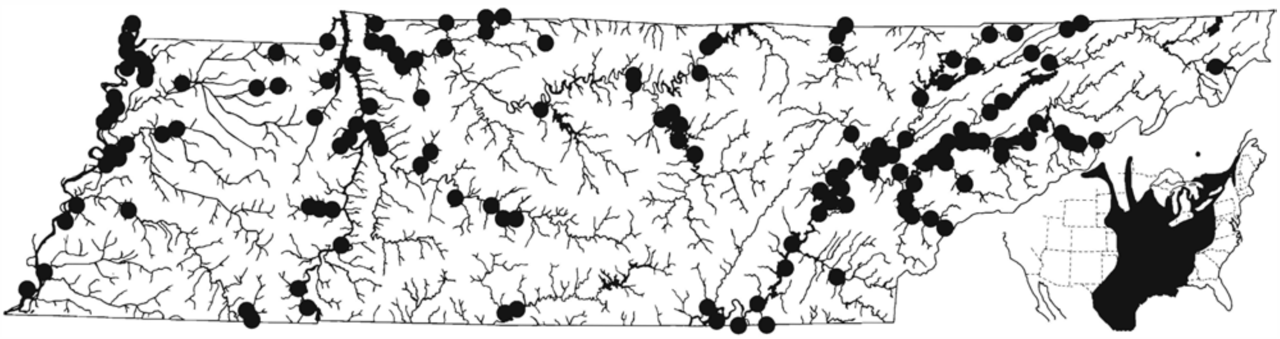
Freshwater drum

Characters: Lateral-line scales 48–55. Dorsal fin with 9 spines in anterior portion and 1 spine and 26–32 soft rays in posterior portion. Anal fin with 2 spines and 7 soft rays. The pharyngeal arches are expansive and fused medially to form a crushing surface which is covered with coarse projections. Jaws with rows of close-set conical (villiform) teeth. Chambers of preoperculomandibular and supraorbital portions of the sensory system conspicuous. Color dusky gray dorsally and sides with a purplish silver sheen, or may be a more drab silvery white.

Biology: The drum, also sometimes called "sheepshead" or "gaspergou" (Louisiana), is a common inhabitant of larger rivers and reservoirs where it lives in backwaters and areas of sluggish current. It is apparently very tolerant of turbidity. The reproductive behavior is not well understood, but it is believed that spawning occurs in midwater when water temperatures reach 18–20 C. The characteristic drumming sound produced by the air bladder in drum is much more prevalent in early summer and is thought to be associated with spawning behavior (Scott and Crossman, 1973). Eggs float until hatching 1–2 days later (Daiber, 1953). Fecundity is understandably high, usually 40,000–60,000 ova/female (Swedberg and Walburg, 1970), as many of the vulnerable eggs doubtless succumb to predation. Larvae are only about 3.2 mm long at hatching and transform to juveniles at about 15 mm TL several weeks later. Growth of juveniles is rapid with young-of-the-year attaining 10–12 cm TL by fall (Purkett, 1958). In Reelfoot Lake, Tennessee, total lengths of succeeding age classes averaged as follows (Schoffman, 1941): age 2, 26.4 cm; 3, 34; 4, 38.3; 5, 40.3; 6, 49.5; 7, 51. Oldest specimens sampled were estimated to be 11 years old and averaged 69 cm TL and weighed about 11 kg. This growth is similar to findings of Purkett (1958) and Linton (1961) in Missouri and Oklahoma. The drum is bottom-oriented in its feeding behavior, although a considerable amount of fish are consumed. Principal diet components in adults are aquatic insect immatures such as mayflies (*Hexagenia*), amphipods, fish (especially shad and young drum), crayfish (Daiber, 1952; Priegel, 1967; Swedberg, 1968; Summerfelt et al., 1972), and perhaps mollusks, for which the pharyngeal apparatus would be well suited for crushing. Oddly, larval stages of drum are known to be piscivorous, feeding on larvae of other fishes until they attain a length of 10–12 mm whereupon they, like many other young fishes, begin to feed on zooplankton (Clark and Pearson, 1979). Juveniles feed on microcrustaceans, midge larvae, and other aquatic insects.

Drum are a relatively important element of the commercial fishery in Tennessee's larger rivers and reservoirs. They are considered fair food fishes. Anglers take them on bait such as worms, crayfish, minnows, or cutbait fished near the bottom. They are sometimes taken on small lures and by jigging (described under large mouth bass). They attain large size, but most adults caught are less than 10 pounds. Tennessee record and

Plate 294. *Aplodinotus grunniens*, freshwater drum, 285 mm SL, Reelfoot L, TN.



Range Map 285. *Aplodinotus grunniens*, freshwater drum (range extends south off inset to Guatemala).

world angling record 23.8 kg (54.5 lb), Nickajack Reservoir, 1972, Benny Hull. The large, pearly "luckystones" familiar to youngsters living near our big rivers, are otoliths (ear stones) from this species.

Distribution and Status: Common in larger rivers, lakes, and reservoirs from the southern Great Lakes region southward in entire Mississippi River basin and in Gulf Coast drainages from Mobile Basin south to Rio Usumacinta, Mexico and Gautemala. Less common in Hudson Bay drainages and St. Lawrence area. Abundant in all larger waters of Tennessee.

Similar Sympatric Species: It would be difficult to confuse the drum with any of its associates after a second look. However, the body shape and long-based dorsal fin is superficially like those of the carpsuckers (*Carpiodes*) and buffalos (*Ictiobus*), both of which lack spinous dorsal fins and have the pelvic fins positioned near midbody.

Etymology: *Aplodinotus* = single back, perhaps in reference to the elongate dorsal fin; *grunniens* = grunting.

Update for 2001 Printing

We have been given the opportunity to provide an update to accompany the second printing of *The Fishes of Tennessee.* This also gives us the opportunity to correct some of the errors that we and our colleagues have detected in the book. Changes that did not affect pagination have been made in the text. Many of the corrections/additions that follow are sufficiently minor that they can be penciled in your book. For the larger changes, you may wish to note on the appropriate page that a significant change has been made.

Although an embarrassingly large portion of the addenda are corrections of our errors, there is considerable new biological data and significant new distributional information. Four additional fish species have been discovered in Tennessee (*Alosa aestivalis,* the blueback herring; *Nocomis leptocephalus,* the bluehead chub; *Ameiurus catus,* the white catfish, and *Gambusia holbrooki,* the eastern mosquitofish), and eight new species (*Notropis albizonatus,* the palezone shiner; *Phoxinus saylori,* the laurel dace; *Etheostoma bison,* the buffalo darter; *E. denoncourti,* the golden darter; *E. kantuckeense,* the Highland Rim darter; *E. percnurum,* the duskytail darter; *Percina kathae,* the Mobile logperch; and *P. stictogaster,* the frecklebelly darter) have been described that occur in Tennessee, four of which were not treated in the book. Recent taxonomic decisions have resulted in changes in nomenclature and elevation of former subspecies to species status. These have resulted in the addition of seven species to the Tennessee fish fauna, and are noted below. Ichthyology continues to be a dynamic science throughout the Southeast, and the first decade of the new millennium will surely result in much additional information regarding the fishes of Tennessee. We hope that most of our errors have been discovered and heartily thank the UT Press staff for accepting the effort and expense necessary to make this second printing as up-to-date as possible.

The most recent rules of zoological nomenclature demand a return to the original spelling for patronymic endings (i, ii, ie) of species epithets. Names whose spellings have been corrected in the text to conform with that rule, plus a few additional corrections, follow: *Acipenser oxyrhynchus* to *O. oxyrinchus, Cyprinella whipplei* to *C. whipplii, Catostomus commersoni* to *C. commersonnii, Moxostoma duquesnei* to *M. duquesnii, Oncorhynchus clarki* to *O. clarkii, Forbesichthys agassizi* to *F. agassizii, Fundulus notti* to *F. nottii, Cottus bairdi* to *C. bairdii, Micropterus treculi* to *M. treculii, Ammocrypta beani* to *A. beanii, Etheostoma chlorosomum* to *E. chlorosoma, E. pottsi* to *E. pottsii, E. whipplei* to *E. whipplii.*

The Names Committee of the American Society of Ichthyologists and Herpetologists/American Fisheries Society will be releasing a revised *Common and Scientific Names of Fishes from the United States and Canada* at about the same time this second printing appears. We are aware of some (but probably not all) changes in that list that will affect Tennessee fishes, and those not corrected in the text are included below.

Addenda

Page 28: We feel that records of *Campsotoma pauciradii* from the upper Hiwassee River system in north Georgia were based on *C. anomalum.*

Nocomis leptocephalus (Girard), the bluehead chub, has been collected in the Little Tennessee River at the mouth of Cochran Creek, below Chilhowee Dam, Blount County, 1997 (North Carolina State Museum 26806). It is also known from recent collections from the French Broad River system in Cane Creek, Mitchell County, North Carolina (UT 44.8552).

Gambusia holbrooki Girard, the western mosquitofish, is now known from Baker Creek, tributary to Little Tennessee River, and Pistol Creek, tributary to Little River, both in Blount County; and from four localities in Chickamauga Reservoir in Hamilton and Rhea counties, all catalogued at the University of Tennessee. It is likely to be found at additional Tennessee localities. These populations are interpreted as introductions. Both eastern North America species of mosquitofish were widely introduced for mosquito control.

Page 35: column 1, second paragraph. Recent surveys of fishes of Tennessee river systems include the following:

Adams, S. R., and G. R. Parsons, 1995, *Fishes of Indian Creek, Wolf River Drainage,* Report to Mississippi Wildlife Heritage Fund, Miss. Mus. Nat. Hist., Jackson.

Baxter, J. T., Jr., 1997. "Fish fauna of the upper Cumberland River drainage in Tennessee," M.S. Thesis, Univ. of Tenn., 101 pages.

Evans, R. B., 1998. "Distribution of fishes and changes in biotic integrity in the New River, Tennessee," M.S. thesis, Univ. of Tenn., 169 pages.

Hughes, M. H., 1994. "The spatial and temporal distribution of fishes in the Holston River system of North Carolina, Tennessee, and Virginia." Ph.D. diss., Univ. of Tenn., 538 pages.

Page 39: An additional excellent general reference on fishes is: G. S. Helfman, B. B. Collette, and D. E. Facey, 1997. The diversity of fishes. Blackwell Science, Malden, Mass.

Page 90: *Ichthyomyzon bdellium* was recently collected in Big South Fork of the Cumberland River at Tenn. Hwy. 297 and at the mouth of Station Camp Creek, Scott County (UT 2.236, 2.270).

Page 91: *Ichthyomyzon castaneus* is now known from Hatchie River system from Cub Creek at Tennessee Highway 125, Bolivar, Hardeman County, 27 March 1998 (Southern Illinois University 32010, Carbondale). Bernard R. Kuhajda (pers. comm.) informed us that the record plotted for the Little Pigeon River system is based on a misidentification of *I. greeleyi,* and that the other two French Broad River system records from above Douglas Reservoir, in the Nolichucky River, are also suspect.

Page 93: The range of *Ichthyomyzon greeleyi* has been extended to the upper Indian Creek system, in Weatherford Creek, Wayne County. (D. J. Eisenhour, pers. comm.)

Page 96: *Lampetra aepyptera* has been taken in the Wolf River system of Benton County, Mississippi (UT 2.253), and is likely to be found in the Tennessee portion of that river.

Page 97: *Lampetra appendix* is now known from the Pigeon River from two localities in Cosby Creek, Cocke County; and from three localities in the Duck River system—Duck River Mile 179, Lillard Mill, Maury County; Buffalo River Mile 18, Perry County, and Piney River at I-40, Dickson County. All are catalogued at UT.

Page 100: Efforts to reintroduce lake sturgeon into the French Broad River below Douglas Dam are underway through a joint effort of the Tennessee Aquarium, TVA, and TWRA.

Page 110: New records for alligator gar in Tennessee include lower Obion River, below Moss Island, several taken by angling circa 1955 (newspaper article in Dyersburg weekly newspaper, *The Spinnet,* provided by Michael Heckethorn, 1996); and a large adult seen while boat shocking in the Forked Deer River about 1 mile above the Obion River, by Allen Pyburn and Steve Seymour, TWRA, both localities in western Dyer County. Size and shape of the latter eliminate the possibility of misidentification of any other gar species

Page 111: The angling record for spotted gar in Tennessee, 9 lbs. 4.8 oz, was taken at Cross Creeks, Land Between the Lakes, Stewart County, 27 June 1999, by Victor Robinson.

Page 117: The Tennessee angling record for the goldeye is 14 oz, taken by Harold Sanders from the Cumberland River 1 mile below Cumberland City, Stewart County, 17 April 1993. This locality should be added to the distribution map.

Page 118: The most easterly dot on the distribution map for *Hiodon tergisus,* on the North Fork Holston River, is not valid.

Page 120: The lower Holston River record for the American eel (River Mile 0.2, Knox County), published by Wilson and Turner (1982) should be added to the distribution map.

Page 122: *Alosa aestivalis* (Mitchill), the blueback herring, has been accidentally introduced into the Tennessee River drainage, perhaps from release of specimens from live wells of fishermen pursuing striped bass. Currently known from Boone Reservoir, Carter Co. (UT 29.196, 1995), and Melton Hill Reservoir at Tenn. Hwy. 61, Anderson Co., fall 1998 (pers. comm. C. F. Saylor, TVA).

It is very similar to the alewife, differing in having a black peritoneum (pale to lightly peppered in alewife), eye diameter less than or equal to snout length (greater than snout length in alewife), and in having more lower limb gill rakers in adults (41–52 versus 38–46 in alewife).

Page 125: Alewife have increased their distribution in the upper Tennessee River, now known from South Holston Reservoir (UT 29.187, 1998), Norris Reservoir (UT 29.159, 1993), Melton Hill Reservoir (UT 29.165, 1995), Watts Bar Reservoir (UT 29.173, 1996), and Chickamauga Reservoir (UT 29.177, 1996).

Page 139: Research on stoneroller systematics by Etnier and H. T. Boschung (in preparation) indicates the following: *Campostoma pullum* (Agassiz) should be recognized as a valid species. It is broadly sympatric with *C. oligolepis* Hubbs & Greene west of the Mississippi River and in northern Illinois and southern Wisconsin. It is the only stoneroller species we have seen from the Great Lakes drainage and from the Wabash River portion of the Ohio River drainage. It also occurs in the Susquehanna River drainage and in direct tributaries to the Mississippi River, both above and below the mouth of the Ohio River, including west Tennessee. *Campostoma oligolepis* is the only stoneroller in most of the Mobile Basin (Burr and Cashner, 1983, reported *C. pauciradii* from single localities in the Etowah and Tallapoosa river systems), and the only stoneroller in the Barren/Green River portion of the Ohio River drainage. It also occurs in Ohio River tributaries in Hardin, Johnson, and Pope counties, Illinois; the Cumberland River below Cumberland Falls (except for portions of Big South Fork); and in the lower Tennessee River upstream approximately to the Blue Ridge physiographic province. In the Cumberland River drainage the transition between *Campostoma anomalum* above Cumberland Falls and *C. oligolepis* below the falls is abrupt. In the Tennessee River drainage, we interpret most populations downstream from the Blue Ridge physiographic province to be *C. oligolepis* that show morphological evidence of past introgressive hybridization with *C. anomalum* (internasal tubercles and anal fin pigmentation of nuptial males). This interpretation restricts *Campostoma anomalum* to the Ohio River drainage above the Wabash River (except for the Barren/Green River system, occupied by *C. oligolepis*), the Cumberland River above Cumberland Falls and the New River portion of Big South Fork, and Blue Ridge portions of the upper Tennessee River drainage. *Campostoma anomalum* appears to be the stoneroller in the Pee Dee, Santee, and Savannah river drainages east of the Appalachian divide. The New River portion of the upper Ohio River drainage and the James and Roakoke river drainages appear to contain an undescribed taxon being studied by D. A. Etnier and W. C. Starnes. *Campostoma pullum* and the Mexican *C. ornatum* are the only two species in the genus that consistently have 4–4 pharyngeal teeth, with the other four species typically or often having a 1,4–4,1 count. The minor row tooth is tiny, fragile, and may be difficult to detect. *Campostoma oligolepis* differs from *C. anomalum, C. pauciradii,* and *C. pullum* nuptial males in often lacking a black band in the anal fin and in lacking nuptial tubercles between the nares. In *C. anomalum, C. pauciradii,* and *C. pullum* there is an arc of three (occasionally only two) large tubercles medial to each nostril. Introgressed *C. oligolepis* may have from 1–4 total internasal tubercles. Scale counts that work nicely for separating sympatric Ozarkian *C. oligolepis* and *C. pullum* are of little use in identifying the typically allopatric eastern species *C. anomalum, C. oligolepis, C. paudiradii,* and *C. pullum.*

Page 153 and elsewhere: *Cyprinella monacha* is being treated as the sole member of the genus *Erimonax* by many workers, as *Erimonax monachus* (Cope).

Page 163 and elsewhere: *Ericymba buccata* is placed in genus *Notropis,* as *Notropis buccatus* (Cope) by some workers.

Page 165: A preimpoundment collection of *Erimystax cahni* from the Clinch River portion of Norris Reservoir, near Tennessee Highway 33 bridge, was overlooked.

Page 169: Flame chubs have been found in the upper portion of the Richland Creek system, a major Elk River tributary in Giles County (UT 44.7866). Ray Katula (pers. comm.) has observed spawning behavior in aquaria where a large variety of potential spawning substrates were provided. Nuptial males formed loose territories over a mound of pebbles in moderate current, designed to simulate a chub nest. Females gathered nearby in areas of less current. A male would occasionally swim to the group of females and attempt to induce one to move to the gravel area. Receptive females wedged themselves into the gravel substrate and remained there, motionless except for spawning vibrations, while flanked by one male or a male on each side. It was estimated that about 20 or fewer eggs were deposited per spawning bout. The eggs, which were not tended by either parent, hatched in 3–4 days at 68° F, and young were about 1 inch long in 8 months.

Page 180: Bighead carp have been reported from the Tennessee River (Kentucky Reservoir) below Pickwick Dam, Dave Risuto, TWRA, 5 May 1997; from Open Lake near the mouth of the Forked Deer River in Louderdale County (Dyersburg State Gazette, 31 August 1994); and we collected juveniles from the lower end of Bear Creek in Tipton County, October 1995, UT 44.7049.

Page 187: Two former subspecies of *Lythrurus ardens, L. a. fasciolaris* (Gilbert), the scarlet shiner, and *L. a. matutinus* (Cope), the pinewoods shiner, have been elevated to species. All Tennessee records of *L. ardens* represent *L. fasciolaris* (W. W. Dimmick, K. L. Fiorino, and B. M. Burr, Copeia 1996:813–823).

Page 192: D. J. Eisenhour (Copeia 1999: 969–980) recognizes former subspecies of *Macrhybopisis aestivalis* as valid species. Except for the Conasauga River, he considers Tennessee specimens to all be referable to *Macrhybopsis hyostoma* (Gilbert), with spotted chub the new common name. The Conasauga River species continues to be undescribed. Type locality for *M. aestivalis* is Rio San Juan, Nuevo Leon, Mexico.

Page 197: Add *Nocomis leptocephalus,* based on North Carolina State Museum 26806, Cochran Creek below Chilhowee Dam, Little Tennessee River system, Blount County, 1997. It differs from *N. micropogon* in having the breast fully scaled (versus often naked or partially naked), having nuptial tubercles in the interorbital region but not on the snout (versus only on the snout), a long and many-looped gut (versus short and S-shaped), and in usually having fewer than 30 body circumferential scales (versus usually 30 or more).

Page 217: Specimens of *Notropis leuciodus* from the Powell River system in Virginia often have the breast scaled.

Page 220: *Notropis photogenis* was recently collected in Big South Fork at Leatherwood Ford, Tennessee Highway 297, UT 44.6511.

Page 222: Populations formerly referred to as *Notropis rubellus* from the Red River drainage of AR, OK, and TX were treated as representing a new species, *N. suttkusi* Humphries and Cashner, rocky shiner (Copeia 1994:82–90). Many workers currently recognize *Notropis micropteryx* (Cope), highland shiner, as a species distinct from *N. rubellus.* It is widespread in Tennessee in the Tennessee and lower Cumberland river drainages and uncommon in the Barren River system (Ohio River drainage). Specimens from the upper Cumberland River (above Cumberland Falls) are thought to represent true *N. rubellus.*

Page 228: Under **Systematics** for *Notropis stramineus,* we mention a pending appeal to the International Commission for Zoological Nomenclature to conserve the name *Notropis stramineus* (Cope) and reject the long unused senior synonym *Notropis ludibundus* (Girard). The appeal, which we thought had already been submitted, was not received by the commission in a timely fashion (R. M. Bailey, 1999, Bull. Zool. Nomenclature 56:240–246), and some ichthyologists have been using the name *N. ludibundus* (Girard) for the sand shiner since the Mayden and Gilbert (1989) publication referred to. Rules of zoological nomenclature call for the "maintenance of existing usage" until a pending case is ruled on by the commission. In this case it may be difficult to determine which of the above names represents existing usage.

Page 235: The palezone shiner was formally described as *Notropis albizonatus* Warren & Burr (M. L. Warren, B. M. Burr, and J. M. Grady, Copeia 1994:868–886).

Page 242: Significant new records for *Phenacobius mirabilis* are Wolf River 4 miles east of Germantown, Horston Levee Road (B. R. Kuhajda, University of Alabama); and Dixon Creek, tributary to South Fork Forked Deer River, at Poplar Corner Road, Haywood Co., 20 May 1994 (R. D. Bivens and C. E. Williams, TWRA, UT 44.8648).

Page 246: The populations from Waldens Ridge mentioned under *Phoxinus erythrogaster* have been described as a new species, *P. saylori,* the laurel dace, by C. E. Skelton. It differs from *P. erythrogaster* in developing black pigment on the underside of the head and anterior part of the breast in nuptial males, and the ventral black stripe on the side is not interrupted and deflected downward at the anal fin origin as it is in *P. tennesseensis.* It differs from both in having a simple, S-shaped gut configuration. It is known from six localities, all on Waldens Ridge, and is being considered for protection under the Endangered Species Act. The description appeared in Copeia 2001:118–128.

Page 254: Many workers recognize *Rhinichthys obtusus* Agassiz, the orangeside dace, as being distinct from *R. atratulus.* All Tennessee populations presumably represent *R. obtusus.*

Page 257: *Rhinichthys cataractae* is known from the Cumberland River drainage from Dry Creek near Dowelltown, DeKalb Co. (USNM 230824 and 231037, 1968) and from Elk Creek, Stewart County (Cornell Univ. 47841, 1964). Lower Elk Creek is now impounded by Barkley Reservoir. Minimal efforts to repeat the Dry Creek collections have not been successful. Larry M. Page has alerted us to the presence of Illinois Natural History Survey records of this species from Alexander and Union counties, Illinois, in the late 1800s.

Page 266: Significant recent records for *Carpiodes velifer* are Tennessee River below Pickwick Dam, Hardin County; Chickamauga Reservoir above and below mouth of Hiwassee River, Hamilton, Meigs, and Rhea counties; and Melton Hill Reservoir, Anderson County.

Page 269: Blue sucker populations from the Mobile Basin have been recognized as representing a different species, *Cycleptus meridionalis* Burr & Mayden, the southeastern blue sucker (B. M. Burr and R. L. Mayden, 1999, Bull. Ala. Mus. Nat. Hist. 20:19–57).

Page 282: Juvenile spotted suckers (*Minytrema melanops*) can be difficult to separate from redhorses (*Moxostoma*). In *Minytrema* there are 16 scale rows around the caudal peduncle, while in all Tennessee *Moxostoma* species there are only 12 (pers. comm. R. E. Jenkins).

Page 287 and elsewhere: *Moxostoma atripinne* has been transferred to genus *Thoburnia,* as *T. atripinnis.*

Page 289: The most northwestern dot on the *Moxostoma carinatum* range map should be deleted. The specimen was actually taken from a ditch 4.5 miles northeast of New Madrid, Missouri, not from the Mississippi River (pers. comm. Dr. R. E. Jenkins). We have recent records of *Moxostoma carinatum* from Big South Fork and lower New River in Scott County (UT 45.1352, 45.1434). Many records of this species from the Little Tennessee River system are based on misidentifications of the Blue Ridge form of *Moxostoma duquesnii,* which has a caudal fin nearly as red as that of *M. carinatum,* or on an undescribed species, the sicklefin redhorse, restricted to the Blue Ridge portions of the Little Tennessee and Hiwassee river systems in Georgia and North Carolina, but so far not recorded from Tennessee (pers. comm. R. E. Jenkins). Jenkins also points out that juvenile *Moxostoma carinatum* have a tiny black dot at the base of each gill raker. This character is lacking in juveniles of the very similar *M. duquesnii* and *M. erythrurum.*

Page 292 and elsewhere: *Moxostoma breviceps* (Cope), the smallmouth redhorse, has been recognized as a species distinct from *M. macrolepidotum.*

Page 298: The snail bullhead, *Ameiurus brunneus,* has been found in the French Broad and Nolichucky river systems in western North Carolina and will almost certainly become part of the Tennessee fish fauna. Characters for distinguishing it from the very similar flat bullhead, *A. platycephalus,* are given on the top of p. 305.

Page 299: The first recorded white catfish from Tennessee was collected in the Pigeon River at Hartford, Cocke County, 21 June 2000, and provided by R. D. Bivens, B. D. Carter, and C. E. Williams of TWRA. It is catalogued as UT 48.1014.

Page 306: A blue catfish weighing 132 lbs (59.9 kg) was recently taken by a commercial fisherman in Pickwick Reservoir, Rogersville, Alabama. It was held alive at the Tennessee Aquarium in Chattanooga for several weeks but finally succumbed to an infection before it could be displayed.

Pages 312 and 317: There is reason for optimism relative to efforts to reintroduce smoky madtoms (*Noturus baileyi*) and yellowfin madtoms (*N. flavipinnis*) into Abrams Creek. Both species are reproducing in the creek. (P. L. Rakes, J. R. Shute, and P. W. Shute, 1999, Env. Biol. of Fishes 55:31–42).

Page 320: Recent records for *Noturus hildebrandi* are available from the Wolf River system (UT 48.884, Benton County, Mississippi, provided by Reid Adams; and Shelby County, Tennessee, at Horton Levee Road, 4 miles east of Germantown (Univ. of Alabama Ichthyological Collection 12116.01) and 100 m upstream from Germantown Road (University of Alabama, uncatalogued, B. R. Kuhajda, pers. comm.).

Page 326: Bernard R. Kuhajda has provided records of *Noturus nocturnus* from Wolf River at Horston Levee Road, 4 miles east of Germantown (University of Alabama Ichthyological Collection 12116.04) and from 100 m above Germantown Road, both from Shelby County (University of Alabama, uncatalogued).

Page 329: Recent Wolf River records for *Noturus stigmosus* provided by B. R. Kuhajda are from 100 m above Germantown Road, Shelby County, 7 November 1998 and 21 August 1999 (University of Alabama Ichthyological Collection 12111.01 and 12299.05, respectively).

Page 331: The Freshwater Fishing Hall of Fame recognizes a 123-lb (55.8 kg) flathead catfish from Elk City Reservoir, Independence, Kansas, as the angling world record. The fish, caught in 1998 by Ken Paulie, was 61 inches long. A 92-lb (37.2 kg) flathead catfish, 55 inches long, was taken from the Mississippi River in Tennessee at the mouth of the Obion River in a hoop net, 30 November 2000, by commercial fishermen K. A. Childress, J. W. Stafford, and J. L . Stafford.

Page 366: An additional population of *Fundulus julisia* has been discovered in the Charles Creek system near McMinnville. This good news is tempered by the apparent extirpation of several formerly known populations (P. L. Rakes, Conservation Fisheries Inc., Knoxville, pers. comm.).

Page 372: *Gambusia holbrooki* is now known to occur in Tennessee. See addenda for page 28 for details.

Page 380: Three records of striped mullet available from the Tennessee portion of the Mississippi River are as follows: River Mile 889, 1983 (B. M. Burr, 1990, Trans. Ky. Acad. Sci. 51:188–189); River Mile 745, 1983, Tenn. Dept. of Health; and from South Memphis, 1996 (D. K. Wingfield, Tenn. Dept. of Health).

Page 383: *Cottus pygmaeus* was a preoccupied name, and has been replaced with *C. paulus* Williams (Copeia 2000:302).

Pages 383–386: Populations formerly considered to represent *Cottus bairdii* from Atlantic slope drainages from Chesapeake Bay south through Roanoke River have been recognized as representing a new species, *Cottus caeruleomentum* Kinziger, Raesly & Neely, Blue Ridge sculpin (*Copeia* 2000:1007–1018).

Page 392: We have seen occasional juvenile *Morone chrysops* with faint parr marks.

Page 396: The undescribed pygmy sunfish discussed from northern Alabama is now *Elassoma alabamae* Mayden, the spring pygmy sunfish (R. L. Mayden, 1993, Bull. Ala. Mus. Nat. Hist. 16:1–14).

Page 411: We now have records of *Lepomis cyanellus* from Tennessee from the French Broad and Pigeon rivers above Douglas Reservoir.

Page 423: The new angling world record for the redear sunfish is 2.48 kg (5 lb 7.5 oz) from Santee Cooper diversion canal, South Carolina, caught by Amos Gay in 1998 (Freshwater Fishing Hall of Fame Vol. 23[1]).

Page 427: The shoal bass now has a formal name, *Micropterus cataractae* Williams & Burgess (J. D. Williams and G. H. Burgess, 1999, Bull. Fla. State Mus. Nat. Hist. 42:80–114).

Page 429: Additional records for *Micropterus coosae* are Sink Creek tributary to Caney Fork River, DeKalb County (pers. comm. F. J. Bulow), Grassy Cove, Cumberland County (pers. comm. S. J. Fraley).

Page 443: The consensus among ichthyologists is to recognize the crystal darter as a member of the monotypic genus *Crystallaria* rather than as a member of *Ammocrypta.*

Page 445: New records for *Ammocrypta beani* include three localities in the Wolf River system of southwestern Tennessee and northwestern Mississippi provided by B. R. Kuhajda and S. R. Adams.

Page 448: Recently described species of subgenus *Ulocentra* are: *Etheostoma chermocki* Boschung, Mayden & Tomelleri, vermillion darter, Black Warrior River system, AL (Bull. Ala. Mus. Nat. Hist. 13:11–20); *E. bellator* Suttkus & Bailey, Warrior darter, Black Warrior River system, AL; and *E. colorosum* Suttkus & Bailey, coastal darter, Gulf of Mexico tributaries from Perdido River through Chocktawhatchee River, AL and FL (Tulane Stud. Zool. Bot. 29:1–28); *E. lachneri* Suttkus & Bailey, Tombigbee darter, Tombigbee River system, AL; *E. ramseyi* Suttkus & Bailey, Alabama darter, Cahaba and Alabama river systems, AL; and *E. raneyi* Suttkus & Bart, Yazoo darter, Yazoo River system, MS (Tulane Stud. Zool. Bot. 29:97–126); and *E. scotti* Bauer, Etnier & Burkhead, Cherokee darter, Etowah River system, GA (Bull. Ala. Mus. Nat. Hist. 17:1–16). In subgenus *Boleosoma* gill membranes are broadly (*E. longimanum, E. podostemone*) to narrowly joined (*E. nigrum, E. olmstedi*).

Page 449: Three taxa formerly in the synonymy of *Etheostoma jordani* were recognized as valid species by Wood and Mayden, 1993 (Bull. Ala. Mus. Nat. Hist. 16:13–46), as follows: *E. douglasi* Wood & Mayden, Tuskaloosa darter, upper Black Warrior River system, AL: *E. chuckwachattee* Mayden & Wood, lipstick darter, Tallapoosa River system above the Fall Line, AL and GA; and *E. etowahae* Wood & Mayden, Etowah darter, Etowah River above Allatoona Reservoir, GA. This reduces the range of *E. jordani* to the Coosa River system (except for the upper Etowah River), the Cahaba River system, and the Tallapoosa River system below the Fall Line.

Page 451: Couplet 1. Two recently described species in the *E. squamiceps* species group of subgenus *Catonotus, E. neopterum* and *E. oophylax,* have modally IX dorsal spines and 11 dorsal soft rays, making the correct choice a guess. The path followed by choosing to go to couplet 2 rather than couplet 20 will lead to those two species.

Page 470: Pollution controls initiated at the paper mill in Canton, North Carolina, have resulted in dramatically improving water quality in the Tennessee portion of the Pigeon River (between Douglas Reservoir and the North Carolina state line). Many fish species not previously known from that area have appeared, and two forms once thought to be subspecies, *Etheostoma blennioides gutselli* and *E. b. newmani,* now occur together in that area, with no evidence of massive hybridization. Evidence to date indicates that these taxa will not fuse into a single gene pool in the Pigeon River. It thus becomes imperative that we recognize the former as a valid species, *Etheostoma gutselli* (Hildebrand), the Tuckasegee darter. The taxonomic status of the remaining subspecies of *E. blennioides, E. b. blennioides, E. b. newmani,* and *E. b. pholidotum,* remains unchanged, at least for the present.

Page 473: A population of *Etheostoma baschungi* has been discovered in Brier Fork, a tributary to the Flint River, near the Alabama border in Lincoln County (pers. comm. P. W. Shute, TVA).

Page 481: Ray Katula (pers. comm.) has observed and filmed spawning behavior of *Etheostoma cinereum* in aquaria. They bury their eggs in gravel in a fashion similar to that mentioned for *E. caeruleum* on page 474.

Page 497: *Etheostoma histrio* has been collected in the Wolf River system in northwest Mississippi and is likely to be in the Tennessee portion of that river. Three taxa formerly in the synonymy of *Etheostoma jordan* were recognized as valid species by Wood and Mayden, 1993 (Bull. Ala. Mus. Nat. Hist. 16:13–46), as follows: *E. douglasi* Wood & Mayden, Tuskaloosa darter, upper Black Warrior River system, AL: *E. chuckwachattee* Mayden & Wood, lipstick darter, Tallapoosa River system above the Fall Line, AL and GA; and *E. etowahae* Wood & Mayden, Etowah darter, Etowah River above Allatoona Reservoir, GA. This reduces the range of *E. jordani* to the Coosa River system (except for the upper Etowah River), the Cahaba River system, and the Tallapoosa River system before the Fall Line.

Page 507: The distributional gap between *Etheostoma pseudovulatum* in the lower Duck River system and *E. oophylax* in eastern tributaries to the Tennessee River downstream (north) of the mouth of Duck River is now smaller, with the latter occurring in Blue Creek, a northern tributary to lower Duck River that enters the Duck just downstream from the mouth of Buffalo River (UT 91.5423).

Page 512: Formerly considered a subspecies of *Etheostoma nigrum, E. susanae* (Jordan and Swain), is now recognized by some workers as a valid species based on mitochondrial DNA analysis (R. M. Strange, 1998, Amer. Midl. Nat. 140:96–102).

Page 515: Populations formerly placed within *Etheostoma parvipinne* from the upper Black Warrior River system in Alabama have been recognized as representing a valid species, *E. phytophilum* Bart & Taylor, the rush darter (H. L. Bart Jr. and M. S. Taylor, 1999, Tulane Studies in Zoology and Botany 31:23–50).

Page 531: The outlying dots on the distribution map for *Etheostoma spectabile* from a western tributary to the middle Harpeth River and from the upper Stones River are both based on misidentifications of *E. caeruleum.* Specimens formerly considered to represent *E. spectabile* from the Duck and Buffalo river systems and smaller tributaries to the lower Tennessee River have been recognized as representing a new species, *Etheostoma bison* Ceas & Page, the buffalo darter. Specimens occurring in the Barren River system of Clay, Macon, and Sumner counties represent an additional new species, *E. kantuckeense* Ceas & Page, the Highland Rim darter. Populations in the Reelfoot Lake area of northwestern Tennessee represent true *E. spectabile.* Populations in the Cumberland River drainage are under study and likely represent additional undescribed species (P. A. Ceas and L. M. Page, Copeia 1997:496–522). In the same paper, *Etheostoma tecumsehi* Ceas & Page, the Shawnee darter, is described from the Pond River portion of the Green River system, KY; and two forms mentioned above as subspecies, *E. fragi* Distler, strawberry darter, and *E. uniporum* Distler, current darter, are eleveated to species status.

Page 541: The first Tennessee record of *Etheostoma swannanoa,* the Swannanoa darter, from the Clinch/Powell River system of Tennessee—Mulberry Creek near Little Mulberry Creek, along Tenn. Hwy. 63, Hancock County—was provided by TWRA biologists.

Page 542: Tennessee River drainage populations of *Etheostoma tippecanoe* were recognized as representing a new species, *E. denoncourti* Stauffer & van Snik, the golden darter (J. R. Stauffer and E. S. van Snik, Copeia 1997:116–122). The new species occurs in the Clinch, Sequatchie, Duck, and Buffalo rivers and differs from *E. tippecanoe* in having scales on the cheek and in having the posterior nasal pore of the cephalic lateralis system well separated from the posterior nasal opening (these openings in contact in *E. tippecanoe*). A paper discussing these and other characters of the two species appeared in Copeia 2000:1097–1103, C. E. Skelton and D. A. Etnier.

Page 555: The duskytail darter has been formally described as *Etheostoma percnurum* Jenkins (Jenkins, R. L., and N. M. Burkhead, Freshwater fishes of Virginia, American Fisheries Society, Bethesda, MD, 1994).

Page 561: Two recently described species removed from the synonymy of *Percina copelandi* (subgenus *Cottogaster*) are *P. aurora* Suttkus & Thompson, pearl darter, Pearl and Pascagoula river drainages, LA and MS; and *P. brevicauda* Suttkus & Bart, coal darter, Mobile Basin, AL (Occ. Pap. Tulane Univ. Mus. Nat. Hist. 4:1–46).

Page 562: Recently described species in the subgenus *Percina* are: *Percina austroperca* Thompson, southern logperch, Choctawhatchee and Escambia rivers, AL and FL; and *P. suttkusi* Thompson, Gulf logperch, below the Fall Line from Lake Pontchartrain tributaries east through Mobile Bay drainages (Occ. Pap. Mus. Nat. Sci. Louisiana State Univ. 69:1–20 and 72:1–27, respectively). *Percina fulvitaenia* Morris & Page, the Ozark logperch, has been elevated to full species status (see pages 570–571). The common name for *P. carbonaria* will be Texas logperch.

Page 568: The blotchside logperch was collected in Shoal Creek, Iron City Park, and Chisholm Creek, also in the Shoal Creek system, both in Lawrence Co., spring 2000 (pers. comm. D. J. Simbeck, TVA). The dot on the map in that area is from a collection from Butler Creek, an additional Shoal Creek tributary.

Page 572: Two recently described species removed from the synonymy of *Percina copelandi* (subgenus *Cottogaster*) are *P. aurora* Suttkus & Thompson, pearl darter, Pearl and Pascagoula river drainages, LA and MS; and *P. brevicauda* Suttkus & Bart, coal darter, Mobile Basin, AL (Occ. Pap. Tulane Univ. Mus. Nat. Hist. 4:1–46).

Page 593: The Mobile logperch was formally described as *Percina kathae* Thompson (B. A. Thompson, 1997, Occ. Pap. Mus. Nat. Sci. Louisiana State Univ. 73:1–34).

Page 594: The frecklebelly darter was formally described as *Percina stictogaster* Burr & Page (B. M. Burr and L. M. Page, 1993, Bull. Ala. Mus. Nat. Hist. 16:15–28).

Page 595: European workers have resurrected the little-used generic name *Sander* Oken, 1817, for the pikeperches. Since this name is older than *Stizostedion* Rafinesque, 1820, it appears that rules of zoological nomenclature will demand name changes for the walleye to *Sander vitreus* (Mitchill) and sauger to *Sander canadense* (Griffith & Smith).

Page 601: The world record walleye, from Old Hickory Reservoir, Tennessee, has been disqualified, and replaced by a 22 lb 11 oz (10.3 kg) fish from Greer's Ferry Reservoir, Arkansas, caught by Al Nelson, 14 March 1982 (Sport fishing Hall of Fame Vol. 20, 1996).

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