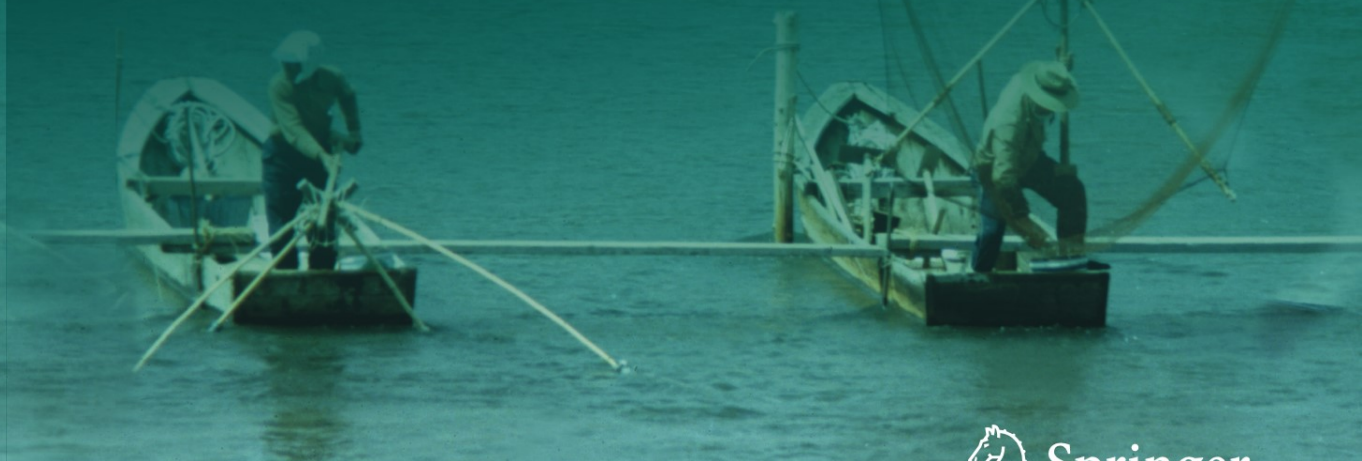
Hiroya Kawanabe · Machiko Nishino
Masayoshi Maehata *Editors*

Lake Biwa: Interactions between Nature and People



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Lake Biwa: Interactions between Nature and People

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Preface

Lake Biwa is situated in the centre of Honshu Island in the Japanese Archipelago. It is 670.3 km^2 in area, and 41.2 m and 103.6 m in mean and maximum depth, respectively. The lake is separated into two parts, the northern main and deeper basin and the southern small and shallower one. The transparency at the centre of the main basin has been decreasing during the past 50 years but is still 4–9 m, while that of the south basin is 2–3 m.

It is one of the world's ancient lakes, having been formed originally about 4.5 million years BP about 50 km south of its present site. Around 400,000 years BP it came to its present site and became deeper. Fossils of the same species or a close relative of the largest fish found in the lake at present, the Biwa catfish *Silurus biwaensis*, have been discovered even in sediments from the oldest age of the lake. Some other endemic fish species in the lake, however, evolved *in situ*, especially after the lake deepened. In such cases, the newly derived species have a more pelagic mode of life or live in open water or show adaptations for survival in rocky shores, compared to the ancestral species which are mainly sandy or muddy littoral inhabitants with a benthonic mode of life. There is a species flock of pleurocerid snails, *Semisulcospira* (*Biwamelania*), and its supposed ancestor *S. (B.) habei* had already appeared by 400,000 years BP.

It is believed that human beings have lived around Lake Biwa for more than 20,000 years, and archaeological evidence demonstrating the relation of human beings and the lake goes back to 8,000 years BP. Most remarkable is the Awadu Lake Bottom sites, around 5,000 years BP, from which it is clear many species of fishes and molluscs were eaten by ancient human settlers for a rather long time. Traces of special fishing installations remain since ancient days: i.e. a 'yana' fishweir at a river mouth and 'eri' pound-net for fish since 2,000 and 1,500 years BP, respectively. Both wooden floats for angling and many types of ceramic net-sinkers have also been discovered, dating since the third century.

Various historical documents pertaining to the lake fisheries survive back to the eighth century. For example, an edict promulgated in 863 prohibited any officer from taking fish away for the imperial court from the fishing grounds around the lake except from fishweirs located in the 4 specified rivers. In 927, the 'Engi-shiki', a collection of laws and regulations, was promulgated, whereby we know that in Ohmi Province surrounding Lake Biwa the following goods were produced and sent to the imperial court: 'fish cheese' of crucian carp and of Biwa salmon, crucian carp with soy sauce, salted crucian carp, boiled ayu-fish with salt, and juvenile ayu-fish.

Given its archaeological and historical background, Lake Biwa is not only an ancient lake in the geological and biological senses but also in a cultural sense, because the relation between human beings and nature, especially the lake, can be traced back to several thousand years BP. In other words, Lake Biwa has developed as a 'life-culture complex' over a long time.

The present book on Lake Biwa is written from this point of view.

*

Around the lake there are many academic institutions. The oldest are the Shiga Fishery Research Station and the Otsu Hydrobiological Station (now the Center of Ecological Research) of Kyoto University, established in 1900 and 1914, respectively. The staffs of these stations have devoted their efforts to limnological, biological, and fisheries research continuously since then, and many scientific results have been cumulated up to now. Rather recently, the Lake Biwa Research Institute, LBRI (now Lake Biwa Environmental Research Institute, LBERI), was established in 1982 and the Lake Biwa Museum (LBM) in 1996, both being set up and operated by the Shiga Prefectural Government. The former is dedicated mainly to research on environmental problems and issues related to the planning of prefectural policy, and the latter is a research-oriented museum dedicated to the 'relation between lake and people', with exhibitions, nature observations, lectures, etc. and with much involvement of the general public.

Concerning Lake Biwa many scientific books has been published up to now but most of them are written in Japanese. In 1975, 'Productivity of freshwater communities in Lake Biwa' edited by the JIBP-PF Research Group of Lake Biwa (chief: T. Miura) was published as a chapter in the book "Productivity of Communities in Japanese Inland Waters". Its coverage was restricted, however, mainly to Shiodu Bay, at the northern end of the lake, as one result of the International Biological Programme in Japan. In 1984 the book "Lake Biwa" (ed. S. Horie) appeared as a volume of the series "Monographiae Biologicae". It was a rather comprehensive book that included six chapters conveying general features, geoscientific features, modern limnology (meteorology, physical, chemical and biological limnology, and metabolism),

paleolimnology (non-biological features, Pleistocene climatic change, ancient lake viewed from paleobiostratigraphy and paleogeochemistry), biogeography, and influence of human activities. In particular it was based on the results of analyses of several boring cores taken from the lake sediments in the 1970s and early 1980s.

In 1997, the 'International Conference on Ancient Lakes: Their Biological and Cultural Diversities' was held at the Lake Biwa Museum, and most papers read at the conference appeared in three books: "Ancient Lakes, their Cultural and Biological Diversity" (ed. H. Kawanabe, G. W. Coulter and A. C. Roosevelt 1999), "Ancient Lakes: Biodiversity, Ecology and Evolution" (ed. A. Rossiter and H. Kawanabe 2000), and "Archaeology of World Lakes" (ed. A. Matsui and K. Makino 2000). In these volumes, respectively, 2, and 3, 8 chapters were dedicated to various aspects of Lake Biwa.

*

The concept of the present book was first suggested in 1999 by Professor David L. G. Noakes, Oregon State University, and several members of LBM and LBERI have discussed in recent years how to achieve it. As was mentioned above Lake Biwa is a 'Life-culture complex'. To reflect this the book includes the following seven chapters: (1) Geological history; (2) Biology; (3) Ecological change; (4) Historical relations of people and the lake; (5) People's use of the lake and their life-style; (6) History of the lake and Yodo River basin management; and (7) Environmental conservation. Each chapter had section editor(s) as indicated in the contents.

As the general supervisor of this book, I would like to extend my sincere thanks to my old friend David L. G. Noakes for his kind suggestion and for establishing our connection to the publisher, and to Drs. M. Akiyama (University of Shiga Prefecture), M. Maehata (LBM), M. Nakamura (former Director of LBRI), M. Nishino (LBERI), K. Takahashi (LBM), and M. Yoda (LBM) for their efforts as each section editor for their extreme efforts to make this book. Thanks are also given to Drs. M. J. Grygier (LBM) and R. Smith (LBM) for polishing the English of much of the submitted manuscripts.

21st January, 2012: The starting day of the coldest 2 weeks in Japan according to traditional beliefs

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Profile of Lake Biwa

Area of Shiga Prefecture	4,017.00 km^2
Catchment area of the lake	3,174.00 km^2
Area of the lake	670.25 km^2
Length (North-South)	63.49 km
Maximum width (East-West)	22.80 km
Minimum width (East-West)	1.35 km
Circumference	235.20 km
Elevation	85.614 m above the lowest sea level of Osaka Bay 84.371 m above mean sea level of Tokyo Bay
Maximum depth	103.58 m
Mean depth (North Basin)	44.0 m
Mean depth (South Basin)	3.5 m
Volume	27.5 billion m^3
Residence time of water	5.5 years
Number of the first grade river flowing into the lake	118
Number of natural outlet	1 (Seta River)
Age of the present lake	ca. 400,000 years

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Topic 1 The Naming of Lake Biwa

Yoshihiro Kimura

Lake Biwa, which is one of the oldest lakes in the world, formed near its present location about 4 million years ago. Despite its long history, the current name of the lake, *Biwa-ko* in Japanese, was introduced to the public only quite recently, approximately 320 years ago. The origin of the name is described here.

Literature sources reveal that the lake had various names in the beginning, before being called *Biwa-ko*. In *Keiranshuyoshu*, a book compiled in the early fourteenth century, it was mentioned for the first time that the lake's outline resembled the shape of a *biwa*, a traditional Japanese lute (see Color page 1). According to this book, the name-giver of the lake was Benzaiten, the goddess enshrined on the island of Chikubushima in the northern part of the lake. Benzaiten was originally the goddess of water, Sarasvati, who presided over a mystical river of the same name in Hindu mythology, and she is depicted as holding a *biwa*. As a guardian deity of water and Buddhism, she was brought to Japan along with Buddhism in the Nara Period (710–794 AD), from India through China.

Why would the shape of the lake be associated with the *biwa* held by Benzaiten? Koso (1274–1347), a famous monk of Enryakuji temple on Mt. Hiei overlooking the lake, who wrote *Keiranshuyoshu*, viewed Benzaiten as a goddess protecting both Mt. Hiei and the lake. From the top of the mountain at a height of 843 m, he may have contemplated the shape of the lake while being inspired by the *biwa* held by Benzaiten. Actually, the top of Mt. Hiei offers a greater view of Lake Biwa than any other mountains surrounding the lake.

The current Japanese name of Lake Biwa first appeared in a literature source in the early sixteenth century. This was *Kojo Hakkei* (Eight Views of the Lake), a collection of Chinese poetry composed by Keijoshurin, a monk of Shokokuji temple in Kyoto. The use of the name *Biwa-ko* became common after 1689 because of the popular diary of the Confucianist scholar Kaibara Ekiken. In his diary, after describing the overall shape of the lake and that of the stringed instrument *biwa*, he explicitly stated, "it is therefore called *Biwa-ko*." Thereafter, this name started to appear in literature, *ukiyo-e* (a genre of Japanese woodblock prints), and maps, and its use became ubiquitous. In particular, Ino Tadataka, a famous geographical surveyor in the mid-eighteenth century, completed an accurate map of the lake using the name of *Biwa-ko*.

As for how the name *Biwa-ko* became popular, its relation with the sound of the *biwa* might be one reason. Words describing waves have been commonly used since ancient times in Japanese poetry as epithets, or *makurako-toba*, in reference to Lake Biwa. The sound of the *biwa* is reminiscent of the sound of waves lapping on the shore. Benzaiten is also known by the name of Myo'onten or Bionten, who presides over sound.

There are countless lakes in the world, among which Lake Kinneret (the Sea of Galilee) in Israel is one of those named after an instrument, like Lake Biwa. The name Kinneret originated from *kinnor*, a Hebrew word for harp. The local people believe that it is derived from the sound of the waves, resembling the tones of a harp. If so, this constitutes a remarkable parallel with the naming of Lake Biwa. It can draw inference from this fact that the shape of the lake and the similarity in the sound of *biwa* and lapping waves of the lake are deeply associated with the naming of Lake Biwa. It is a precious lake providing us with beautiful scenery along with cultural affection.

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Color Plates

'*Biwa*': Japanese traditional instrument. Lake Biwa is named after this instrument. See Topic 1 (photo courtesy of Hikone Castle Museum)

Aerial view of Lake Biwa showing Chikubushima Island in the foreground (photo courtesy of Shiga Prefectural Government)

Aerial view of Lake Biwa: around the Biwa-ko Ohashi Bridge (photo courtesy of Shiga Prefectural Government)

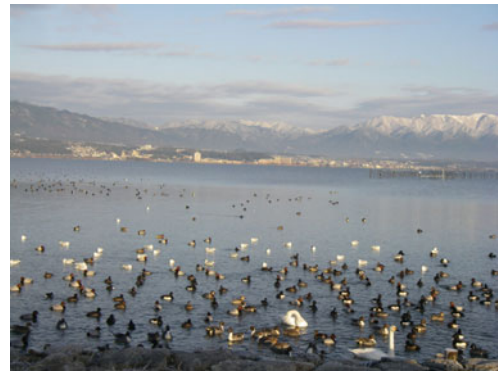
Aerial view of the southern part of Lake Biwa: residential and business districts of Otsu City, the Omi-Ohashi Bridge, and an *eri*-fishing trap in the foreground (photo by R. J. Smith)

Changing seasons around Lake Biwa

Spring: Oura is known for its magnificent cherry trees (photo courtesy of Shiga Prefectural Government)

Summer: Omi-Maiko Beach, one of many swimming beaches in the western shore of Lake Biwa (photo courtesy of Shiga Prefectural Government)

Autumn: Chikubushima Island before sunset: a small island in northern Lake Biwa. See Topic 1 (photo by M. Matsuda)



Winter: Lake Biwa becomes a paradise for waterfowl in this season (photo by M. Maehata)

Chapter 1　Geological history of Lake Biwa and its biota

Outcrop of the Ko-Biwako Group in the Hattori River. This area was the site of the first paleo-lake, ca. 3.5 Ma. See Chapter 1-2 (photo by Y. Satoguchi)

This clay bed formed on the bottom of Lake Katata. Faults like that in this photo occurred around Lake Biwa after ca.　0.4 Ma. See Chapter 1-2 (photo by Y. Satoguchi)

Eb-Fukuda Tephra. This bed of volcanic ash from 1.75 Ma represents fallout from an explosive volcanic eruption 200 km away to the east. See Chapter 1-2 (photo by Y. Satoguchi)

Pharyngeal tooth fossils of Cyprinus *(Mesocyprinus) okuyamai* unearthed from the Oyamada clay layer formed ca. 3.5 Ma. See Chapter 1-3 (photo by T. Nakajima)

Chapter 2 Biodiversity and its changes in Lake Biwa

(1) Extinct organisms in and around Lake Biwa

Japanese otter *Lutra nippon*: Stuffed specimen at the Shimono-kae Elementary School, Kochi Prefecture, Shikoku Island. See **Topic 6** (photo by M. Ando)

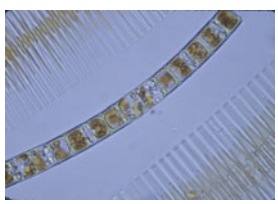
Japanese rose bitterling, *Rhodeus ocellatus kurumeus*, 4-5 cm standard length (SL) (photo by H. Akiyama)

Kissing loach (*Parabotia curta*), 15-20 cm SL (photo by H. Akiyama)

Golden venus fish (*Hemigrammocypris rasborella*), 4-6 cm SL. This fish has not been found in Lake Biwa for near 30 years (photo by H. Akiyama)

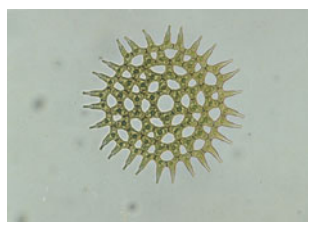
Potamogeton dentatus from Lake Tega-numa, Chiba Prefecture, the Kanto District (photo by E. Hamabata)

(2) Endemic species & varieties of protists and plants of Lake Biwa



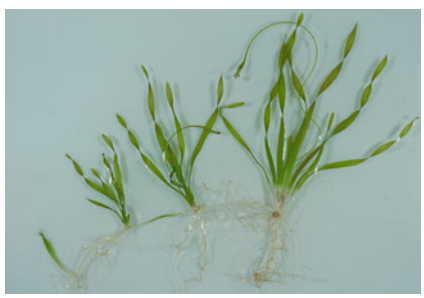
Aulacoseira nipponica (photo by S. Ichise)

Stephanodiscus suzukii (photo by S. Ichise)



Pediastrum biwae (photo by S. Ichise)

Difflugia biwae (photo by S. Ichise)



Vallisneria asiatica var. *biwaensis* (photo by E. Hamabata)

Potamogeton biwaensis (photo by E. Hamabata)

(3) Endemic benthic invertebrates of Lake Biwa **(photographs by M. Nishino)**

<BL: body length, SL: shell length, SH: shell height, SW: shell width> **See Chapter 2**

Hyriopsis schlegeli **(adult: 22.4 cm SL)**

Oguranodonta ogurae **(adult: 7.7 cm SL)**

Inversiunio reinianus **(adult: 4.75 cm SL)**

Corbicula sandai **(adult: ca. 41 mm SL (left); small shell; 4.8 mm SL (right))**

Pisidium kawamurai **(adult: 5.1 mm SL)**

Radix onychia **(adult: 11.1 mm SH (left); live: ca. 11.0 mm SH (right))**

Valvata biwaensis **(adult: 4.2 mm SW)**

Gyraulus biwaensis **(adult: 3.8 mm SW)**

Semisulcospira (Biwamelania) multigranosa **(adult: 27.7 mm SH; embryonic: 5.0 mm, 3.2 mm SH)**

Semisulcospira (Biwamelania) reticulata **(adult: 43.3 mm SH; embryonic: 3.6 mm SH)**

Semisulcospira (Biwamelania) ourense **(adult: 28 mm SH; embryonic: 2.6 mm SH)**

(3) (continued) **Endemic of benthic invertebrates of Lake Biwa** (photographs by M. Nishino)

Jesogammarus (Annanogammarus) annandalei (male: 10.9 mm BL)

Kamaka biwae, (male: 2.4 mm long (upper); female: 2.5 mm long (lower))

Ephoron limnobium (larva:13.0 mm BL, (left); male: BL unmeasured (right) (photos by S. Ishiwata)

Bdellocephala annandalei (adult: 21 mm BL (left); cocoon: 2.7 mm in diameter (right))

Copulating *Apatania biwaensis*

(4) Endemic species & subspecies of fish of Lake Biwa, See Chapter 2-5

(Photographs courtesy of Lake Biwa Museum (LBM))

Biwa salmon, male (*Oncorhynchus masou* subsp.), 30-60 cm in standard length (SL)

Biwa ayu (*Plecoglossus altivelis* subsp.), 8-10 cm SL

Oily minnow (*Sarcocheilichthys biwaensis*), 15-17 cm SL

Biwa minnow *(Sarcocheilichthys variegatus microoculus),* 13-20 cm SL

Sugo gudgeon (*Squalidus chankaensis biwae*), 10-13 cm SL

(4) (continued) **Endemic species & subspecies of fish Lake Biwa,** See **Chapter 2-5**

Round crucian carp (*Carassius auratus grandoculis*), 20-35 cm SL

Biwa culter (*Ischikauia steenacheri*), 25-40 cm SL

Deep-bodied crucian carp (*Carassius cuvieri*), 20-40 cm SL

Willow minnow (*Gnathopogon caerulescens*), 8-13 cm SL

Yodo gudgeon (*Biwia yodoensis*) 5-6 cm SL

Biwa striated spined loach (***Cobitis*** sp. S), 7-8 cm SL

Biwa yellow-gill (*Rhinogobius* sp. BW), 3-4 cm SL

Biwa sculpin (*Cottus reinii*), 10-12 cm SL

Large striated striped loach (*Cobitis* sp. L), 8-11 cm SL

Biwa goby (*Gymnogobius isaza*), 6-8 cm SL

Rock catfish (*Silurus lithophilus*), 50-60 cm SL

Biwa catfish (*Silurus biwaensis*), 70-110 cm SL

Chapter 4 (partially Chapter 5) History of the relationship between people and Lake Biwa

The last *Maruko-bune*. See **Chapter 4-2-4** (photo by M. Yoda)

Investigation of remains under water. See **Topic 11** (photo courtesy of Shiga Prefectural Board of Education)

The Awazu Site on the lake-bottom. See **Chapter 4-1-1** (photo courtesy of Shiga Prefectural Board of Education)

Hiyoshi San'nosai [San'no Festival of the Hiyoshi Grand Shrine]. See **Topic 14** (photo by M. Yoda)

Awazu Goku [Offering to the lake god]. See **Topic 14** (photo by M. Yoda)

Funa-zushi. See **Chapter 5-2-3(1)** (photo by M. Maehata)

Chapter 5 The use of Lake Biwa and people's lifestyle: Fishing in and around Lake Biwa

Funa Sashi-ami fishery (gill net for crucian carp) (left) and crucian carp (right) caught. See **Chapter 5-1-2** (photos by T. Sato)

Eri fishery. See **Chapter 5-1-2** (photo by M. Maehata)

Yotsude-ami fishery in the lower reaches of the Ado River. See **Chapter 5-1-2** (photo courtesy of Lake Biwa Museum [LBM])

Jibiki-ami (seine net) fishery formerly operated at Oki-shima Island, northern basin of Lake Biwa. See **Chapter 5-1-2** (photo courtesy of LBM)

Yana fishery (*Kattori-yana*) in th Ado River. See **Chapter 5-1-2** (photo by M. Yoda)

Chapter 6 Evolution toward integrated basin management in Lake Biwa and the Yodo River basin

Seta River Wier (left 'Setagawa Araizeki' in Japanese); water level of Lake Biwa is controlled by this wier. Its maximum flow is 800 tons/sec. A portion of its predecessor, the Nango Wier (right, 'Nango Araizeki' in Japanese), built in 1905 (Meiji Era) is preserved just upstream from the present wier. See **Chapter 6-1-3** (photos courtesy of Biwako Rivers Office, Kinki Regional Development Bureau, the Ministry of Land Infrastructure, Transport and Tourism of Japan (right) and M. Maehata (left))

Lakeside Road (lake levee), which was built as part of the Lake Biwa Comprehensive Development Project, interrupting the continuity between water and land of the water ecotone (photo by M. Maehata)

Oki-shima port in Omi-Hachiman city, one of the renewed ports built as part of the Lake Biwa Comprehensive Development Project (photo by M. Maehata)

Chapter 7 Environmental conservation of Lake Biwa

Alien fishes of North American origin caught by seine net at Kitakomatsu beach, north basin of Lake Biwa. See **Chapter 7-2-4(1)** (photo by M. Maehata)

Jibiki-ami (seine net) fishing, which is now undertaken only several times per year to entertain tourists. In this event, the fishes caught are usually used as the basis for environmental education benefiting the participants. See **Chapter 5-1-2** (photo by M. Maehata)

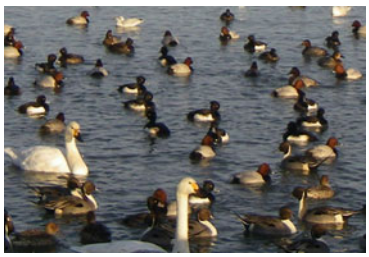
Water lettuce (*Pistia stratiotes*) growing thickly in Akanoi Bay, 2007. See **Chapter 7-2-3(1)** (photo by M. Maehata)

Extermination of Senegal tea plant (*Gymnocoronis spilanthoides*) by voluneers. See **Chapter 7-2-3(1)** (photo by K. Nakai)

Extermination of alien plant, water lettuce (*Pistia stratiotes*), using a waterweed mowing craft. See **Chapter 7-2-3(1)** (photo by K. Nakai)

Damage by the Great Cormorant (*Phalacrocorax carbo*) is observed in the forest of the Isaki Peninsula, Omi-Hachiman city, overlooking the beach in the north basin of Lake Biwa. See **Chapter 7-2-4** (photo by M. Maehata)

Hayazaki-naiko [Hayazaki attached lake], site of restoration experiment. See **Chapter 7-2-1(4)** (photo by M. Nishino)



Lake Biwa is a paradise for waterfowl. In winter, various waterfowl, firstly many kind of duck coming from northern countries, are obsererved. See **Topic 25** (photo by M. Maehata)

1 Geological History and Transition of the Biota of Lake Biwa

Keiichi Takahashi

The Lake Biwa area is one of the most active Cenozoic tectonic regions of the Japanese islands. District-wide geological structures and a large depressional basin are recognized in this area. The formation and development of the lake were controlled by fault movements that occurred through the Pliocene and Pleistocene epochs of the Cenozoic era.

The predecessor of Lake Biwa, known as Paleo-lake Biwa, formed almost four million years ago during the early Pliocene, in the Ueno Basin located about 50 km southeast of the present-day lake. This lake subsequently migrated northward to the present-day position of Lake Biwa. The 1,500-m thick sediments deposited in Paleo-lake Biwa ("Kobiwako" in Japanese) and on the surrounding alluvial plains, are called the Kobiwako Group. Mostly consisting of river and lake deposits, they also contain 150 thin volcanic ash layers, which are used to accurately date the deposits.

The Kobiwako Group contains both aquatic and terrestrial fossils, including algae, diatoms, wood, leaves, pollen, protozoa, sponges, mollusks, insects, fish, turtles, crocodiles, birds, and mammals. As these fossils can be accurately dated, they are very useful for research on the development of the area. The transition of the aquatic biota has sometimes been correlated by researchers to local climate and changes in the depth or size of the lake. However, it is now recognized that global environmental changes and terrestrial connections to the continent have played an important role in shaping the biota of the region.

The following section describes the origin, morphology, and temporal succession of the cyprinid fish fauna, and the geological history of Lake Biwa.

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1.1 Geomorphology of Lake Biwa and the Surrounding Region

Yoshihiro Uemura

Abstract Lake Biwa and Omi Basin are located in the Inner Zone of southwest Japan in the geological sense, and are surrounded by mountain in the eastern and the western margins. The boundary between the basin and the mountains are formed by N–S striking reverse faults. It is a characteristic of the structural framework called Kinki Triangle.

Terrace surfaces in the Omi Basin are divided into four terrace groups. The distribution and the developing process of the terrace topography are greatly different between the eastern and the western areas of the lake. The formational process of the terraces in the eastern and the western coast areas of the Lake Biwa indicates that the deformation style of the Omi Basin is greatly controlled by the master fault of the western coast area.

Alluvial plain around Lake Biwa is the largest one in Japan. The average subsidence rate of the west coast reaches more than twice the rate of the east. This indicates that the subsidence rate of the west could have been significantly affected by the activity of west coast active fault system.

Lake Biwa is divided into the large northern and the small southern lakes. The lake bottom topography in the northern lake is gently dipping from the east to the west, and is the deepest in the western margin. Investigations by air gun and the uniboom revealed that three sublacustrine active faults distribute offshore of the west, south, and east coast along the boundary between the subaqueous terrace and the bottom of the lake basin.

Keywords Terrace surface • alluvial plain • reverse fault • sublacustrine active fault • Omi Basin

Introduction

Lake Biwa is located in the Omi Basin, which is an inland basin with 30 km from east to west and 50 km from north to south, in the Inner Zone of southwest Japan. The Omi Basin is a tectonic depression surrounded by the Mino, Ibuki, and Suzuka Mountains in the eastern margin, and the Tanba, Hira, and Hiei Mountains in the western margin. The boundary between the basin and the mountains are formed by N–S striking reverse faults (*Fig. 1*). The basement rocks in the area are underlain by the Paleozoic to Mesozoic sedimentary rocks of the Tanba Belt and cretacious granitic and rhyolitic rocks. Reverse fault system of an N–S trend has been controlled under the compressional stress of an E–W direction. It is a characteristic of tectonic framework of the Kinki Triangle. The catchment area of Lake Biwa is about 3,848 km^2 and the altitude of the lake level is 84.6 m. Seta River is the only natural outlet of Lake Biwa, and is known by different names as Uji River and Yodo River. It flows into Osaka Bay and Pacific Ocean finally. As the nick point is on the way to between Kyoto Basin and Lake Biwa, it has never been affected by glacio-eustatic sea-level change since the middle Quaternary. This chapter describes the following items: (1) hills and terraces topography around Lake Biwa, (2) landform and deposits of alluvial plain, and (3) sublacustrine active faults of the lake bottom.

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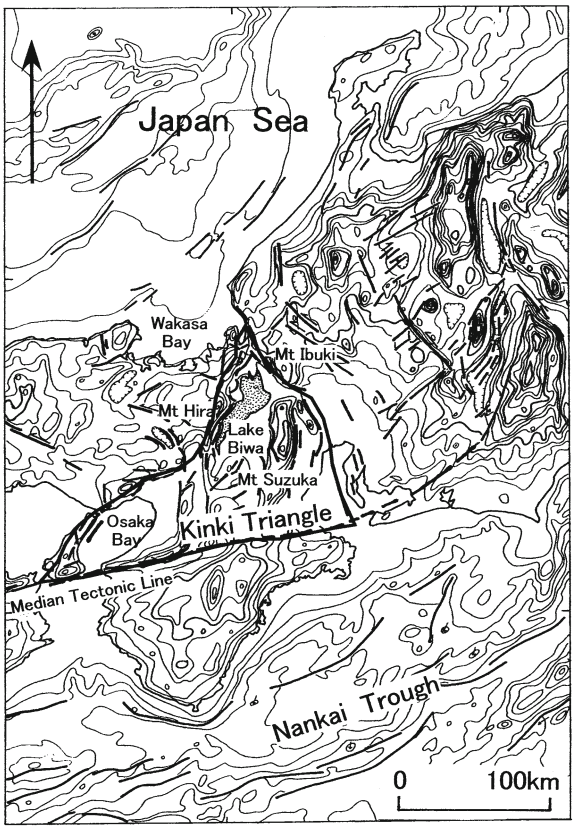

Fig. 1
Tectonic map of Kinki region (Compiled by Uemura).

Hills and Terraces

Terraces are divided into four surface groups: the highest, higher, middle, and lower in descending order. Hills are underlain by Kobiwako Group of the Plio-Pliestocene series (*Fig. 2*). As the distribution and the developing process of the terrace topography are greatly different between the eastern and the western areas of the lake.

In the eastern area, the Koto, Konan, and Seta hills occupied wide distribution. The hills formed *low-relief topographic* features with constant height and is in a dynamic equilibrium state. On the top of hill, the highest terrace is left partially. This indicates that a large piedmont alluvial fan had been formed covering the hill 400,000–500,000 years ago.

Well-developed terrace surfaces can be seen in the areas of Yasu, Hino, and Seta Rivers. The higher terrace, which is composed of gravel bed of about 5 m thick, is almost on the same level with the hill's surface or above it. The middle terrace is divided into upper and lower surfaces. Deposits of the upper surface usually consist of the lower gravel bed of 3–5 m thick, and the upper sand bed and clay bed of about 5 m thick. The upper clay bed is interbedded with a tephra that is a correlative with the DHP tephra (Daisen-Hiruzenbara tephra, dating to about 100,000 years ago).The lower surface was a small surface consisting of gravel bed of less than 5 m thick. The lower terrace is distributed widely and consisted of fan gravels. The AT tephra (Aira-Tanzawa tephra, dating to about 29,000 years ago) is interbedded with deposits of the upper surface. The most distinctive deformation of the terraces in the eastern area is controlled by tilting to the northwest direction accumulatively.

In the Katata and Aibano Hills in the west area, many landslides and collapses are distributed, because the age of uplifting of hills is younger. The terraces are typically developed along the Ado River. The higher terrace has the depositional surface at the top of hill, and composed of gravel bed of over 20 m thick. The middle terrace is divided into four or five small surfaces. Those are composed of gravel beds of 1–3 m thick. The second terrace from the top of the Taisanjino Terrace is interbedded with the Aso 4 tephra (dating to about 87,000 years ago) and the DNP tephra (Daisen-Namatake tephra, about 83,000 years ago). The lower terrace is divided into two surfaces consisting of gravel bed of 1–3 m thick. The deposits of the upper surface is interbedded with the AT tephra. The eastern margin of the hills and the terraces has been deformed by active faults with N–S trend such as the Katata, Aibano, and Kamidera faults. The amount of vertical displacement of the AT tephra by those faults reaches 20–30 m. The terrace surfaces have been accumulated deformation of reverse gradient to the west (upper stream) side, caused by reverse faulting. The deference of formational processes of the terraces between the east and the west areas is mainly caused by activity of the Biwako west coast fault system as master fault.

Topographic Development and Alluvium in the Coastal Plain

The largest lake plain in Japan is developed around Lake Biwa. The Koto plain in the east is composite alluvial lowland that was formed by Yasu, Hino, Echi, and Inukami Rivers. In the west of the lake, alluvial fans by debris flow deposits and delta fan are predominated. The northern area is characterized by rias coast that is the mountain slope adjacent to the lake, and development of the plain is poor. In the Koto plain, alluvial fan, natural levee zone, and

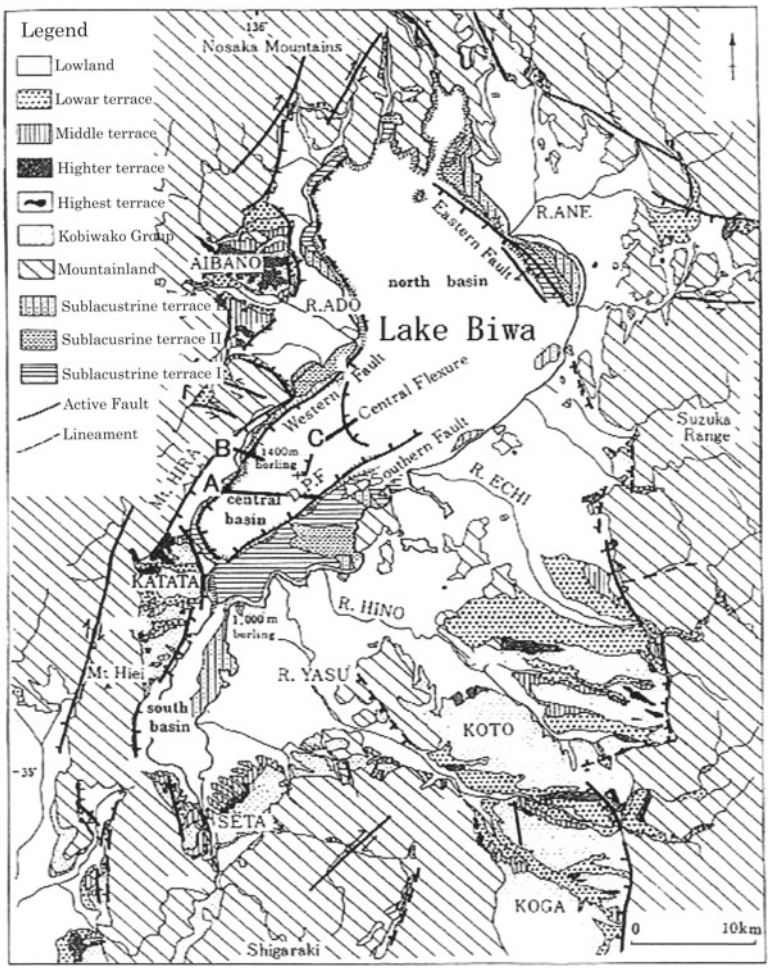

Fig. 2
Distribution of terrace surfaces and sublacuastrine active faults in and around Lake Biwa (Uemura 1999).

delta are arranged from upstream to downstream (*Fig. 3*). As Yasu River has much supply of sand and mud, the progress of the delta into the lake reached 1–2 km during the past 1,000 years. A number of isolated mountain masses are distributed in Koto plain, and it leads to many attached lakes and swamps around them caused by weak sedimentation. Beach ridge distributed from the mouth of Echi River to Hikone City has average width of 250 m, relative elevation of 2.5 m, and length of 20 km, and is formed by the strong influence of the northwest wind and coastal current. As alluvial plain has never been affected by the glacial sea-level changes, the processes of sedimentation of alluvium are completely different from those of the marine coastal plain. The stratigraphic division of alluvium of the Koto plain can be divided into the following four layers in ascending order (Yokoyama and Uemura 1983): (1) the lower gravel layer distributed deeper than 10–20 m; (2) the middle layer with good continuity, consisting of mud and peat; (3) the upper gravel layer that cuts off the middle layer; and (4) the mud layer on the top. The A–B section of *Fig. 4*, which is the section at 4 km inland from the coast, shows tube-shaped gravel bed that rapidly changed to the mud or peat beds.

Meanwhile, in the C–D section on the coast, cycle of clay (Bottomset Beds) and sand (Foreset Beds) is repeated three times, and unconformity and buried valley are not recognizable. The age of lower gravel bed is about 30,000–50,000 years, and the extension to the lake bottom is correlated with the layer of the first subaqueous terrace. The middle mud bed is interbedded with the AT tephra, and is characterized by containing subalpine macro plant and pollen fossils. The age of the middle mud bed is 20,000–30,000 years. As the age of the AT tephra is about 29,000 years, the burial depth of this tephra in the underground indicates the average subsidence rate during 29,000 years. In the Koto plain, the subsidence rate is 0.3–0.8 m/1,000

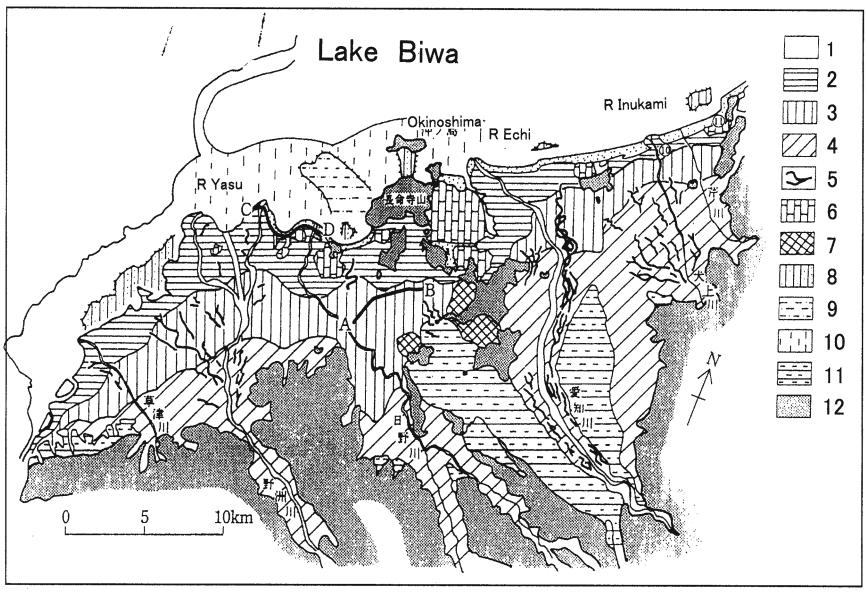

Fig. 3
Landform classification map of Koto plain (Yokoyama and Uemura 1983). 1 Bar, 2 Delta, 3 Natural levee zone, 4 Alluvial fan, 5 Former river course, 6 Reclaimed land, 7 Drowned valley swamp, 8 Sublacustrine terraces III, 9 Sublacustrine terraces II, 10 Sublacustrine terraces I, 11 Terrace, 12 Hill & Mountain area.

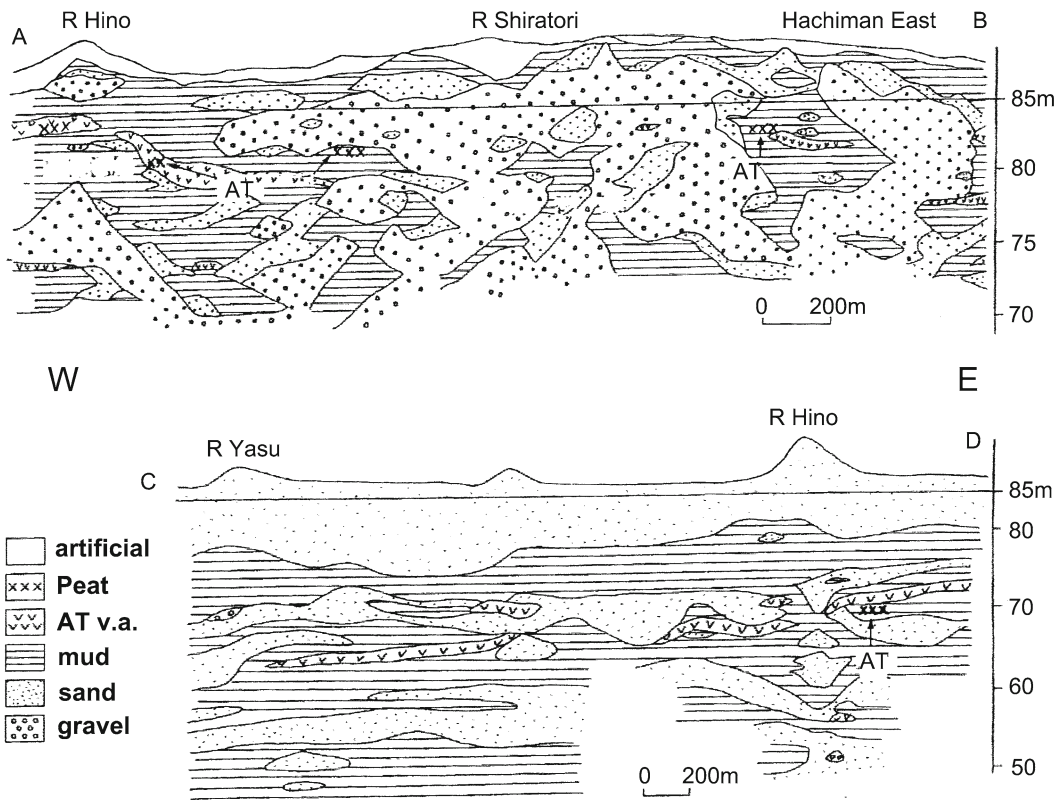

Fig. 4
Two geological cross-sections of alluvial plain of Koto area (Compiled by Uemura).

years, and in the west coast area, it is about 1.5 mm/1,000 years, which is more than twice of the eastern area. In addition, from the burial depth of archeological remains and surfaces, the subsidence rate in the eastern area is about 0.7 mm during about 6,000 years, and in western area it is about 1.6 mm during 25,000 years ago. Thus, the average subsidence rate of the western coast reaches twice that of the eastern coast. This indicates effects by the activity of the west coast fault system.

Sublacustrine Active Fault of Lake Biwa

Lake Biwa is divided into the northern lake (which is 90% of the entire area) and the small accessory southern lake. The lake bottom topography in the northern lake is dipping gradually from the east to the west, and the deepest is in the western margin. The western margin is bounded by steep cliff (*Fig. 5-A*). This means the characteristics of a fault angle basin with master fault as west coast fault system. The north lake basin is divided into two: the north basin, which is 60–80 m in depth, a long axis toward the northwest direction, and the middle basin toward the northeast direction. Each basin forms as bent shaped over each other. The subaqueous terrace is divided into the third subaqueous terrace (5 m in depth), the second subaqueous terrace (10 m in depth), and the first subaqueous terrace (20–30 m in depth) in descending (Kotani 1971). Investigations with air gun and uniboom revealed that three active fault systems are distributed along the west, south, and east margins of lake bottom as the boundary between the subaqueous terrace and bottom of the lake basin (*Fig. 2*, Horie and Tanaka1983; Uemura and Taishi 1990).

The western sublacustrine active fault continues for about 45 km along the west shore of the lake, and steep cliffs are developed. Anticline structure and rift valley off the Hira Mountain are parallel and indicate echelon pattern strikes N40°W. According to *Fig. 5-B*, acoustic basement has raised to shallow at the axis of an anticline, and two minor faults have arisen following the growth of active fold in the east wing. This fault has cut the K-Ah tephra (Akahoya volcanic ash, dating to 75,000 years ago), and was activated around 2,000–3,000 years ago. However, the age of activity of the master fault is not obvious during the late Quaternary. The deformation pattern is similar to ridge and trough topography that arised at hanging wall of subduction zone. This reflects the structure that the block of Lake Biwa is underthrusting the Hira Mountains. The southern sublacustrine active fault system trends northeast to southwest, and continues for 17 km from off delta of Yasu River to Nagahama City. The fault has developed steep cliffs with 5–30 m in relative elevation, which continues to the cliff of the first subaqueous terrace. The cliff is most obviously developed off the Okishima Island, and the AT tephra seems that it was deformed along the cliff, but deposits after K-Ah tephra has never been deformed. The eastern sublacustrine active fault system continues for about 13 km to the northwest from off Kohoku Town to off Nagahama City. It forms cliffs with 10–30 m in relative elevation. There is a flexure concealed by sediment off the Nagahama, but the activity after the K-Ah tephra is never recognized. Central Flexure forms saddle topography separating the northern and middle basins. It lasts about 6 km in the north and south, and shows convex in the west. The flexure is elevated in the western side. Its hanging wall is dipped to the west showing small deformation (*Fig. 5-C*). The amounts of displacement are 12 m at the bottom surface, 18 m at the K-Ah tephra, 40 m at the AT tephra, and 170 m at TS surface (the base of the Biwako Clay Bed, dating to about 400,000 years ago).

The activity of flexure started after the sedimentation of the Biwako Clay Bed, and the average displacement rate during past 400,000 years is estimated 0.4 m/1,000 years. The drilling point fault is located in the east slope of the middle lake basin and can follow about 3 km in the N10°E direction. This fault has the high-angle fault plane with a dip in the west, and is seen clearly as accumulation of the eastern rise and the dip–slip displacement. The amounts of displacement is 2 m at the U-Oki tephra (Ulreung-Oki tephra, dating to 9,300 years ago), 4 m at the AT tephra, 12 m at Daisen-Namatake tephra, 50 m at TS surface, and about 120 m at the top of basement rock. The average rate of displacement was estimated at 0.05–0.07 m/1,000 years during 3,000,000–500,000 years ago, but 0.1 m/1,000 years since 500,000 years ago, which indicates that the rate of displacement has been accelerated as double after 500,000 years ago. Those sublacustrine active faults are characterized as reverse faults. In addition, the eastern and western sublacustrine fault systems are accompanied by strike-slip component based on the topography such as echelon pattern of faults and bulges. The north and the middle lake basins are originated as lamp valleys bounded on both sides by conjugate system reverse faults with strike-slip component.

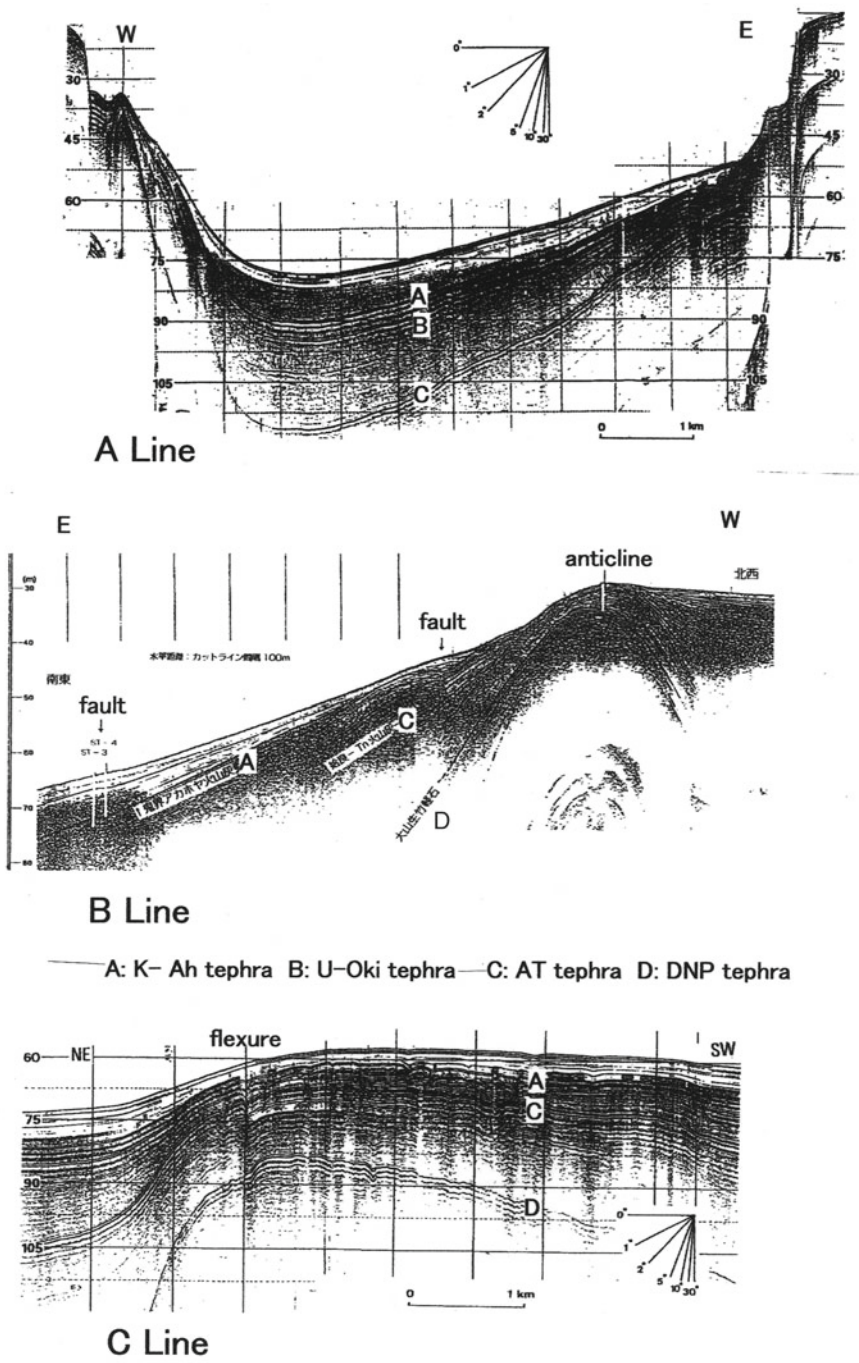

Fig. 5
Uniboom record of E–W cross-section of the central basin of Lake Biwa (Uemura and Taishi 1990).

1.2 Geological History of Lake Biwa

Yasufumi Satoguchi

Abstract Studies of the Pliocene to Pleistocene Series distributed around Lake Biwa have shown that the geological history of the lake goes back approximately 4 million years. These stratigraphic beds, formed from sediments deposited in and around Paleo-lake Biwa, collectively are called the Kobiwako Group and are divided into seven or eight formations based on their lithofacies. The boundaries between the formations represent widespread changes in the depositional environment. The geological history of Paleo-lake Biwa may be summarized as follows. Paleo-lake Oyamada, the first predecessor of Lake Biwa, formed in the Iga Basin 4 million years ago. After that lake had filled in, it re-emerged to the north as Paleo-lake Ayama, which was wider and deeper than the previous lake. There was no large lake for a while, but then a small lake formed in the area south of the present lake's location. Research on the bottom sediments of the present lake has revealed a stable lake environment for the past 430,000 years and evidence of various geological events including tectonic activity around the lake and explosive volcanic activity in southwestern Japan. The lake-bottom sediments have also preserved information on global climate changes. Lake Biwa has, therefore, been a recorder of environmental change.

Keywords Kobiwako Group • Pliocene–Pleistocene • lacustrine and fluvial sediments • stratigraphy • tephra

Introduction

It is well established that Lake Biwa has a geological history extending back about 4 million years. This history has been studied and reconstructed on the basis of sediments of the Pliocene–Pleistocene Series, distributed mainly in the hills around Lake Biwa (*Fig. 1*; Takaya 1963; Yokoyama 1969; Kawabe 1989). These sedimentary

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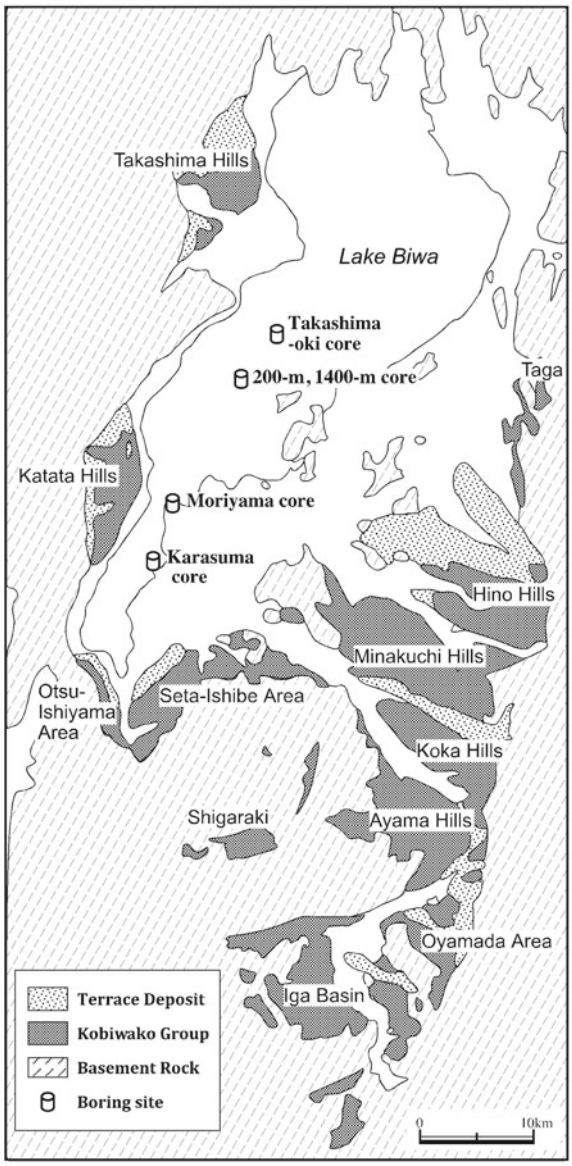

Fig. 1
Distribution of the Kobiwako Group and boring sites (The geological map is simplified from Kawabe 1989, and place-names and boring sites are retouched).

beds, which are collectively called the Kobiwako Group, have trapped evidence of the environment, flora, and fauna of the paleolakes that preceded the present lake, and also provided a record of significant geological events. Additional evidence is preserved in the massive clay beds deposited beneath the bottom of the stable present lake over the past 430,000 years. These clay beds have also preserved records of global environmental changes.

This chapter reviews the geological history and environmental changes of Lake Biwa on the basis of previously published research.

Kobiwako Group

The Kobiwako Group is mainly distributed in the hills around Lake Biwa, but the sediment accumulated beneath recent Lake Biwa is stratigraphically continuous with it. The Kobiwako Group consists of lacustrine and/or fluvial sediments divided into seven or eight formations based on their lithofacies (e.g., Yoshikawa 1984): the Ueno, Iga, Ayama, Koka, Gamo, Kusatsu, Zeze, and Katata Formations in ascending order (*Fig. 2*). Some consider the Zeze Formation to be part of the Katata Formation (Yoshikawa 1984), and the upper part of the Katata Formation is sometimes split off as the Ikadachi Formation because of its gravelly lithofacies (Yoshikawa and Yamasaki 1998). The stratigraphy of the Kobiwako Group has been reconstructed on the basis of lithofacies and tephra beds, the latter serving as key beds for this purpose because of the many characteristic tephras intercalated in the Japanese Neogene and Quaternary Systems. The chronology of the group has been established by magnetostratigraphy (Hayashida and Yokoyama 1983; Kobiwako Research Group 1977, 1981, 1992; Yokoyama et al. 1979; Hattori River Foot Print Fossils Research Group 1996) and by correlation with widespread tephras (Yoshikawa 1984, 2001).

The Ueno Formation is distributed in the southern part of the Iga Basin in Mie Prefecture and consists of gravel, sand, silt, and massive clay (Kawabe 1989). The massive clay bed is called the Nakamura Member and is distributed in the Oyamada area. This clay demonstrates that a paleolake, named "Paleo-lake Oyamada," existed in that area for hundreds of thousands of years. The base of the Ueno Formation, which is also the base of the Kobiwako Group, dates to approximately 4.4 Ma (mega-annum: million years ago) based on the presence of two widespread tephras, the Hojiro II and Shibutagawa volcanic ash beds. The estimated ages of these beds in the marine-sediment Miura Group on the Boso Peninsula are 3.9 and 4.2 Ma, respectively (Satoguchi et al. 2005; Satoguchi 2006). Coarse gravels are found in the western part of the basin, becoming coarser toward the west. The lowermost part is at the center of the basin. The sediments of the western part of the basin comprise the upper part of the Ueno Formation (Satoguchi 2006).

The Iga Formation, composed mainly of gravel and sand, is distributed around the northern and western sides of the Iga Basin. The sediment grain size is coarsest at the western end, which shows that the sediment was supplied from the west. This formation characteristically contains gravel derived from the Koto Rhyolitic Rocks, which are distributed around the present lake (Kawabe 1989).

The Ayama and Koka Formations are composed of thick and widely distributed massive clay. They reach from the northern part of the Iga Basin to the Ayama and Koka Hills, respectively (Kawabe 1989). These formations are intercalated with some sand beds, which often have wave-ripple cross-lamination and relatively thick, upward-coarsening facies succession. Many of these beds were deposited in deltas. The centers of the depositional basins of the Ayama and Koka Formations are in the Ayama Hills and the northern part of the Koka Hills, respectively (Kawabe 1981). The thick massive clay beds of these formations demonstrate the past existence of stable paleolakes called "Paleo-lake Ayama" and "Paleo-lake Koka," which formed successively. The boundary of the Gauss/Matsuyama Chron, a magnetostratigraphic division, is around the top of these formations (Hayashida and Yokoyama 1983). The newly defined boundary of the Pliocene/Pleistocene is also around this stratigraphic position.

The Gamo Formation, mainly composed of alternating layers of sandy gravel and mud, lies atop the Koka Formation and is widely distributed from the northern part of the Koka Hills to the Hino Hills. The formation becomes thicker eastward. The center of the depositional basin is estimated to be around the Hino Hill (Kobiwako Research Group 1983; Satoguchi 2009). There must have been small lakes and/or ponds in that age because there is only limited occurrence of massive clay. These lakes and ponds are referred to as "Paleo-lakes Gamo," in this chapter.

The upper part of the Gamo Formation is a sandy facies, on top of which lies the gravel-dominated Kusatsu Formation. This latter formation is exposed in the northwestern parts of the Ishibe-Seta, Minakuchi, and Hino Hills (Yoshikawa 1984), and its coarse sediments are thought to have been supplied from the rising Suzuka Mountains (Yokoyama 1969). The Gokenjaya volcanic ash bed (Eb-Fukuda tephra; Nagahashi et al. 2000),

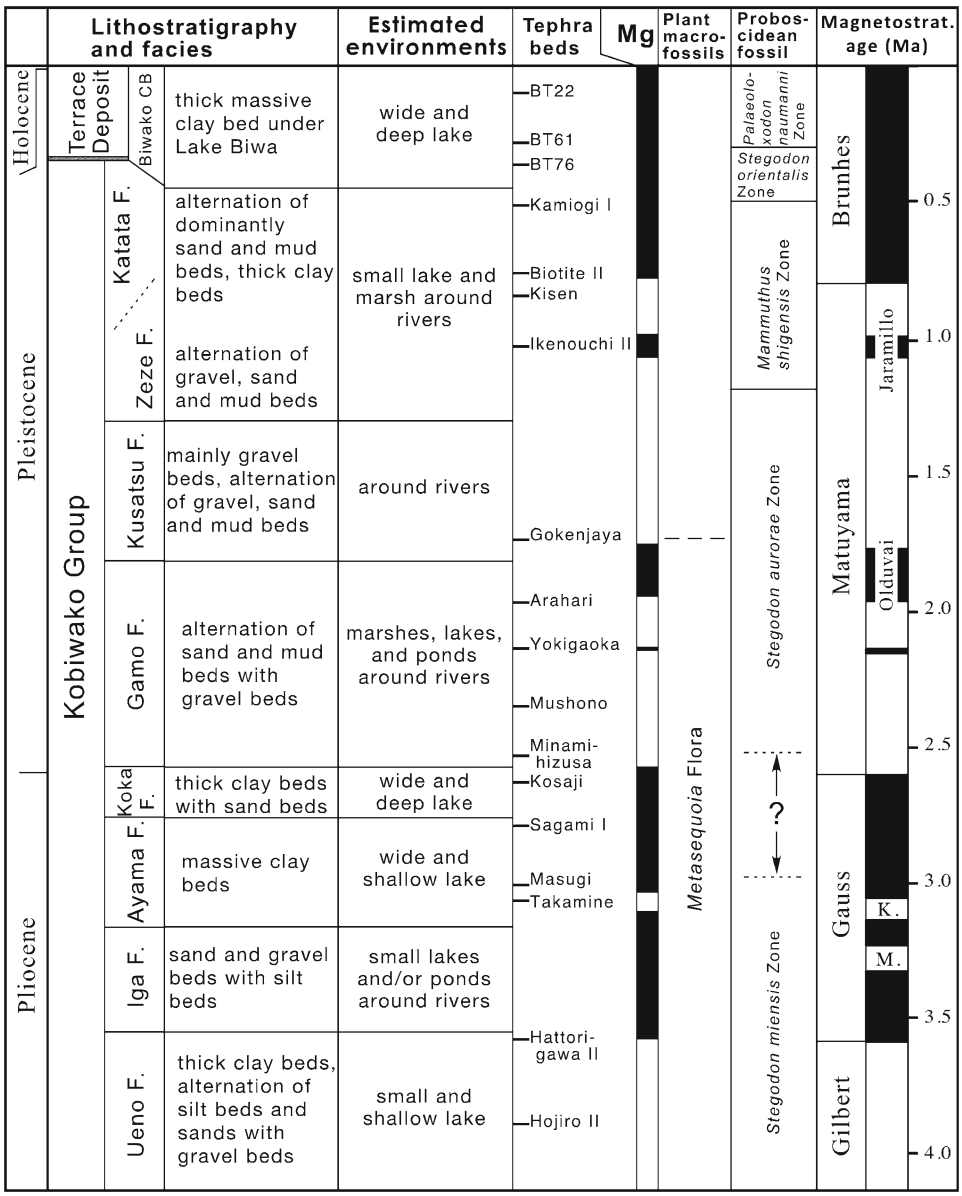

Fig. 2

Stratigraphic graph of the Kobiwako Group (Modified from Yoshikawa and Yamasaki 1998) F: Formation.

intercalated in the lower part of this formation, also underlies the Karasuma Peninsula (drilling site of the Karasuma Core; Karasuma Deep Boring Research Group 1999). Sedimentation at the site of the Karasuma Core began 1.8 Ma, judging from the age of the lowest volcanic ash (1.75 Ma; Yoshikawa et al. 1996); the gravel beds below this volcanic ash bed were deposited on basement rocks.

The Zeze Formation, distributed in the Otsu-Ishiyama area, is composed of alternating layers of gravel, sand, and mud. Interbeds are relatively more dominated by mud than in the Kusatsu Formation. This formation is sometimes considered to be part of the Katata Formation, because both have similar lithofacies and their horizons partly overlap (Yoshikawa 1984; Yoshikawa and Yamasaki 1998).

In the hills, the top layer of the Kobiwako Group is the Katata Formation. Found in the Katata Hills, it consists of massive clay beds and interbeds of sand and mud. Thick massive clay beds demonstrate the existence of stable lakes. The uppermost part of this formation is composed of coarse gravel beds and is called the Ryuge Sand and Gravel Member (Hayashi 1974). The gravel was supplied from the Hira-Hiei Mountains due to active tectonics in this period. Yoshikawa and Yamasaki (1998) split this gravel member off as the separate Ikadachi Formation, because it reflects a special sequence of geological events around Lake Biwa. It has been suggested that the actual topmost layer of the Kobiwako Group is the Takashima Formation, distributed in the Takashima Hills, farther north. However, the Shiratsuchidani volcanic ash bed intercalated in the Takashima Formation is correlated to the Ikenouchi II volcanic ash bed (i.e., the widespread "Ss-Pnk tephra"; Machida and Arai 2003), the age of which is 1.05 Ma (Tsuji et al. 2005), in the middle of the period of deposition of the Zeze Formation (Yamasaki et al. 1996). Therefore, these two formations (Takashima and Zeze) are considered to constitute a single formation (Yoshikawa and Yamasaki 1998).

This sequence of formations shows differences from one to the next that reflect the environmental conditions when each was created, especially as concerns the presence or absence of a wide lake. Their boundaries correspond to widespread environmental changes; for example, occurrence of a thick and continuous clay bed over a wide area indicates the existence of a stable, wide lake in that period.

Beneath the Lake Bottom

Although knowledge of the older geohistory of Lake Biwa has come from research on sediments of the Kobiwako Group distributed around the lake, sediments beneath the lake provide important materials for understanding the formation of the present lake. Sediment cores have been obtained from below the present lake bottom to depths of 200, 1,400, and (off Takashima) 141 m (Horie 1984; Yoshikawa and Inouchi 1991, 1993), and also from the shore of the lake at Moriyama (1,000 m) and the Karasuma Peninsula (Yokoyama et al. 1976; Karasuma Deep Boring Research Group 1999; *Fig. 3*).

There is a thick massive clay bed beneath the lake bottom. This has been called by various names: the "T" Bed (Yokoyama and Takemura 1983), the Biwako Clay Bed (Yokoyama 1985; *Fig. 2*), or the Biwako Formation (Yoshikawa and Yamasaki 1998). The thickness of this clay bed at the site of the 1,400-m boring core is approximately 250 m (Takemura 1990). Mayers et al. (1993) estimated the age of the bottom of the clay as about 430 ka (kilo-annum: thousand years ago). If so, the existence of this bed shows that Lake Biwa has been a stable lake since 430 ka in its present basin. The lithofacies of the sediments below the clay bed are interbeds of mud, sand, and gravel that overlie the rough topographic basement rocks.

Early Paleo-lake

The geohistory of Lake Biwa started in the Iga Basin about 4.4 Ma. It is not clear that a lake existed in that basin at the beginning of sedimentation in the area; however, the first paleolake, called Paleo-lake Oyamada, appeared before 4.0 Ma at least, as is shown by the age of a widespread tephra, identified as the Hojiro II volcanic ash, which is intercalated in the lower clay bed in the Oyamada area. The lake was located at the eastern part of the basin, that is, the Oyamada area. The deepest part of the lake was toward the east, but its depth was probably only several meters, with an expanse thought to be almost the same as that of the southern part of the present Lake Biwa. Although Paleo-lake Oyamada was shallow and small, it existed for hundreds of thousands of years, from sometime before 4.0 Ma to about 3.5 Ma (i.e., the period of deposition of the Ueno Formation). In the western part of the basin, the start of sediment deposition was delayed until about 3.8 Ma (Satoguchi 2006), and the sedimentary environments there were rivers and/or marshes. The plant macrofossils show the climate to have been much warmer than now (Kida 1998). A river flowed out of the lake to the east (Kawabe 1989; *Fig. 4*), although the present outlet river from that area flows in a different direction. Farther to the west, the present Osaka Plain was not a sedimentary basin during that age; however, there was a sedimentary basin to the east, around the present Ise Bay (Research Group for Natural History of Lake Biwa 1994).

Thereafter, Paleo-lake Oyamada was filled in by coarse sediment supplied from the present Lake Biwa area. The region of origin is clear because the coarse sediment includes gravel derived from the Koto Rhyolitic Rocks found around the present lake. Rivers that flowed along the west side of the Iga Basin carried these sediments, some of them flowing into the area from the west. There was no wide lake during the subsequent period of deposition of the Iga Formation, when the sedimentary environments were mostly rivers and/or marshes (Kawabe 1989).

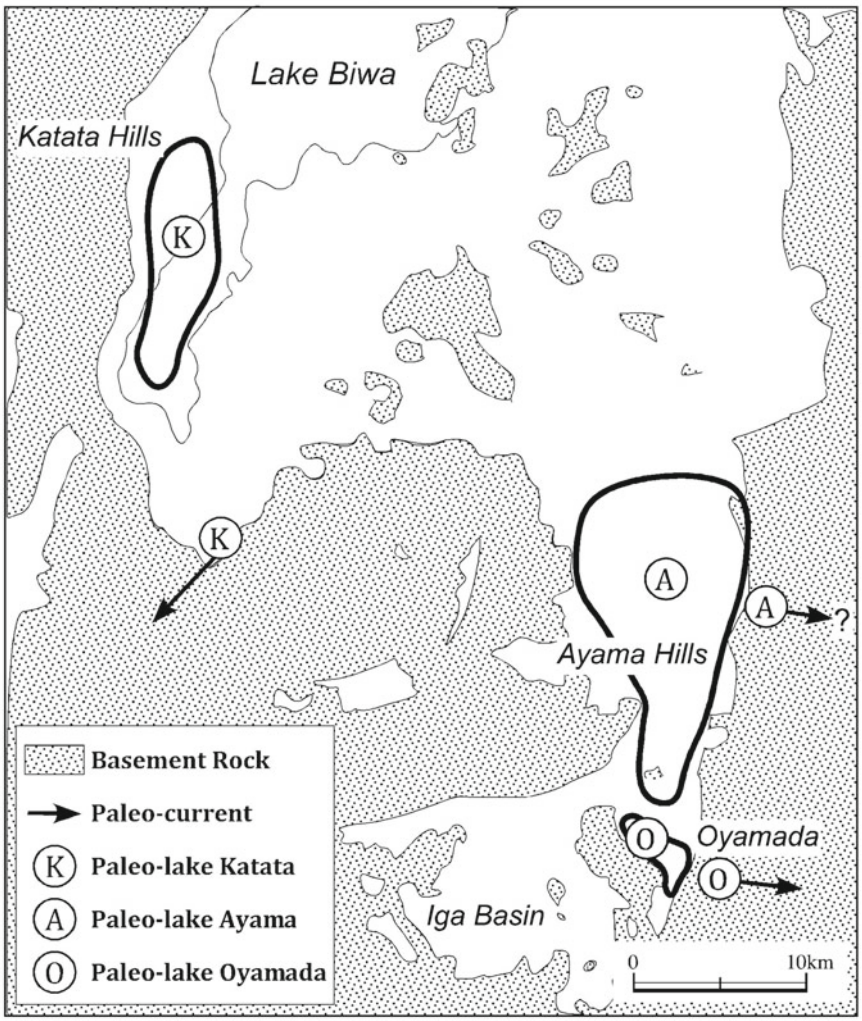

Fig. 3

Paleo-lake positions (Simplified and otherwise modified from Kawabe 1989 and Research Group for Natural History of Lake Biwa 1994). Paleo-currents show directions of outflow from each paleo-lake.

The principal rivers of the area still flowed to the east (*Figs. 3* and *4*), although the Osaka Basin had started receiving deposits from somewhere by then.

A lake reappeared in the period of deposition of the Ayama and Koka Formations. This lake, called Paleo-lake Ayama, was wider and deeper than Paleo-lake Oyamada. Its center during its early stages (the period of deposition of the Ayama Formation) was toward the south. Its expanse was almost two-third the size of the present lake. In the later stages (the period of deposition of the Koka Formation), the center of the lake moved northward as the lake became smaller and deeper (Kawabe 1989). Paleo-lake Ayama in this later stage is also known as Paleo-lake Koka. The southern part of the lake was filled in during this stage, probably during the period from about 3.2 to 2.6 Ma, and ultimately the rest filled in as well.

Reduction and Disappearance of the Lake

After the filling in and disappearance of Paleo-lake Ayama, there were small ponds and/or marshes to the southeast and south of the present lake, which are collectively called Paleo-lakes Gamo (corresponding to the period of deposition of the Gamo Formation). The Mushono volcanic ash

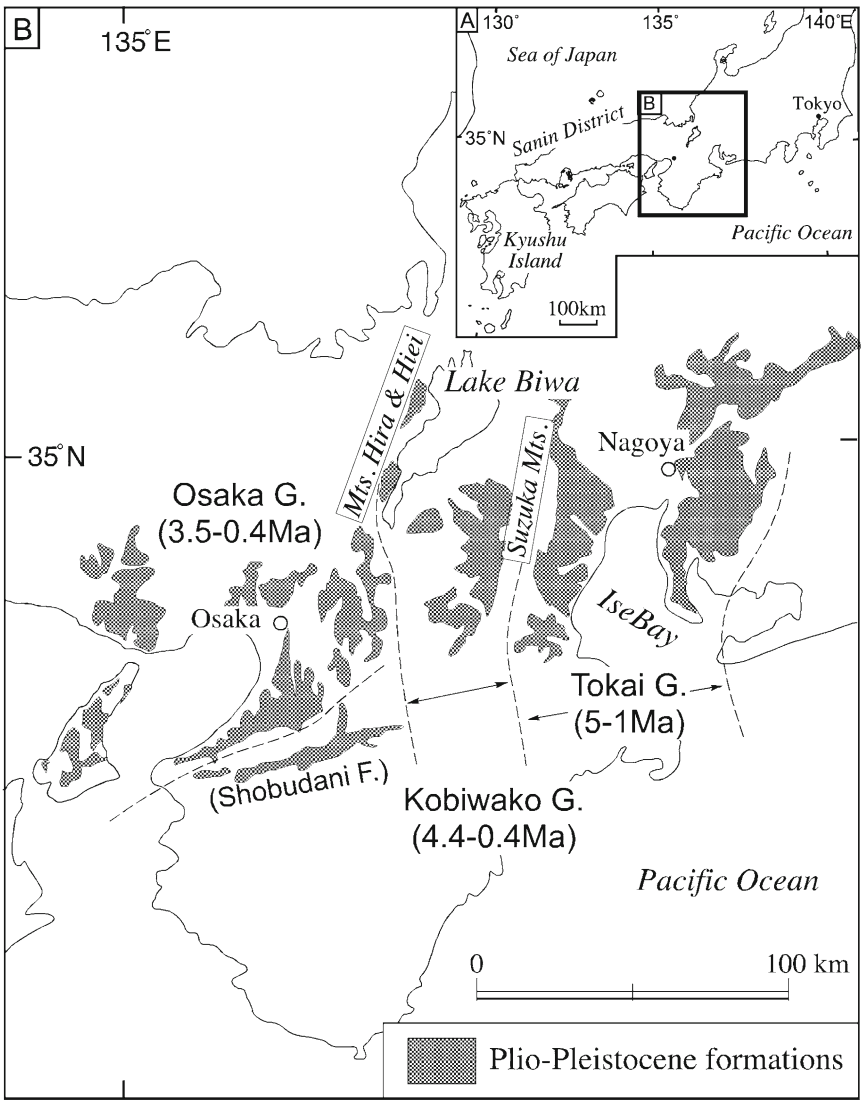

Fig. 4

Pliocene to Pleistocene formations of central Honshu Island (Simplified from Japan Association for Quaternary Research 1987). The boundary lines between these sedimentary Groups (*G.*) are approximate. The periods of deposition of the Tokai, Kobiwako, and Osaka Groups are shown as ranges of millions of years (Ma), based respectively on Satoguchi et al. (1999, 2005), Yoshikawa and Yamasaki (1998), Satoguchi (2006), Yoshikawa et al. (1996) and Satoguchi et al. (1999). Ages of the Kobiwako and Osaka Groups are those of outcrops; in the recent, these sediments have mainly come to lie beneath plains and/or bodies of water.

bed, characterized by fluvio-lacustrine volcaniclastic resedimentation far from the volcanic source (Kataoka 2005), is intercalated in the lower part of the Gamo Formation. The thickness of the sediment bed in these small water bodies was about 3 m at places that could be interpreted as a lacustrine deltaic unit (Kataoka 2003). Therefore, the water depth at that time was more than 3 m at least; furthermore, the thin beds of lacustrine sediment show that these lakes and ponds were not stable (Kobiwako Research Group 1977).

In the period of deposition of the Kusatsu Formation, the uplifting of Suzuka Mountains increased the supply of coarse sediments. Sedimentary environments then were mostly rivers and back-marshes, which were unstable.

Research on one fossil lowland forest has demonstrated instability due to short-interval floods, whereas the surrounding environment, a forest of *Metasequoia*, was stable (Yamakawa et al. 2008). Sediment deposition started in the southern area of the present Lake Biwa in this period. Geographical features in the present lake area included the development of valleys with a north–south orientation (Uemura and Taishi 1990), which already at this time started to be filled in from the south (Masuda et al. 2010). The lake's outflow was a river draining westward.

At the Present Position

The lake formed quite early in the present position of Lake Biwa's southern basin, but it is not clear when this process began. Paleo-lake Katata already existed by about 0.9 Ma, evidence for which is provided by the presence of the Kisen volcanic ash layer intercalated in the massive clay (Hayashi 1974); this ash represents a widespread tephra of 0.9 Ma (the Ss-Az tephra; Machida and Arai 2003). Although the lake was unstable in this early stage (the period of deposition of the Katata Formation), there were times when it stabilized for a long period of time. This lake spread farther to the west than now, around the Katata Hills. During this period, the north–south oriented valleys were filled in throughout the region now covered by the northern part of the present lake, and a plain existed there with some mountains of basement rock (Uemura and Taishi 1990; Satoguchi 2010) and southward-flowing rivers.

Lake Biwa expanded to the north by 430 ka. Since then, it has been stable, although its areal extent has changed as the result of periphery tectonics and climate changes. Active uplift of the Hira-Hiei Mountains began around the same time, and this increased the supply of gravel to the west of the lake. Tectonics to the west of Lake Biwa was active especially after 400 ka, causing the uplift of the mountains and subsidence of the lake floor.

Lake Biwa as a Recorder of Environmental Changes

Lake Biwa has been a stable lake since about 430 ka when fine sediment began to accumulate on its bottom. Sediments on the bottom of a stable lake are known to preserve detailed environmental data, and in order to gain access to this resource, boring cores have been taken from the center of Lake Biwa (*Fig. 1*). These include the 200- and 1,400-m cores of Horie (1984), the 141-m Takashima-oki core of Yoshikawa and Inouchi (1991), the BIW95 cores of Takemura et al. (2000), and others.

Fossil pollen has served to document the flora and paleoclimate around this lake (Miyoshi et al. 1999; Nakagawa et al. 2008, 2009). The climate changes indicated by pollen can be correlated with marine oxygen isotope records (Nakagawa et al. 2008), so in essence one can say that global climate changes have been recorded in Lake Biwa. Changes in silicate content also provide information on Asian and global environmental trends. For example, changes in the biogenic silica content in diatom fossils correspond with global climate changes for the past 400,000 years (Kuwae et al. 2002). Also, eolian quartz flux ("yellow sand") provides direct information on variations in the East Asian winter monsoon for the past 145,000 years, and this flux is also correlated with marine oxygen isotope records (Xiao et al. 1997). Validation of arsenic content as a proxy for lake-level change was discussed by Toyoda and Shinozuka (2004). There have been many other studies on Lake Biwa's paleoenvironment, especially for the most recent several tens of thousands of years (e.g., Yamada 2004; Hayashida et al. 2007).

Many tephra beds are intercalated in the massive clay bed underlying Lake Biwa (Takemura and Yokoyama 1989; Yoshikawa and Inouchi 1991, 1993; Nagahashi et al. 2004; Satoguchi et al. 2008). Most of these tephras were supplied from areas to the west, namely Kyushu and the San-in (or Sanin) District of Honshu; however, some were from other areas. The history of explosive volcanic activity in southwestern Japan has been discussed on the basis of these tephras (Yoshikawa and Inouchi 1993; Nagahashi et al. 2004).

Relationship Between the Japanese Islands and the Asian Continent

When the early Paleo-lake Oyamada existed, the Japanese Islands were connected to the Asian continent. Knowledge of such connections is important for understanding the formation and changes of the Japanese fauna. For example, the species composition of proboscidean fossils from the Kobiwako Group has changed over time, and the timing of these changes is closely related to periods of geographical continuity with the continent (e.g., Takahashi and Namatsu 2000). The opening of the southern channel of the Sea of Japan seems to be an important factor in understanding continuation with the continent. When the southern channel is open, there is inflow of the warm Tsushima Current into the Sea of Japan from the East China Sea. Kitamura and

Kimoto (2004) used fossils of molluscs and planktonic foraminifera in the Pliocene–Pleistocene formations around the Sea of Japan, to show that there was no inflow of the current until 3.1–3.0 Ma and that it flowed only rarely from then until 1.72 Ma. From 1.72 to 0.98 Ma, however, warm-current inflow took place during every interglacial highstand of the sea. It is possible that the current flow was especially strong during the glacial period of 1.45–1.32 Ma. Reconnection with the continent after 1 Ma is demonstrated by a change in the terrestrial fauna around Lake Biwa (e.g., Dobson and Kawamura 1998).

1.3 Origin and Temporal Succession of the Cyprinid Fish Fauna in Lake Biwa

Tsuneo Nakajima

Abstract Many cyprinid fossils are found in the Early Miocene and the Plio-Pleistocene sediments in Japan. The fossiliferous localities of the Miocene are mainly distributed along the Sea of Japan and in the Setouchi basins, the inland basins in southwestern Japan. The Plio-Pleistocene cyprinid fossils are found in the sediments of Paleo-lake Biwa and the other Setouchi basins. The cyprinid fauna in Paleo-lake Biwa largely differ from what is present in Lake Biwa in the composition of subfamilies, but it resembles the Miocene fauna. The fossil data from Japan and China lead to the conclusion that the new elements, such as xenocypridines and cultrines, have evolved in large rift valley lakes formed at the eastern margin of the Asian continent during the Late Paleogene to the Early Miocene. The Miocene cyprinid fauna continued to survive in southwestern Japan, and their descendants inhabited Paleo-lake Biwa. The new cyprinids evolved from their descendants that inhabited Paleo-lake Biwa. They have, however, become extinct due to the drastic change of the environment brought by the tectonic movements during the Pleistocene, by which Lake Biwa expanded and developed its open and deep offshore. As a result of such an environmental change, endemic fishes have speciated in Lake Biwa.

Keywords Paleo-lake Biwa • cyprinid fauna • fossils • Plio-Pleistocene • Miocene

Introduction

Lake Biwa is an ancient lake originated from one of the lakes formed in the Setouchi basins, the inland basins formed in southwestern Japan, in the Pliocene. The sediments of Paleo-lake Biwa and its river systems are collectively called the Kobiwako Group, from which fossil cyprinids consisting of six subfamilies are collected. These are cyprinines, xenocypridines, cultrines, gobionines, leuciscines, and acheilognathines in order of decreasing abundance (Nakajima 1986a).

From the Ueno Formation, the lowest part of the Kobiwako Group, fossils of cyprinid pharyngeal teeth have been collected abundantly. The cyprinid fauna is found to have the richest variety and abundance in the Kobiwako Group. Nearly all the taxa are different at the species level from extant forms. However, most of them represent extant genera while some have become extinct. The cyprinid fossil assemblage from the Ueno Formation representing the Pliocene cyprinid fauna of Japan is called the Iga Cyprinid Fauna. It is largely different from that of the present Lake Biwa in the composition of subfamilies, but resembles that of the Pliocene Yushe Fauna in China, the Miocene Iki Fauna, and others in Japan (Nakajima 1986a).

In this chapter, I will state the origin of the Iga Cyprinid Fauna, the geotectonic history of Lake Biwa, and the temporal succession of the cyprinid fauna in Paleo-lake Biwa. Then, I will discuss the appearance of the endemic species in the present Lake Biwa and the extinction of elements in the Iga Fauna on the basis of fossil data, and how human activities affect the cyprinid fauna in the lake.

Origin of the Iga Cyprinid Fauna

In the Early Miocene, the cyprinid fauna in Japan, represented by the Iki Cyprinid Fauna and others, was very rich. It consisted of xenocypridines (extinct *Iquius*), cultrines (extant *Hemiculter*, *Sinibrama*, *Ancherythroculter*, and extinct *Mioculter*), cyprinines (extant *Cyprinus* and extinct *Lucyprinus*), danionines (extant *Zacco*), and Acheilognathinae (extinct *Paleorhodeus*) (Tomoda et al. 1977; Nakajima 1993). The abundance of fossils in many

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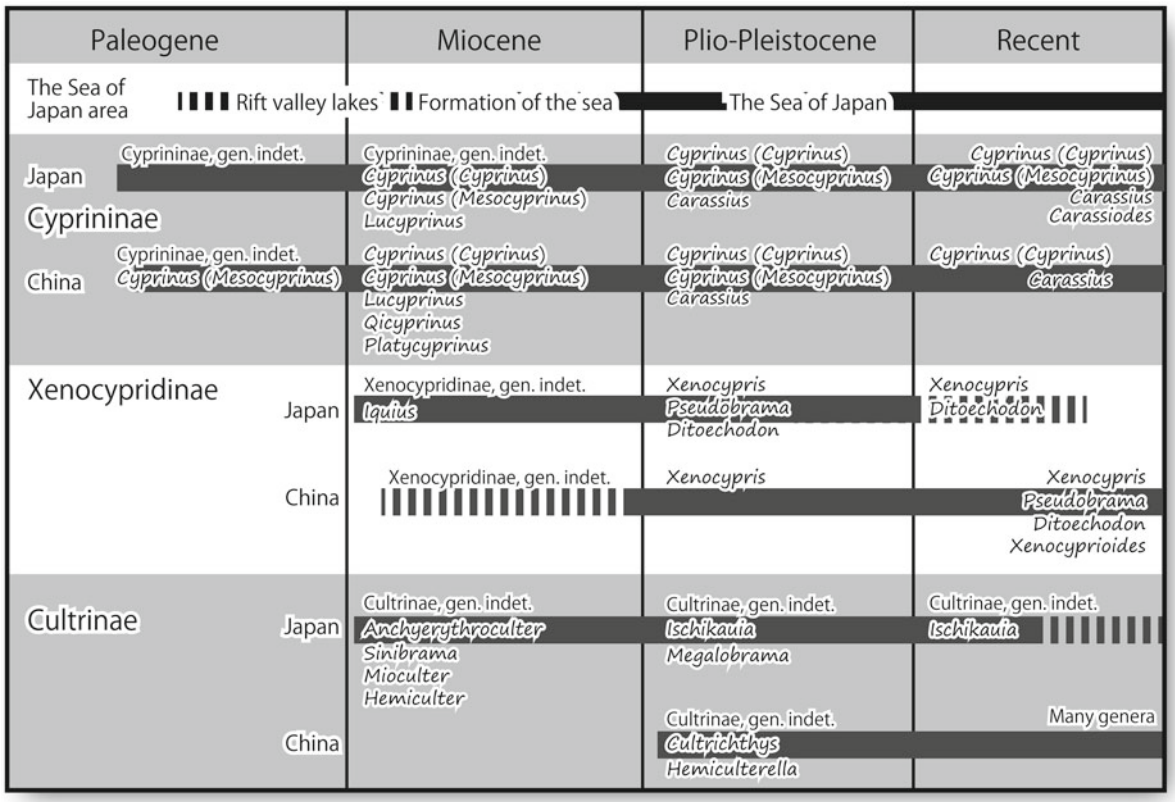

Fig. 1

Comparison of fossil cyprinines, xenocypridines, and cultrines between Japan and China.

localities suggests a predominance of xenocypridines in the Miocene fauna of Japan (Nakajima 1991).

On the other hand, the Miocene cyprinid fauna in China, represented by the Shanwang Fauna from Shandong Province, contains cyprinines (extant *Cyprinus* and extinct *Lucyprinus*, *Qicyprinus*, and *Platycyprinus*), danionines (extinct *Miheilichthys*), gobionines (extant *Gnathopogon*), and leuciscines (extinct *Plesioleuciscus*) (Zhou 1990). Among these, only *Cyprinus* and *Lucyprinus* among cyprinines were common in both regions. In China, cultrines never found, and xenocypridines were very meager during the Miocene. Therefore, the cyprinid fauna of that time significantly differed between China and Japan though the Japanese archipelago was still part of the Asian continent in the Early Miocene.

The Pliocene cyprinid fauna in China is represented by the Yushe Fauna from Shanxi Province. It contains xenocypridines (*Xonocypris*), cultrines (*Culter* and *Hemiculterella*), cyprines (*Cyprinus* and *Carassius*), hypophthalmichthines (*Hypophthalmichthys*), leuciscines (*Leuciscus*, *Mylopharyngodon*, and *Ctenopharyngodon*), and gobionines (*Gnathopogon*) all of which were extant genera (Liu and Su 1962). Cultrines first appeared in the Pliocene; xenocypridines became more its present state in the Pliocene after the appearance of cultrines in the Miocene.

The fossil data obtained from China and Japan (*Fig. 1*) lead me to the following idea. During the Miocene, old elements such as *Lucyprinus*, *Qicyprinus*, and *Platycyprinus* constituted the cyprinid fauna in China. In the Early Miocene, new elements such as cultrines and xenocypridines characterizing the modern cyprinid fauna of East Asia originated in the "Japanese area," which was situated in the marginal part of the Asian continent at that time. The new cyprinid fauna including cultrines and xenocypridines probably spread from the marginal part to inland China during the Miocene.

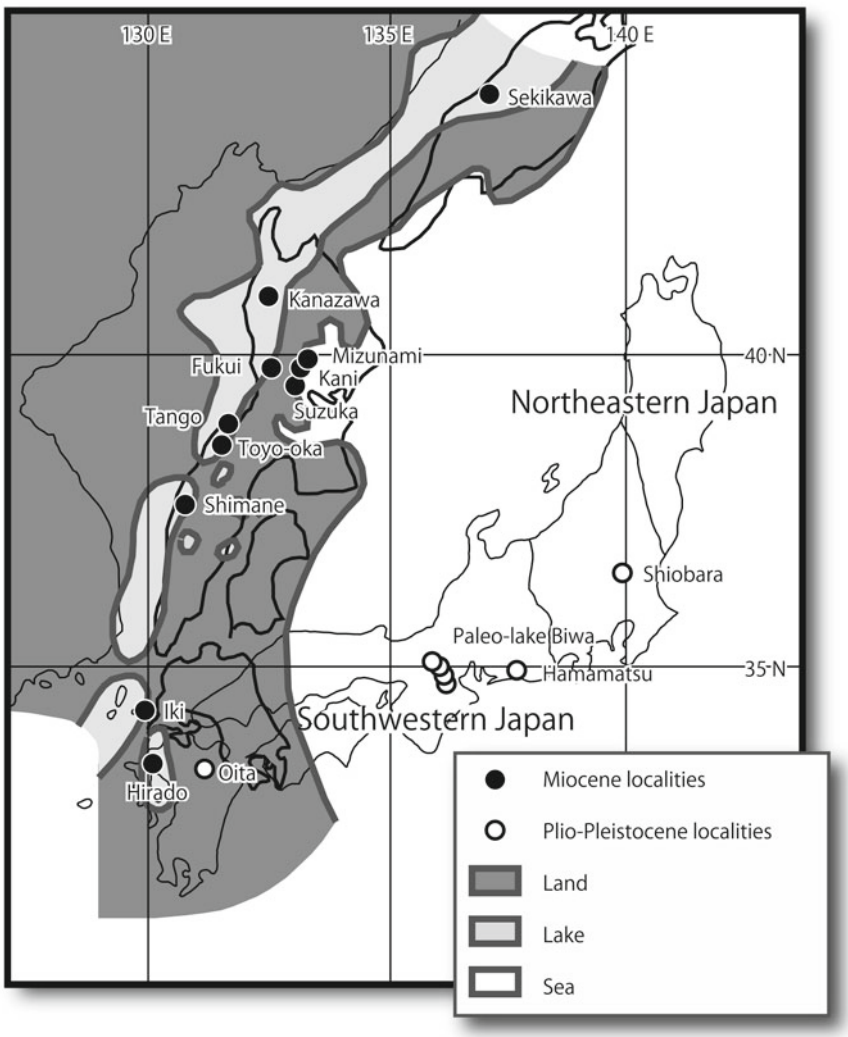

Fig. 2

The lakes in the large rift valley 17 Ma (Modified from Itoigawa and Shibata 1993) and cyprinid fossil localities. Fine lines show present coastline. Fossiliferous localities of Miocene sediments are plotted at locations before the rotation of the Japanese archipelago and those of Plio-Pleistocene at present locations.

The paleomagnetic data suggests that the Japanese archipelago was the marginal part of the continent until the Early Miocene. Southwestern Japan, thereafter, started to rotate clockwise while northeastern Japan started to rotate counterclockwise to reach the present location about 14 million years ago, as shown in *Fig. 2*. During the Late Paleogene to the Early Miocene, a large rift valley was formed between the continent and the Japanese archipelago (Otofuji and Matsuda 1984). Wide distribution of freshwater sediments indicates that several large lakes were formed there. Such a large-scale geological activity seems to have generated new environments in the marginal part of the continent, different from those in inland areas. Such unique environments might have provided preferable conditions for the new cyprinid fauna to originate.

In the Middle Miocene, the Japanese archipelago was transgressed by the sea. The rift valley between the continent and Japanese archipelago was expanded by the

rotation of the island arc, resulting in the formation of the Sea of Japan. The transgression was on a large scale in northeastern Japan, while it was comparatively calm in southwestern Japan (Makiyama 1956). Therefore, lands remained in southwestern Japan with freshwater bodies (Shibata 1985), where the cyprinid fauna, although poor, was still able to survive.

During the uplift of the Japanese archipelago in the Late Miocene, southwestern Japan was connected to northeastern Japan and the islands approached their present shape (Minato et al. 1965).

In the Early Pliocene, some sedimentary basins were formed in the Setouchi Geologic Province of southwestern Japan. The sedimentary basin of Paleo-lake Biwa originated as one of them (Itihara 1966). The Miocene cyprinid fauna survived through the ages in southwestern Japan, and the descendants constituted the Iga Cyprinid Fauna that seems to widely inhabit the freshwater bodies in the Setouchi Geologic Province.

Geotectonic History of Lake Biwa

The sedimentary basin where Lake Biwa is currently located originated in the Pliocene from one of the Setouchi basins. Some of the lakes formed in the basins disappeared later, and others suffered transgression. Paleo-lake Biwa did not always remain a stable condition, and it was filled up with fluvial sediments twice during its history. However, the sedimentary basin itself did not suffer transgression, and it had maintained its freshwater condition until today. The history since the formation of Paleo-lake Biwa until the present Lake Biwa was reviewed by Kawabe (1994) and Yoshikawa and Ymasaki (1998), and Satoguchi (2011). The summary is given below.

The sediments deposited in Paleo-lake Biwa and its river systems are widely distributed in the current Lake Biwa area, namely in the Omi and Ueno basins. The strata collectively called the Kobiwako Group can be lithologically divided into eight formations: the Ueno, Iga, Ayama, Koka, Gamo, Kusatsu, Zeze, and Katata Formations in ascending order (see *Fig. 2* in Stoguchi's chapter of this publication). Among these, the Iga and Kusatsu Formations are of fluvial sediments.

The lake formed in the Oyamada area around the Ueno Basin, about 50 km southeast of the present Lake Biwa, is called Paleo-lake Oyamada (3.5–3.1 Ma). During this phase, the lake was shallow under a subtropical climate. The deposits of Paleo-lake Oyamada, forming the Ueno Formation, abundantly contained remains of highly diverse land and freshwater species, such as diatoms, vascular plants, protozoa, sponges, molluscs, fishes, reptiles, and mammals. Composition of the fauna resembles that of the eastern part of the Asian continent, suggesting a geological connection between Mainland China and the Japanese archipelago (Matsuoka 1987). About 3.1 Ma, a huge volume gravel and sand was transported from a northwestern direction by a river inferred to be about 50 km long. Thereby, Paleo-lake Oyamada was filled up and disappeared. The deposition of fluvial sediment since then developed into the Iga Formation. The river waned with time, and a shallow lake again appeared in the Oyamada area, called Paleo-lake Ayama (2.9 Ma). The fauna of Paleo-lake Ayama became poorer than that of Paleo-lake Oyamada, though some of the molluscs and fishes inhabiting Paleo-lake Oyamada had survived (Matsuoka 1987; Nakajima 1986a). The sediments deposited during the period of Paleo-lake Ayama constituted the Ayama Formation.

The sedimentary basin moved northward, and the lake became remarkably deeper (2.6 Ma). This deep lake is called Paleo-lake Koka, representing one of the stable phases of Paleo-lake Biwa. Its sediments are contained in the Koka Formation. The predominant diatom changed from the species complex of *Aulacoseira praeislandica* in Paleo-lake Ayama to *A. solida* in Paleo-lake Koka (Tanaka and Matsuoka 1985), which reflects a drastic change in the aquatic environment. The fauna of Paleo-lake Koka is characterized by a low density of littoral molluscs (Matsuoka 1987) and the dominance of crucian carp among fishes (Nakajima 1986a).

The area covered with the sediments of Paleo-lake Oyamada, Ayama, and Koka was uplifted, and sedimentary basin migrated further to the north, occupying the southern half of the present Omi Basin (2.2 Ma). This movement made the lake smaller and shallower, generating many swamps and lakes. These lakes, called Paleo-lakes Gamo, were very unstable. From two to one million years ago, the Suzuka Mountains were uplifted in the east of the basin. Extensive erosion of the mountains supplied a huge volume of gravel and sand into the lakes, which again created a fluvial environment at the basin. Paleo-lakes Gamo, responsible for the deposition of swampy sediments presently found in the Gamo Formation, thereby disappeared, and fluvial sediments found in the Kusatsu Formation began to deposit (1.8 Ma).

A small and shallow lake was formed in the Otsu and Katata area on the south and southwest side of present Lake Biwa (1.4 Ma). This lake, Paleo-lake Katata, was surrounded by swamps, whereas the area of the present Lake Biwa was still occupied by fluvial environments. Some of the existing endemic molluscan species appeared in Paleo-lake Katata (Matsuoka 1987). Then, the lake gradually

expanded (0.4 Ma). During this environmental change, the molluscs increased in number and variety, and many other existing endemic species emerged (Matsuoka 1987). Upon the strata, the sediments with a different lithoface, named Ryuge sand and gravel layer, the most upper part of the Katata Formation, was deposited. The lithoface indicates that elevation of the present Hira and Hiei Mountains became active on the west side of the lake (Hayashi 1974). During the Middle to Late Pleistocene, fault activities along the lake shore became intense, generating a plain at the deep bottom of the lake (Ithihara 1982). Such activities formed the new open and deep offshore habitat and the new littoral rocky habitat. On the emergence of such habitats, the endemic fishes speciated to utilize and exploit their respective habitats. A series of sediments above, constitute the Biwako clay bed, the most upper part of the Katata Formation.

Temporal succession of cyprinid fauna in Paleo-lake Biwa

Paleo-lake Biwa was formed about 4 million years ago. The history from the formation of Paleo-lake Biwa until the present Lake Biwa is divided into the following phases: Paleo-lake Oyamada, the first fluvial phase; Paleo-lake Ayama, Paleo-lake Koka, and Paleo-lakes Gamo, the second fluvial phase; and Paleo-lake Katata and Lake Biwa, the third fluvial phase. There was a change in the cyprinid fauna at each phase.

As mentioned previously, the Iga Cyprinid Fauna found in the Ueno Formation, the sediments of Paleo-lake Oyamada, consists of six subfamilies. Cyprinines were dominant, which were followed by xenocypridines and cultrines. Common carps of the genus *Cyprinus* occupied 65% of all the fossil teeth of cyprinids, indicating its predominance in Paleo-lake Oyamada (Nakajima 1986b).

The fossil molluscs from the Ueno Formation were dominated by viviparid gastropods, such as *Igapaludina stricta* and *Bellamya suzukii* (Matsuoka 1987). The abundance of fossil diatoms assumed that the diatom productivity in Paleo-lake Oyamada was fairly high (Tanaka et al. 1984). The diatom flora probably supported the xenocypridines and molluscs in the lake. The abundance of viviparid gastropods indicates the presence of rich littoral flora of submerged plants and benthic and epiphytic diatoms. The rich benthic community might have supported the most dominant fish, the common carp, which are typically benthivorous.

Fewer fossil molluscs were found in the Ayama and Koka Formations. The littoral molluscs, *Igapaludina*, *Tulotomoides*, and *Inversidens*, were low in diversity. The profundal molluscan association containing *Anodanta* (*Plesioanodonata*) *matajiroi* predominated (Matsuoka 1987). Characteristics of the diatom flora as well as the molluscan fauna of the Ayama and Koka Formations indicated that the lake was oligotrophic to mesotrophic with a wide profundal zone and a narrow littoral zone. Further, the species complex of *A. praeislandica* dominates over other species in the Ayama Formation, whereas *A. solida* predominates in the Koka Formation. The change in the diatom composition reflects the change of the aquatic environment of the lake from Paleo-lake Ayama to Paleo-lake Koka. Probably, the lake became significantly deeper (Tanaka and Matsuoka 1985). The number of fossil cyprinids found from the Ayama and Koka Formations was also fewer than those from the Ueno Formation. They consisted of only three subfamilies: cyprinines, cultrines, and xenocypridines (Yasuno 1983; Nakajima 1986b). Nearly all fossil teeth found from the Koka Formation were teeth of crucian carp, *Carassius*, which seemed to have dwelled in the upper zone of the offshore water as plankton feeders adapted for oligotrophic open water.

The cyprinid fauna in Paleo-lakes Gamo was slightly richer than that of Paleo-lake Ayama and Koka. It consisted of three subfamilies, cyprines, xenocypridines, and acheilognathines. The genus *Carassius* decreased in composition of the fossil assemblage (Nakajima 1986b). Among the fossil diatoms, *Melosira undulate* was the dominant species in the lower Gamo Formation, but no fossil diatoms were found in the upper Gamo Formation (Tanaka and Matsuoka 1985). The fossil molluscs of the Gamo Formation were quite different at the species level from those in the older formations. Thickened bivalves accounted for a large part of the fossil molluscs. They inhabited streams rather than lakes (Matsuoka 1987). Many fossil wood beds are intercalated in the upper part of the Gamo Formation. These findings indicated the presence of unstable shallow waters of swamps in the later stage of Paleo-lakes Gamo.

In the Katata Formation, the diatom fossils were represented by the assemblage of *Fragilaria*, *Gomphonema*, *Cymbella*, and *Achnathes*. The composition of species did not change through the formation. The diatom assemblage predominated by these benthic species suggests that Paleo-lake Katata presumably was not a stable lake (Research Group for Natural History of Lake Biwa 1986). Paleo-lake Katata was a small and shallow lake and located in the Katata area on the southwest shore of present Lake Biwa. Some of the present endemic molluscan species first appeared in the early stages of Paleo-lake Katata. They were *Heterogen longispira* and *Unio* (*Nodularia*) *biwae*. In

the upper part of the Katata Formation, the fossil molluscs became more abundant and various, and many present endemic species appeared (Matsuoka 1987). This faunal change might indicate that the lake gradually opened up in its later stages. The richness of cyprinid fauna in Paleo-lake Katata was second to that of Paleo-lake Oyamada. They consisted of cyprinines, xenocypridines, cultrines, leuciscines, and gobionines. Most of the teeth belonged to extinct species that seem to be the ancestral forms of the present endemic species, *Ischikauia steenackeri* and *Carassius cuvieri*, found from the upper part of the Katata Formation (Research Group for Natural History of Lake Biwa 1986).

Appearance of the Endemic Species and Extinction of Old Elements of Iga Cyprinid Fauna

Three taxa of the crucian carps, *C. cuvieri*, *C. auratus grandoculis*, and *C. auratus langsdorfi*, inhabit the present Lake Biwa. The first two are endemic to the lake but their food habits and habitats are different from each other. The pharyngeal teeth differ, reflecting respective food habits. The pharyngeal teeth of *C. cuvieri* are remarkably distinctive. Its enameloid layer is the thinnest among the three taxa, and the dentine is composed of two layers, the outer orthodentine and the inner vasodentine. The interglobular dentine is developed in the outer part of dentine. The structure of pharyngeal teeth in *C. cuvieri* is adaptive for phytoplankton feeding (Kodera 1985).

Regarding the fossil teeth from the uppermost part of the Katata Formation, the vasodentine is not seen, and the enameled layer is very thin and the interglobular dentine widely occupies the central part of the dentine layer (Kodera 1985). The fossil teeth of the Katata Formation are the prestage of those in *C. cuvieri*, from which the *C. cuvieri* in modern Lake Biwa probably has evolved.

The environments of modern Lake Biwa, with an open and deep offshore and rocky shore, are utilized by most of the present endemic fishes (e.g., *Gnathopogon caerulescens*, and *C. cuvieri*), which have not been found in Paleo-lake Katata. In the uppermost part of the Katata Formation, the Ryuge sand and gravel layer, the change of the lithofacies indicates that the elevation of the Hira and Hiei Mountains was actualized (Hayashi 1974). The faults along the shore of the lake were active, and the deep bottom plain of the lake was formed during the Middle to Late Pleistocene (Ithihara 1982). The northern part of Lake Biwa was formed after sedimentation of the Katata Formation about 400,000 years ago. Most of the endemic fishes speciated in the lake when the open and deep offshore environment was developed.

Xenocypridines and cultrines were major elements of the cyprinid fauna in Paleo-lake Biwa. They are flourishing in China at present; however, they are extinct in the Japanese archipelago except for *I. steenackeri*. Why have they become extinct?

Xenocypridines are bottom dwellers in large, calm rivers, and shallow large lakes. They mainly feed on attached algae with horny lips and specialized pharyngeal teeth (Yang 1964). The Japanese osmerid "ayu fish," *Plecoglossus altivelis*, is amphidromus, and it has adapted to torrential rivers, which also feeds on attached algae. The ayu fish, of which an ancestral form has been found from the Miocene sediment (Tomoda 1985), seems to have evolved during the Pliocene to the Pleistocene in the Japanese archipelago. Thus, the ayu fish or its ancestral form seems to have coexisted with xenocypridines from the Miocene to the Pleistocene.

In the Pleistocene, the mountains were rapidly uplifted and basins were subsided in the Pleistocene by the Island Arc Movement (Fujita 1973). Thereby, rivers became torrential, and large lakes disappeared except for Lake Biwa. Consequently, the freshwater bodies in the Japanese archipelago became unsuitable for the xenocypridines. Moreover, Lake Biwa became deeper in the Middle to Late Pleistocene (Ithihara 1982), and landlocked population of the ayu fish flourished in the lake (Kawanabe 1976), which competed with the xenocypridines for food. Meanwhile, attached algae decreased around the same time.

Most cultrines are also adapted to large, calm rivers and large, shallow lakes. Its extinction also seems to be closely related to the tectonic movements in the Japanese archipelago during the Pleistocene. The environments of Lake Biwa with an open and deep offshore and rocky shore, utilized by most endemic fishes, were also developed along with these tectonic movements. From these, it is concluded that the speciation of endemic species in Lake Biwa and the extinction of the major elements of Iga Cyprinid Fauna, such as xenocypridines and cultrines, have occurred only recently in the history of Lake Biwa.

Fish Remains from Archaeological Sites Around Lake Biwa

Some of the xenocypridines and cultrines, however, survive in Lake Biwa with mankind in the Jomon Period (13,600–900 BC). Their tooth remains found in Jomon archaeological sites (Nakajima et al. 1996, 2005; Nakajima 1997). Why did they become extinct then? Did the Jomon people eat them up? Jomon people were not supposed to have such advanced fishing techniques.

The xenocypridines and cultrines, which survived in the Jomon Period but became extinct before present, were littoral zone dwellers not able to inhabit the offshore of deep lakes. After settling down around Lake Biwa, people's life gradually became highly associated with the lake, and it started to affect the coastal environments since the Jomon Period. The people began to cultivate rice in paddy fields in wetlands around the lake in the Yayoi Period (900 BC–300 AD). The expansion of paddy fields around the lake seems to have been profitable for fish in the lake, because many spawning and nursery sites were formed. However, the artificial environmental change on the lakeshore might have been fatal rather than beneficial to relict fish species whose population kept on dropping.

Thus, those fishes that survived the drastic change of lake's environment during the Middle to Late Pleistocene encountered mankind in the Jomon Period and have become extinct before present. The extinction of a fish species other than xenocypridines and cultrines recently occurred at another archaeological site. The extinction of many littoral fish of Lake Biwa is supposed to be resulted from human activities.

Conclusions

The analysis of the fossil data drew the following conclusion. The new elements of cyprinid fauna, such as xenocypridines and cultrines, evolved in the large rift valley lakes formed at the eastern margin of the Asian continent during the Late Paleogene to Early Miocene, which then spread to inland China. The Miocene cyprinid fauna continued to survive in southwestern Japan, and their descendants inhabited Paleo-lake Biwa. Xenocypridines and cultrines were major elements of the cyprinid fauna in Paleo-lake Biwa, which nearly became extinct due to drastic change of the environments. This was caused by the tectonic movements during the Pleistocene, which also resulted in the expansion of Lake Biwa forming its open and deep offshore environments. Such environmental change also brought the speciation of endemic fishes in Lake Biwa. It is only recently in the history of Lake Biwa that the speciation of the endemic fishes and extinction of xenocypridines and cultrines occurred. Some of them survived until recently in the lake but became extinct due to the influence of human activities.

Topic 2 Fossil Biwa Catfish, *Silurus biwaensis*, from Paleo-lake Biwa

Midori Kobayakawa

Three species of the catfish genus *Silurus* are found in Japan, and two of the three, *Silurus biwaensis* and *S. lithophilus*, are endemic to the Lake Biwa basin (Kobayakawa 1989). What time and from where did they invade into Lake Biwa?

Noteworthy fossils of silurid fish were collected in Hata, Ueno, and Mie prefecture, Japan, by Mr. S. Okuyama (Kobayakawa and Okuyama 1994). They were all from the same sediments, the lowest part of the Kobiwako Groups that estimated to have piled between 3.15 and 3.4 Ma (Kawabe 1989). Fragments of skull, vertebrae with Weberian apparatus, pectoral spine, and cleithrum were found from the same area in the same horizon.

Are they parts of a single species or not? Characteristics of all parts of fossils coincided with those of existing *S. biwaensis*: gentle curve of mesethmoid anterior margin, small granules on the anterior surface of pectoral spine, the larger angle with the vertical and horizontal parts of cleithrum, sparse large teeth on the premaxillary tooth plate, and sharp angle formed by the left and right wings of parasphenoid (*Fig. 1*). No other fossil catfish was found from the same sediment, except for bagrids. It has come to the conclusion that the silurid fossils from Hata were a single species, *S. biwaensis*.

S. biwaensis, which grows sometimes more than 1 m, is the biggest fish in recent Lake Biwa, and is no exaggeration to hold the top of ecological niche there. Its habits seem to be well adapted to offshore ecology of recent Lake Biwa. Based on the width of the mesethmoid, the fossil *S. biwaensis* was estimated about 55 cm in standard length. The food and habit might be different from recent *S. biwaensis*, because the environment of Paleo-lake Biwa at that time seemed to be marshier without offshore area where the food fish species for the catfish were different from recent ones (Nakajima 1989).

The phylogenetic relationships of *Silurus* species, based on the morphology, show that *S. biwaensis* is more closely related to recent Chinese species *S. meridionalis* than *S. asotus*, which is widely distributed in the East Asia, both

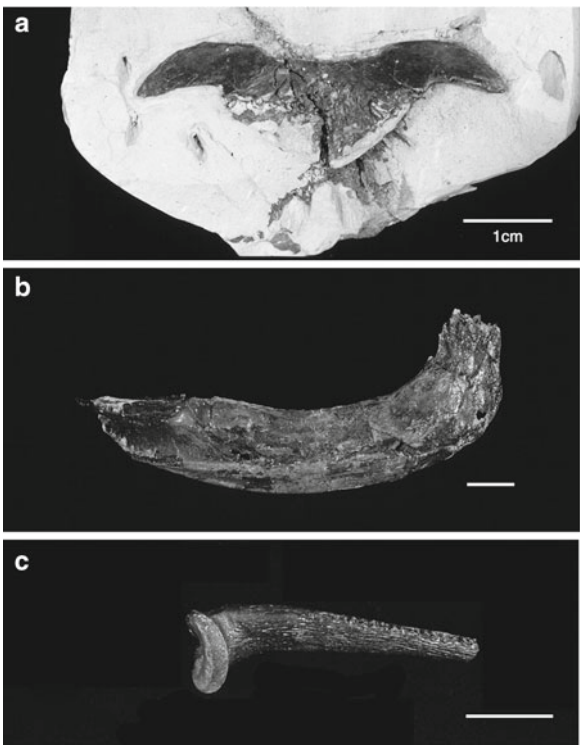

Fig. 1
Fossil *Silurus biwaensis* a: mesethmoid, b: left cleithrum, c: left pectoral spine.

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Japanese islands, and China. Even if the food ichthyofauna changed, *S. biwaensis* has survived since Pliocene changed its habit supported by sufficient food fishes in Paleo-lake Biwa (Nakajima 1989).

Many silurid pectoral spines were excavated from Awazu shell mound of the Jomon Period (ca. 5,000 years ago). Interestingly, small granules, which were a characteristic of *S. biwaensis*, were found on the anterior surface of all the pectoral spines excavated there. People at that time seemed to utilize *S. biwaensis* enthusiastically, but it is still a question when another endemic silurid, *S. lithophilus*, appeared in Lake Biwa.

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2 Biodiversity of Lake Biwa

Machiko Nishino

Biodiversity Survey in Lake Biwa

It was Mori (1970) that first listed the animal and plant species of Lake Biwa. The list was revised twice and Mori and Miura (1990) finally listed a total of 1190 taxa, including 55 species of water birds. However, as their earlier lists published in 1970 and 1980 were devoid of any accounts, figures or citations, and citations in the revised list in 1990 was based only on the newly described or recorded species in the subsequent studies, their reliability was questioned. Since late 1980s, intensive faunal surveys were conducted of the lake and its adjacent areas, with detailed taxonomic examination for Oligochaeta (Ohtaka and Nishino 1995, 1999), Cladocera (Tanaka et al. 2004), Ostracoda (Smith and Janz 2008, 2009), Cyclopoida (Ishida 2002), Harpacticoida (Ishida and Kikuchi 2000), Trichoptera (Tanida et al. 1999) and Chironomidae (Sasa and Kawai 1987; Kawai et al. 2002b), etc.

During the course of these surveys, two new genera and about 60 new species were described from the lake for the first time. For example, two new genera, *Apocarchesium* (Ji and Kusuoka 2009) and *Levicoleps* (Foissner et al. 2008) of Ciliata, 11 diatom species (Mayama et al. 2002; Ohtsuka 2002; Ohtsuka and Tuji 2002; Tuji 2002, 2003; Tuji and Kociolek 2000), a Turbellaria (Timoshkin et al. 2004), a Cestoida (Shimazu 1994), four Nematoda (Gagarin 2000, 2001a, b, 2003), a Nemertea (Chernyshev et al. 1998), eight pleurocerid snails (Watanabe and Nishino 1995), 15 Ostracoda (Smith and Janz 2008, 2009), an Oligochaeta (Martin and Ohtaka 2008), 10 Chironomidae (Sasa and Kawai 1987), and one species respectively of Ephemeroptera (Ishiwata 1996), Trichoptera (Nishimoto 1994), fish (Kawase and Hosoya 2010), and Bryozoa (Hirose and Mawatari 2011). However, several species, such as the new ciliate genera *Apocarchesium*, an oligochaete *Embolocephalus yamaguchii*, and three chironomids *Hydrobaenus biwaquartus*, *Tanytarsus biwatrifurcus* and *Glyptotendipes biwasecundus*, were later found to be also distributed in the localities other than Lake Biwa or synonymized. This means that further examination is required to determine the endemicity of the newly described species.

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Species Diversity in Lake Biwa

As presented in *Table 1*, more than 2300 taxa have so far been reported from the lake and its adjacent areas. The number of aquatic taxa is about 1700, eliminating plants on the shore, reptile and water bird species. Recently, Timoshkin et al. (2011) reported more than 100 newly recorded species from the lake, involving 33 species of Monogenea and two species of Digenea. Number of aquatic alien species is about 40. As parasitic species, as well as some aquatic insects and water mites were not completely counted in this appendix, number of taxa may increase in the future. About 100 taxa have never been found except in Lake Biwa; out of the above taxa, 61 taxa are regarded as endemic at the present time. Among the Japanese freshwater biota so far reported, two-thirds of the freshwater fish taxa, about a half of the submerged and floating water plant species, 40% of the freshwater mollusc taxa and about 20% of Ephemeroptera, 25% of Odonata, 15% of Trichoptera, 15% of Chironomidae, are reported from the lake (Nishino, 2009; Sects. 2.4.4 and 2.4.6).

Among the endemic taxa, four species are planktonic, 40 benthic (two plant and 38 invertebrate taxa), a parasitic and 16 nektonic (*Table 2*). About a half of molluscs (29 out of 56 indigenous taxa) and one-fourth of fishes (16 out of 46 indigenous species or subspecies) are endemic. In other words, endemic species of the lake are mostly characterized by molluscs and fishes. It is noteworthy that the pleurocerid gastropod *Semisulcospira* (*Biwamelania*), composed of 15 endemic species, is considered as a sole species flock of Lake Biwa (Sect. 2.4.4; Nishino and Watanabe 2000).

Nishino and Watanabe (2000) indicated that there was only one endemic genus with a single species, a viviparid snail *Heterogen longispira*, and that most endemic taxa constituted one genus with one or two species. Kondo (2008) regarded an unionid *Oguranodonta ogurae* as endemic genus, though Nishino and Watanabe (2000) doubted the independence of this genus. A protozoa *Leviceps biwae* is another candidate for an endemic genus with a single species, although the newly described protozoan genus,

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Table 1

Numbers of species or taxa found in and around Lake Biwa (Data derived from Appendix 2)

	Total taxa number	Endemic taxa	Endemic ?	Alien species (including escaped, planted and ornamental)	Life form Planktonic (PA), Pleustonic (PE), Benthic (B), Nektonic (N), Parasitic (PR)
Plants on the shore area[a]	565 (7)			171 (4)	PE
protozoa	137		6		PA, B, PR
Bacillariophyceae	65	3			PA, B
Phytoplankton[b]	455				PA, B
submerged macrophytes	53	2		4	B
Porifera	14	1			B
Cnidaria	2				B
"Turbellaria"	29	2		2	B
Trematoda	1			1	PR
Cestoda	3			1	PR
Nemertea	1		1		B
Acanthocephala	10				PR
Rotifera	174				PA, B
Nematoda	47	1	2		B, PR
Mollusca	64	29		8	B
Oligochaeta	49				B, PR
Hirudinea	18	1			B, PR
Cladocera	55	1		1	PA, B
Copepoda	33				PA
Ostracoda	40		16		B.
Branchiura	1				PR
Malacostraca	16	3		4	B, PR
Odonata	54				B
Ephemeroptera	27	1	2		B
Plecoptera	2				B
Hemiptera	3				B, PE
Neuroptera	3				B
Coleoptera	8				B
Chironomidae	158		7		B
Trichoptera	55	1			B
Bryozoa[c]	14			1	B
Fishes[d]	57	16		11	N
Amphibia	19			1	B
Reptilia	16			2	
Aves	177			1	
Total	2423	61	34	206	
Total (excluding terrestrial plants, Reptilia and Aves)	1674	61	34	38	

[a] As three submerged macrophyte species are included, their species number is deleted, and two alien floating plant species in Sect. 3.1.4 (Table 1) are added. The species number of floating plant is in parentheses.

[b] Though the list of phytoplankton includes Bacillariophyceae, only three endemic species are overlapped in that of Bacillariophyceae listed by Dr. Ohtsuka. Thus, three species are deleted in the number of species of the phytoplankton list

[c] After Hirose and Mawatari (2011) and Nishino (1993)

[d] *Plecoglossus altivelis* in Lake Biwa is regarded as endemic in Sect. 2.5 and Appendix 2, but not counted in this list, because its endemicity is not commonly accepted.

Table 2

List of the endemic taxa in Lake Biwa and their designated category in the Red List of Japan (Ministry of Environment) and of Shiga Prefecture (Shiga Prefectural Government)

Taxa	Scientific name	Red List of the Ministry of Environment	Red List of Shiga Prefecture	life form
Bacillariophyceae				
1	*Aulacoseira nipponica*			Planktonic
2	*Stephanodiscus suzukii*			Planktonic
3	*Stephanodiscus pseudosuzukii*			Planktonic
Angiospermae				
4	*Potamogeton biwaensis*		EN	Benthic
5	*Vallisneria biwaensis*			Benthic
Porifera				
6	*Spongilla inarmata*	DD		Benthic
Platyhelminthes				
7	*Macrostomum kawamurai*			
8	*Bdellocephala annandalei*	CR+EN	EN	Benthic
Mollusca (Gastropoda)				
9	*Heterogen longispira*	NT	R	Benthic
10	*Semisulcospira* (*Biwamelania*) *arenicola*	NT	R	Benthic
11	*Semisulcospira* (*Biwamelania*) *decipiens*	NT		Benthic
12	*Semisulcospira* (*Biwamelania*) *dilatata*	DD	EN	Benthic
13	*Semisulcospira* (*Biwamelania*) *fluvialis*	DD	EN	Benthic
14	*Semisulcospira* (*Biwamelania*) *fuscata*	VU	EN	Benthic
15	*Semisulcospira* (*Biwamelania*) *habei*			Benthic
16	*Semisulcospira* (*Biwamelania*) *morii*	NT	R	Benthic
17	*Semisulcospira* (*Biwamelania*) *multigranosa*	NT	R	Benthic
18	*Semisulcospira* (*Biwamelania*) *nakasekoae*	CR+EN	EN	Benthic
19	*Semisulcospira* (*Biwamelania*) *niponica*	NT		Benthic
20	*Semisulcospira* (*Biwamelania*) *ourense*	DD	EN	Benthic
21	*Semisulcospira* (*Biwamelania*) *reticulata*	NT		Benthic
22	*Semisulcospira* (*Biwamelania*) *rugosa*	DD	EN	Benthic
23	*Semisulcospira* (*Biwamelania*) *shiraishiensis*	NT	R	Benthic
24	*Semisulcospira* (*Biwamelania*) *takeshimensis*	NT	R	Benthic
25	*Valvata biwaensis*	NT		Benthic
26	*Radix onychia*	NT		Benthic
27	*Gyraurus biwaensis*	NT		Benthic
28	*Gyraurus amplificatus*		DD	Benthic

(continued)

Table 2
(continued)

Taxa	Scientific name	Red List of the Ministry of Environment	Red List of Shiga Prefecture	life form
Nematoda				
29	*Raphidascaris gigi*			Parasitic
Mollusca (Perecypoda)				Benthic
30	*Anodonta calipygos*	VU	R	Benthic
31	*Cristaria plicata clessini*		R	Benthic
32	*Lanceolaria oxyrhyncha*			Benthic
33	*Inversiunio reinianus*	VU	EN	Benthic
34	*Oguranodonta ogurae*	CR+EN	CR	Benthic
35	*Unio douglasiae biwae*			Benthic
36	*Hyriopsis schlegeri*	CR+EN	CR	Benthic
37	*Corbicula* (*Corbicula*) *sandai*	VU	R	Benthic
38	*Pisidium kawamurai*			Benthic
Annelida (Hirudinea)				
39	*Ancyrobdella biwae*	DD	EN	Benthic
Crustacea				
40	*Daphnia biwaensis*		CR	Planktonic
41	*Kamaka biwae*		R	Benthic
42	*Jesogammarus* (*Annanogammarus*) *annandalei*	NT	R	Benthic
43	*Jesogammarus* (*Annanogammarus*) *naritai*	NT	R	Benthic
Insecta				
44	*Apatania biwaensis*			Benthic
45	*Ephoron limnobium*	DD		Benthic
Pisces				
46	*Salmo (Oncorhynchus) masou rhodurus*	NT	DD	Nectonic
47	*Sarcocheilichthys biwaensis*	CR	CR	Nectonic
48	*S. variegatus microoculus*		R	Nectonic
49	*Squalidus chankaensis biwae*	NT	DD	Nectonic
50	*Gnathopogon carulescens*	CR	EN	Nectonic
51	*Biwia yodoensis*			Nectonic
52	*Ischikauia steenackeri*	EN	CR	Nectonic
53	*Carassius carassius grandoculis*	EN	R	Nectonic
54	*Carassius cuvieri*	EN	R	Nectonic
55	*Silurus biwaensis*		R	Nectonic
56	*Silurus lithophilus*	NT	EN	Nectonic
57	*Gymnogobius isaza*	CR	EN	Nectonic
58	*Cottus reinii*	EN		Nectonic
59	*Rhinogobius* sp. BW[a]	DD		Nectonic
60	*Cobitis* sp. L[a]	EN	CR	Nectonic
61	*Cobitis* sp. S Biwako form[a]	EN	CR	Nectonic

CR; Critically Endangered, EN; Endangered, VU; Vulnerable, NT; Near Threatened, R: Rare, DD; Data Deficient

[a] Though these species have not yet been described as a distinct species, their endemicity is accepted by the ichthyologist.

Apocarchesium, was later found to be also distributed in a locality other than the lake.

On the other hand, there are some species widely distributed in Japan or Asia in which the population from Lake Biwa shows quite different features in morphology or ecological characteristics from those in other localities (Nishino and Watanabe 2000). One example is a caridean shrimp *Palaemon paucidens* and ayu fish *Plecoglossus altivelis* subsp. Both species are widely distributed in Japan and adjacent areas, and females of Lake Biwa bear or lay much smaller and more numerous eggs than those in other populations. Also, they differ from other population genetically.

2.1 Protozoa of Lake Biwa

Yasushi Kusuoka

Abstract Lake Biwa has many protozoa, including numerous ciliates that contain symbiotic algae, a possible result of the lake's long oligotrophic history. The testate amoeba *Difflugia biwae* was considered an endemic protozoan of Lake Biwa for many years, but recent findings in China suggest that it may be more widespread. Discoveries of protozoa from Lake Biwa are still ongoing, and two recent findings include two new genera and species of ciliates: *Levicoleps biwae* and *Apocarchesium rosettum*. The former has so far only been found from Lake Biwa, but the latter has subsequently been found in China and the USA, highlighting the difficulty of identifying truly endemic species of protozoa.

Keywords Protozoa • Ciliata • Endemic Protists • Symbiotic algae

Introduction

Lake Biwa, the largest and oldest lake in Japan, has a history of more than 4 million years since the formation of the original Paleo-lake Biwa, and at least 300,000 years has passed since the formation of the present lake basin (Research Group of the Natural History of Lake Biwa 1994). During this long period, it is considered that this lake had been oligotrophic (i.e., clear water and low productivity; Toyoda 1993) until the recent activities of mankind affected the lake.

Lake Biwa is one of the few lakes of the world in which long-term monitoring of the plankton has continued. The Shiga Prefecture Fisheries Experiment Station has been monitoring the plankton in the north basin of Lake Biwa since 1951 (Shiga Pref. Fish. Exp. Sta. 1952), and the Lake Biwa Environmental Research Institution (previously the Shiga Prefecture Institution of Public Health and Environmental Science) has continued intensive monitoring of the plankton since 1977 (Ichise et al. 2004).

Traditionally, single-celled organisms with animal-like features, such as amoeba and ciliates, have been called protozoa. Recent advances in molecular phylogeny have shown that protozoa are not a single genetic group, but a complex of organisms with similar morphological features originating from different genetic groups (Scamardella 1999). For example, it has been found that ciliates (traditionally placed in protozoa) and dinoflagellates (traditionally placed in algae) belong to the same group, the Alveolata. In this chapter, the traditional term "protozoa" will be used because the phylogenic position of the groups are constantly changing according to new findings, and when considering the functional role and life history of organisms in the lake ecosystem, the concept of protozoa is much better suited.

Although there is a lot of information about Lake Biwa's phytoplankton, there is very little information about its protozoa. The main reason for this is that the shape of most protozoa changes beyond recognition or burst when fixed by formalin or ethanol, and that there are not many taxonomists working on protozoa in Japan. Of the protozoa, *Difflugia biwae* was one of the most frequently recorded species in Lake Biwa until its disappearance (see below). Because of the conspicuous shape of its rigid shell, it can easily be identified to the species level even after it is fixed by formalin or ethanol.

Recently, two new genera and species of ciliates have been described from Lake Biwa (Foissner et al. 2008; Ji and Kusuoka 2009). Some aspects of the newly discovered ciliates and ciliates with symbiotic algae, which characterize Lake Biwa, will be discussed.

Ciliates with Symbiotic Algae

Many ciliates from Lake Biwa and its watershed are green due to inclusions of symbiotic algae, and these ciliates demonstrate various modes of life. For example, carnivorous ciliates such as *Pelagodileptus trachelioides*, *Burselopsis spumosa*, *Didinium* sp., *Monodinium* sp., bacterial feeders

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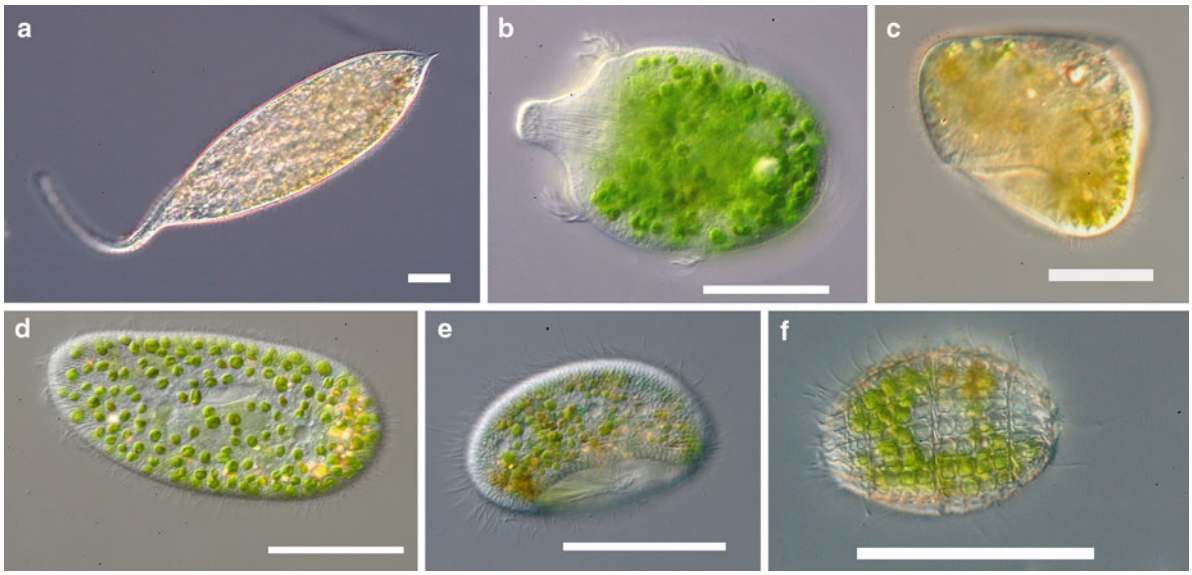

Fig. 1

Some ciliates with symbiotic algae from Lake Biwa. (a) *Pelagodileptus trachelioides*, (b) *Didinium* sp. (c) *Stokesia vernalis*, (d) *Paramecium bursaria*, (e) *Histiobalantium nutans*, (f) *Coleps hirtus viridis*. Live specimens photographed with a differential interference contrast microscope. Bars indicate 50 µm.

such as *Paramecium bursaria* and *Vorticella* sp., algal feeders such as *Histiobalantium natans viridis* and *Strombidium* sp., omnivorous ciliates such as *Stentor polymorphus*, and scavengers such as *Coleps hirtus viridis* have been observed (*Fig. 1*). As algal symbiosis is widespread in various groups found in the lake, this can be considered a characteristic of ciliates of Lake Biwa. So far, there is no evidence that the symbiosis of ciliates and algae evolved in Lake Biwa. However, considering the long oligotrophic (i.e., few nutrients available in the water) history of this lake, and the fact that ciliates with symbiotic algae have higher growth and survival rates under starved conditions (Stabell et al. 2002), it can be assumed that during the long history of Lake Biwa, of the various ciliates that reached Lake Biwa, those with symbiotic algae had a better chance of surviving during periods when food was scarce compared with their asymbiotic counterparts.

Difflugia biwae: A Protozoa Long Believed to Be Endemic to Lake Biwa

Difflugia biwae, a species of testate amoeba (amoeba with shells), was first described by Kawamura (1918). This species is very conspicuous because of its large size (300–400 mm; Kawamura and Hada 1965) and unique shape of its shell. Different from any other species in the genus *Difflugia*, its shell has a wide trumpet-like opening at the anterior end and a long tail-like protrusion at the posterior end (*Fig. 2*). The interesting fact about this species is that while most *Difflugia* species are solely benthic, *D. biwae* has a planktonic stage. According to Negoro (1954a), *D. biwae* was observed in the plankton from July to November and was the most dominant zooplankton species in August 1952 (*Fig. 3*).

For more than 50 years, this species was considered endemic to Lake Biwa (Negoro 1954, Nishino and Watanabe 2000). Unfortunately, no live specimen has been observed from Lake Biwa since October 1981 (Ichise et al. 2004), and there is concern that it is now extinct in the lake. However, in 2005, Yang and Shen reported the existence of *D. biwae* from three lakes in China. At present, it is not certain whether the Chinese and Lake Biwa populations are really the same species, as the shells of the Chinese specimens (165–306 µm in length) are smaller than those of *D. biwae* from Lake Biwa (300–400 µm in length as reported by Kawamura and Hada 1965, and 250–350 µm in length as reported by Ichise et al. 1998). A genetic comparison of the two populations is needed, but unfortunately only formalin-fixed specimens of the Lake Biwa population are available, which are not suitable for DNA analysis.

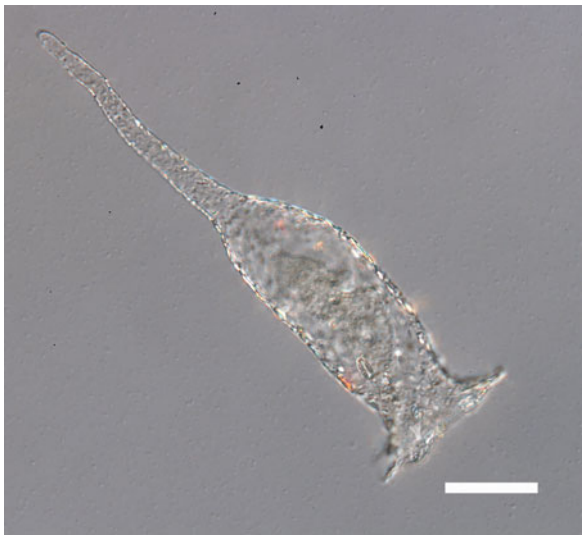

Fig. 2
Shell of *Difflugia biwae*. Fixed specimen photographed with a differential interference contrast microscope. Bar indicates 50 µm.

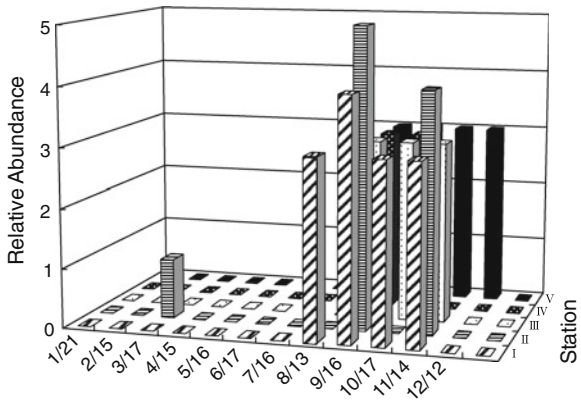

Fig. 3
Relative abundance of *Difflugia biwae* in the year 1952. Original data from Shiga Prefecture Fisheries Experiment Station Report (Figure redrawn from Ichise et al. 2004).

Recently Described Ciliate Species from Lake Biwa

Levicoleps biwae (*Fig. 4*) was described as a new genus and species from Lake Biwa by Foissner et al. (2008). It is a ciliate belonging to the Family Colepidae of the Order Prorodontida, and can be distinguished from other colepids by its lack of posterior armor spines, number of ciliary rows, and multiple caudal cilia. So far, *Levicoleps* has only been reported from Lake Biwa, but we will have to wait until further information concerning the distribution of this species is accumulated until we can determine if it is endemic to Lake Biwa or not.

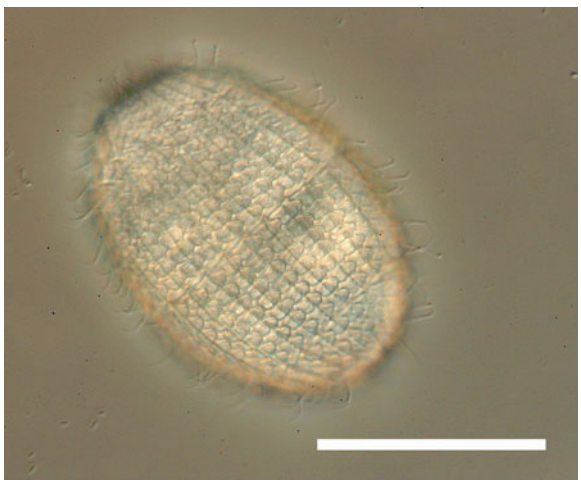

Fig. 4
Photograph of *Levicoleps biwae*. Live specimen photographed with a differential interference contrast microscope. Bar indicates 50 µm.

Fig. 5
***Apocarchesium rosettum* colony, stalk elongated (*left*), and contracted (*right*). Live specimen photographed with a differential interference contrast microscope. Bar indicates 50 µm.**

Apocarchesium rosettum (*Figs. 5* and *6*) was reported as a new genus and species from Lake Biwa in 2009 (Ji and Kusuoka 2009). It is a ciliate in the Family

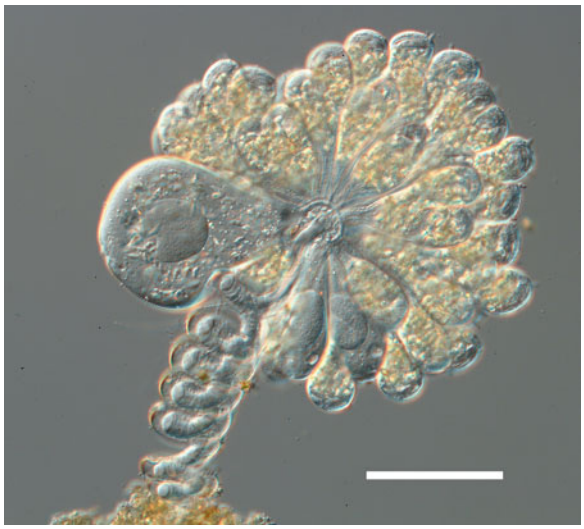

Fig. 6

***Apocarchesium rosettum*, all cells in the colony are attached to the nail-head-like structure at the end of the stalk. Live specimen photographed with a differential interference contrast microscope. Bar indicates 50 µm.**

Vorticellidae of the Order Sessilida in the Subclass Peritrichia. The genus *Apocarchesium* was newly erected for this species because unlike previously described peritrichs, this species is colonial, with an unbranched stalk that contracts spirally, and all cells in the colony are attached to the nail-head-like structure at the end of its single stalk in a rosette fashion. It is quite commonly found in the south basin of Lake Biwa attached to macrophytes in the summertime. Initially, it was thought that this peritrich might be endemic to Lake Biwa or at least to East Asia, because of its very unique shape and common habitat. Had it inhabited Europe or North America where intensive studies of ciliates have been conducted for long periods, it would have been described long ago. However, recently, *A. rosettum* was discovered in Guanzhou, China, and North Carolina, USA (Sun et al. 2011).

A. rosettum collected from China, the USA, and Lake Biwa has very similar sequences of small subunit ribosomal RNA (SSrRNA) (Sun et al. 2011) and can be considered the same species. Furthermore, Norf and Foissner (2010) described a new species of *Apocarchesium* (*A. arndti*) from the River Rhine in Germany, and apart from the fact that *A. arndti* makes microzooids (Norf and Foissner 2010), which have not been observed in *A. rosettum*, the morphology of the two species is very similar. As there is a possibility of synonymy, close comparisons of the morphology and gene sequence of the two *Apocarchesium* species must be made.

Endemism Versus Cosmopolitan in Microorganisms

There is a debate whether microorganisms are cosmopolitan (Finlay 2002, Fenchel 2005), or have restricted distributions (Foissner 2006, 2008). Data on the protozoa from Lake Biwa might make this debate more complicated. As mentioned above, *Difflugia biwae* has long been considered endemic to Lake Biwa, but recently has been reported from China (Yang and Shen 2005). Although the two populations might be different species, they are very closely related, which means that the ancestor of the two populations traveled between China and Lake Biwa. Very recently, a third population of *D. biwae*-like shelled amoeba was found in a lake near Chiang Mai, Thailand (Tuji, personal communication). This could mean that the distribution of *D. biwae* is much more widespread, and it could be found in other locations in Asia.

The distinctive species *Apocarchesium rosettum* and the very similar *A. arndti* have only recently been reported from Lake Biwa, China, the USA, and Germany (Ji and Kusuoka 2009, Norf and Foissner 2010, Sun et al. 2011). These findings show that even very conspicuous organisms can easily be overlooked, so species that are thought to be endemic or with restricted distributions might just be overlooked in other areas and are waiting to be found. On the other hand, as Norf and Foissner (2010) mentions, "If such prominent species (like *Apocarchesium*) escaped researchers for 200 years, then one can imagine that there must be thousands of undiscovered inconspicuous species," so there might be many endemic species yet to be found.

Levicoleps biwae is a colepid so far reported only from Lake Biwa. Endemic colepid genera have been reported from other ancient lakes, such as *Baikalcoleps*, *Kotinia*, *Tiarinella*, and *Macrocoleps* from Lake Baikal (Obolkina 1995), and *Planicoleps* from Lake Tanganyika (Dragesco and Dragesco-Kerneis 1991). With the finding of *Levicoleps* from Lake Biwa, colepid ciliates might be considered important species to study the evolution of endemic species in ancient lakes (Foissner et al. 2008).

It is difficult to come to a conclusion whether endemism occurs in protists or not. However, what is certain is that there are many undescribed protozoa in Lake Biwa waiting to be found, and the study of protozoa in Lake Biwa could shed more light on this debate.

2.2 Characteristics of the Phytoplankton Flora and Long-term Changes in the Phytoplankton Community of Lake Biwa

Shigeo Tsujimura · Satoshi Ichise

Abstract More than 600 species of phytoplankton have been observed in Lake Biwa, and several of these, *Stephanodiscus suzukii*, *Stephanodiscus pseudosuzukii*, and *Aulacoseira nipponica*, are considered to be endemic. Outbreaks of a specific species have often been observed since the 1960s when eutrophication progressed largely in Lake Biwa. *Uroglena* red tides and cyanobacterial blooms have been recorded since 1977 and 1983, respectively. The seasonal succession of the phytoplankton community represented by some dominant species has changed according to the lake's trophic state. Some dominant species before the 1960s, such as *A. nippponica* and *Pediastrum biwae*, have decreased, while *Staurastrum dorsidentiferum* var. *ornatum* has become the dominant species during the last three decades. The highs of the phytoplankton biovolume observed in warm seasons decreased after the 1980s, probably due to the limitation of phosphorus. On the other hand, cyanobacteria, dinophytes, and cryptophytes have shown increasing trends, and the lows of the biovolume in cold seasons are getting higher, probably because they are related with increased water temperatures.

Keywords Phytoplankton • Endemic species • Eutrophication • Seasonal succession • Rotifer

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Introduction

The term "plankton" means organisms that drift or are suspended in water bodies. Thus, plankton are defined by their ecological niche, and they consist of various taxonomic groups regardless of autotrophy or heterotrophy. Plankton play a vital role in aquatic food webs, especially in the pelagic zone. Phytoplankton are the primary producer in the food chain, obtaining their energy by photosynthesis. While they function to sustain aquatic ecosystems, some specific species cause red tides or cyanobacterial blooms by their extraordinary proliferations. Zooplankton live heterotrophically, and they are the primary consumer of the phytoplankton. At the same time, zooplankton are important food resources for higher trophic consumers like fish. This section mainly explains the characteristics of phytoplankton flora and their long-term changes in Lake Biwa. In addition, occurrences of picocyanobacterial blooms are introduced because it seems to be a peculiar event that occurs only in large and deep mesotrophic lakes, like the north basin of Lake Biwa.

Phytoplankton Flora in Lake Biwa

Various types of phytoplankton inhabit Lake Biwa. The former Shiga Prefectural Institute of Public Health and Environmental Science and Lake Biwa Environmental Research Institute have been conducting regular monitoring of the Lake Biwa phytoplankton since 1979, and they have observed over 600 algal species so far. However, taxonomical studies of algal flora are still insufficient to estimate the total algal species living in Lake Biwa. For example, Ito (1988) studied scale-bearing chrysophytes in the south basin of Lake Biwa using a scanning electron microscope, and he reported 42 taxa of this algal group, among which 30 taxa, 17 new to Japan and 13 previously recorded, were newly recorded for Lake Biwa. Thus, rigorous and thorough

surveys focused on specific phytoplankton groups will lead to the finding of many other new records.

Several phytoplankton species that have been reported from Lake Biwa are considered to be endemic. Although the green alga *Pediastrum biwae* with two varieties have been previously described as endemic to Lake Biwa (Negoro 1954), it is unclear if they are endemic because of their morphological variability and resemblance to *Pediastrum simplex*. In fact, *P. biwae* has been reported from various regions and countries since its first description, while *P. simplex* has been recorded from Lake Biwa. The centric diatom *Stephanodiscus carconensis* and its variety *S. carconensis* var. *pusilla*, long regarded as typical Lake Biwa phytoplankton especially in winter, have since been described as new species, *Stephanodiscus suzukii* and *Stephanodiscus psedosuzukii*, respectively (Tuji and Kociolek 2000; Tuji and Houki 2001). These two species, and the centric diatom *Aulacoseira nipponica*, which had previously been identified as *Aulacoseira solida* (Tuji 2002), are considered to be endemic to Lake Biwa (see Topic 3).

Plankton can be classified by their size: picoplankton <2.0 μm, nanoplankton 2–20 μm, microplankton 20–200 μm, macroplankton 200–2,000 μm, and megaplankton >2,000 μm. The phytoplankton community in Lake Biwa is characterized by the dominance of microphytoplankton or phytoplankton forming large colonies, such as the desmid *Staurastrum dorsidentiferum* var. *ornatum* and the diatom *Fragilaria crotonensis* (Tezuka 1984). These relatively large-sized phytoplankton are hardly grazed by zooplankton compared to nanophytoplankton. As a result, the contribution of phytoplankton to the total planktonic biomass in Lake Biwa is quite high compared with those in other large lakes, such as Lake Constance and the Great Lakes of North America. This indicates the low efficiency of energy transfer from phytoplankton to zooplankton in Lake Biwa (Urabe et al. 2002).

Changes in Phytoplankton Communities Through the Process of Eutrophication

While many phytoplankton species have been recorded from Lake Biwa, the pattern of their appearance in a year is quite regular; that is, many species are observed periodically, and several phytoplankton species dominate during certain months or seasons of a year. Negoro (1956) called such a species succession represented by several dominants as a "plankton calendar," and he reported the seasonality of dominant phytoplankton species in the north basin based on surveys of plankton conducted in 1950 and 1952: *Stephanodiscus suzukii* during January–March, *Aulacoseira nipponica* in April, November, and December, *Asterionella formosa* (Bacillariophyceae) in May, *Acanthoceros zachariasi* (Bacillariophyceae) in June and October, *Ceratium hirundinella* (Dinophyceae) in July, and *Pediastrum biwae* in August and September. It could be said that this plankton periodicity was a characteristic of the phytoplankton flora in Lake Biwa before it was affected by anthropogenic eutrophication. The plankton calendar became irregular with the advancement of eutrophication (Negoro 1981; Nakanishi 1984).

Table 1
Significant phytoplankton events in Lake Biwa

1958–1960	Proliferation of *Closterium aciculare* (more than 100 cells/ml) in the north basin
1969–	Musty odors, 2-methylisoborneol (MIB), and geosmin produced by *Phormidium*, *Anabaena*, and *Oscillatoria*
1977–	Occurrence of freshwater red tides caused by *Uroglena americana*
1983–	Occurrence of *Microcystis* and *Anabaena* blooms in the south basin
1989–1991	Extraordinary proliferation of picocyanobacteria (up to 2×10^6 cells/ml)
1994–	Occurrence of *Microcystis* blooms in the north basin
1998–	Occurrence of *Oscillatoria kawamurae* blooms in the south basin
1999–	Occurrence of *Aphanizomenon flos-aquae* blooms in the south basin

Table 1 summarizes some of the significant phytoplankton events in Lake Biwa. The desmid *Closterium aciculare* var. *subpronum* proliferated in the spring of 1958 (Negoro 1960), and seems to be the first reported case of discolored water caused by phytoplankton growth in the north basin. Following the explosive multiplying of *Closterium*, another desmid, *Staurastrum dorsidentiferum* var. *ornatum*, proliferated vigorously from 1961 to 1966 (Negoro 1981). Concerning the identification of *S. dorsidentiferum* var. *ornatum*, Gontcharov et al. (1999) studied its morphological features in detail and concluded that this *Staurastrum* species that grew abundantly in Lake Biwa had been misidentified and was actually *S. pseudosebaldi*. Since the 1960s, many problems caused by phytoplankton proliferation, such as musty odors, red tides, and cyanobacterial blooms, have been reported in Lake Biwa, and eutrophication has become a major concern for the residents and an important social and political issue of the local government (see Topic 7 and Chap. 7). Nakanishi (1984) updated the plankton calendar in the 1970s as follows: *A. nipponica* during January–April and November–December, *A. formosa* in May, *S. dorsidentiferum* var. *ornatum, C. aciculare* var. *subpronum*, and/or *P. biwae* during June–October.

Blooms of Cyanobacterial Picoplankton

Picoplankton consist of planktonic bacteria and some tiny phytoplankton. Picophytoplankton were not recognized until the end of the 1970s, when their biomass was estimated for the first time by using epifluorescence microscopy. Nowadays, it is well known that picophytoplankton are ubiquitously distributed in both marine and freshwater ecosystems, and they play an important role as the primary producers in the food chain, especially in meso- and oligotrophic waters. Nagata (1986) reported the seasonal abundance and vertical distribution of picophytoplankton in Lake Biwa for the first time. According to the report, the cell density of picophytoplankton increased to 10^5 cells/ml during summer and the relative contribution of the <3 µm chlorophyll-*a* to the total chlorophyll-*a* attained was up to 45%.

Blooms of picophytoplankton occurred in the early summer of 1989 and 1990 (Maeda et al. 1992). The water turned a brown-black color, and the Secchi transparency decreased to about 2 m due to the mass development of picophytoplankton. The peak cell densities were more than 10^6 cells/ml in both 1989 and 1990. Globally, this is one of the most prolific growth incidents in a lake reported so far. Three strains (two phycoerythrin-rich and one phycocyanin-rich types) were isolated from the blooms. Kane et al. (1997) studied the strains phylogenetically and clarified that all of them belong to the *Synechococcus* group of cyanobacteria.

Although such extraordinary outbreaks observed in 1989–1991 have not occurred since then, the proliferation of picocyanobacteria are observed during every summer. Wakabayashi and Ichise (2004) studied the distribution of picocyanobacteria in Lake Biwa during 1994–1998, and they showed that the phycoerythrin-rich types dominated in both the south and the north basins, and the distribution of the phycocyanin-rich type was restricted to shallow and eutrophicated areas of the south basin and lakeshore areas of the north basin.

Changes in Phytoplankton Communities in the North Basin of Lake Biwa During the Past Three Decades

The regular monitoring of phytoplankton has been conducted by the former Shiga Prefectural Institute of Public Health and Environmental Science, and the Lake Biwa Environmental Research Institute since 1979. It has clarified the changes in phytoplankton abundances and compositions during the last three decades. Shiga Prefectural Government has endeavored to reduce nutrient loading into the lake after the first major outbreak of a red tide in 1977. As a result, the chlorophyll-*a* concentrations have decreased in both basins of Lake Biwa since the 1980s. Thus, the period is probably positioned as an early stage of oligotrophication.

Table 2 shows the frequency of 15 of the most abundant species of phytoplankton in a pelagic station of the north basin observed twice a month during the last three decades. Compared with the plankton calendar shown by Negoro (1956), some differences are noticeable. *Staurastrum dorsidentiferum* var. *ornatum* has become the dominant species throughout a year. Its biovolume took up more than 40% of the total during the observation period. Although *Acanthoceros zachariasi* had been a dominant species in June and October before the 1960s, the diatom has since almost disappeared. *Pediastrum biwae*, which was a member in the plankton calendar, also shows a gradually decreasing trend (Ichise et al. 2001). This species was the dominant only once during the observation period.

The numbers of species in 1 ml water samples collected from the sampling stations in the north and the south basins have decreased during the last 30 years (*Fig. 1*). Thus, the diversity of phytoplankton species has decreased. *Fig. 2* shows the changes in total biovolume of phytoplankton at the north basin station. The highs of the biovolume observed in warm seasons of a year are getting lower, and the lows in cold seasons are getting higher during the same period. The trend of lower highs is considered to reflect the phosphorus limitation in summers due to the reduction of nutrient loading. The dominance of large-sized green algae, such as *Staurastrum dorsidentiferum* var. *ornatum* and *Closterium aciculare*, is the characteristic of phytoplankton flora in Lake Biwa after the 1960s, but the ratio to total biovolume has decreased in accordance with the decrease in the total biovolume (*Fig. 3*). On the other hand, the biovolumes of cyanobacteria, dinophytes and cryptophytes have been increasing. The proliferation of *Gomphosphaeria lacustris* and *Aphanothece clathrata* are outstanding among cyanobacterial species. The bloom-forming cyanobacteria *Microcystis* spp. have also been observed with increasing frequency in pelagic areas of the north basin. The appearance of *Microcystis* is considered to be brought about by its transportation from inshore to offshore areas by gyres formed in Lake Biwa (Ishikawa et al. 2002). The increases of dinophytes and cryptophytes contribute to the increasing trend of the phytoplankton biovolume in cold seasons. Some other algae, like the desmid *Staurastrum arctiscon*, also increased during these periods, while *Aulacoseira*

Table 2

Seasonal successions of dominant phytoplankton species in a pelagic station of the north basin of Lake Biwa during the last three decades

	Month (number of observations)																							
	Jan		Feb		Mar		Apr		May		June		July		Aug		Sept		Oct		Nov		Dec	
Species	(28)	(30)	(29)	(30)	(30)	(28)	(30)	(30)	(30)	(28)	(30)	(30)	(30)	(29)	(30)	(29)	(29)	(30)	(30)	(30)	(29)	(29)	(30)	(29)
Cyanophyceae																								
Gomphosphaeria lacustris														3	2		1	1	1	1				
Chrysophyceae																								
Uroglena americana								1	8	17	3													
Bacillariophyceae																								
Aulacoseira nipponica		1		2	3	2		2																
Stephanodiscus suzukii	4	4	3	3	4	5	4	2	2		1		1	1						1	1		3	3
Stephanodiscus pseudosuzukii	3	2	2	2	2	3	3	2			1	2											2	2
Fragilaria crotonensis	2	1	1	2	3		4	4	3	1	4	2											1	1
Cryptophyceae																								
Cryptomonas sp.	2	3	4	5	1	3	2	1	2	2			1					1					3	2
Dinophyceae																								
Gymnodinium helveticum		2	4	5	5	3	4	2	1															1
Ceratium hirundinella		1	1	1			1		1		1	3	1			1			2			1		2
Chlorophyceae																								
Planktosphaeria sp.			1								2	1	3	1			2	1	1			1	2	1

Coelastrum cambricum													1	2	2	4	4	3	2	1	1	1	1	
Zygnematophyceae																								
Mougeotia sp.		1					2	1	1		5	3		1	1			1						
Closterium aciculare var. *subpronum*	2	2			1	3	4	5	5	4	7	11	8	2	1							1		
Staurastrum arctiscon	3	2	4	1	2	2		1		1	1	1	2	2	1			2	2		1	2	4	4
Staurastrum dorsidentiferum var. *ornatum*	10	10	7	6	7	3	2	1	3	2	5	7	11	15	18	20	18	19	20	26	25	19	13	10

Figures indicates the number of times each species was recorded as dominant in biovolume during surveys conducted twice a month from 1979 to 2008

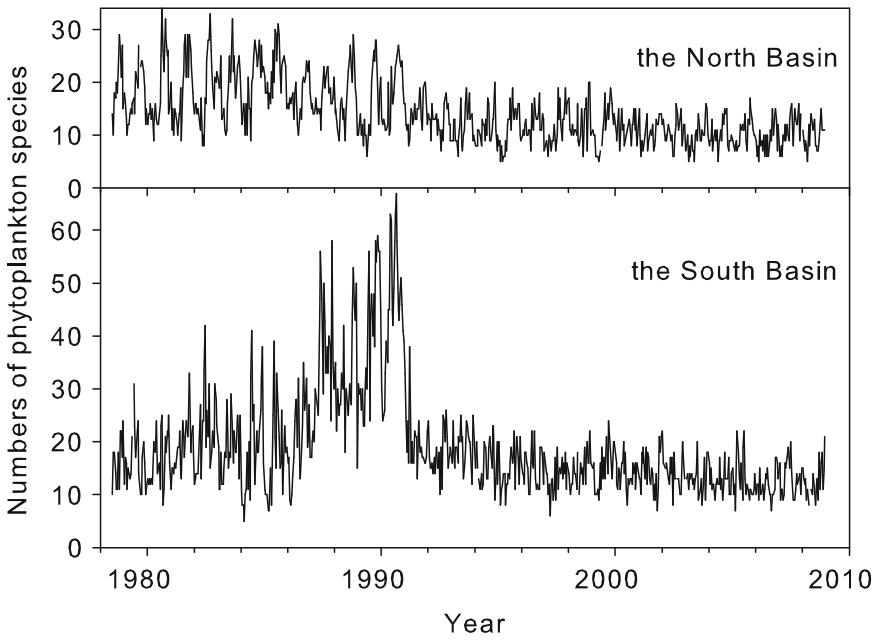

Fig. 1
Changes in the numbers of phytoplankton species in 1 ml water samples taken from stations in Lake Biwa.

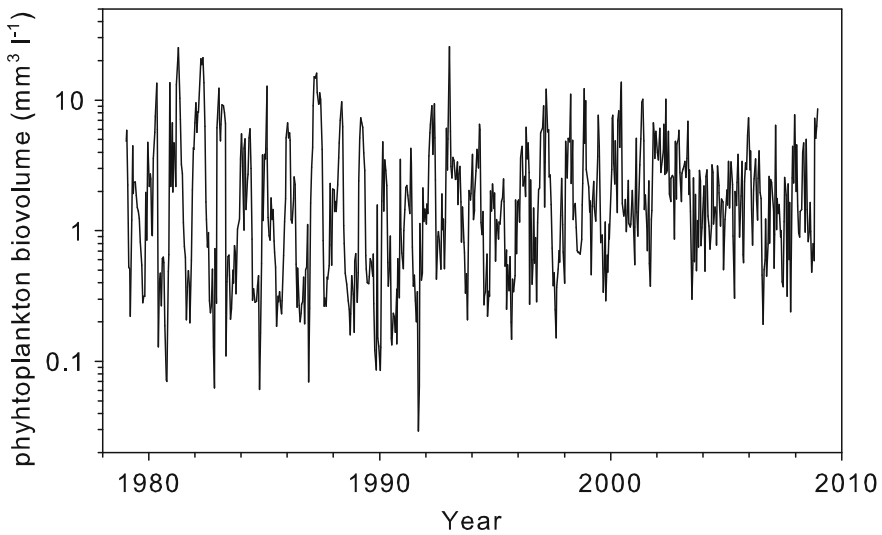

Fig. 2
Changes in phytoplankton biovolume in a pelagic station of the north basin of Lake Biwa.

nipponica tended to decrease. Another species of *Aulacoseira*, *Aulacoseira granulate*, has been proliferating frequently in recent years. Tsugeki et al. (2010) reconstructed the phytoplankton communities of the twentieth century by analyzing algal remains and fossil pigments in the sediments of Lake Biwa. Their study also showed the decrease of *A. nipponica* after 1980, while *Fragilaria crotonensis* became dominant. The changes in the phytoplankton community in cold seasons are probably related with an increase in water temperatures and weaker vertical mixing (Tsugeki et al. 2010).

Characteristics of the Rotifer Fauna of Lake Biwa

Zooplankton mainly consist of protozoa trt, rotifers, and crustaceans. Since the protozoa and the crustaceans in Lake Biwa are discussed in Sects. 2.1 and 2.4.5, respectively, the characteristics of the rotifer fauna are briefly reported here. The density of rotifers increased during the process of eutrophication. The density of rotifers observed was under 10^2/l in the 1920s, but increased to 10^2/l in the 1960–1970s. The density had exceeded 10^3/l in the late 1970s, and peaked

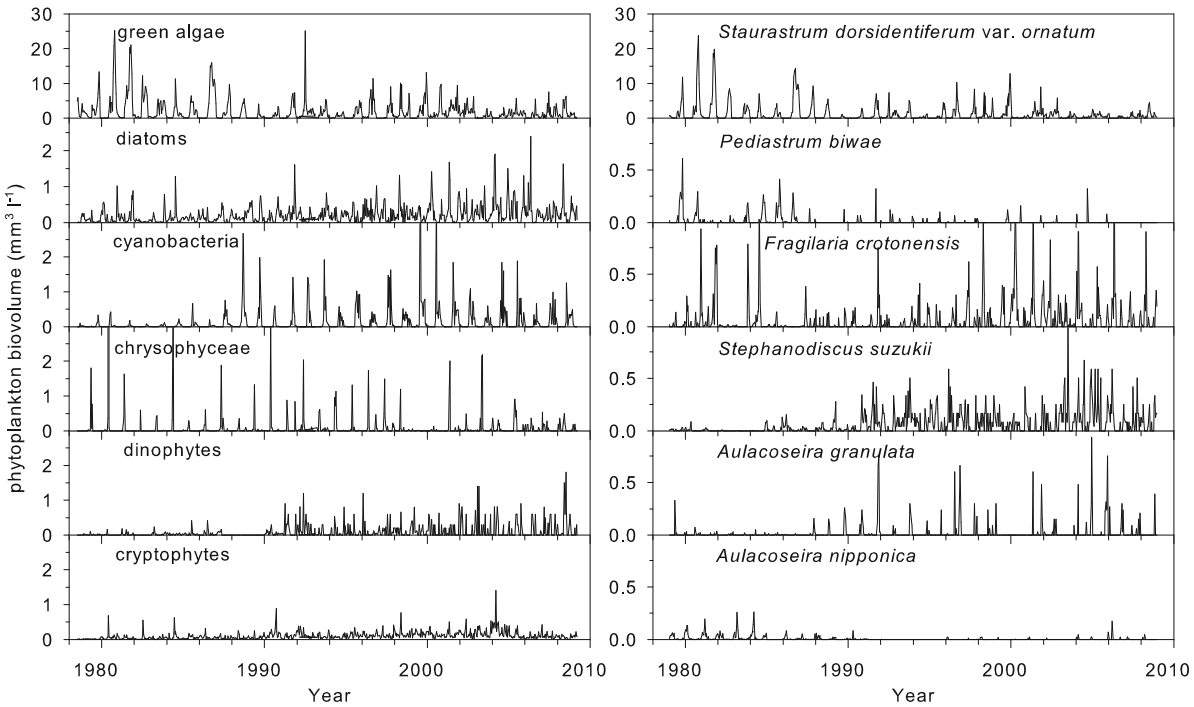

Fig. 3

Changes in the biovolumes of algal taxa and some representative species (two green algae and four diatoms) in a pelagic station of the north basin of Lake Biwa.

in the 1990s. About 80 species of rotifers have been recorded from Lake Biwa. Most of them are cosmopolitan species of oligo- to mesotrophic lakes in the temperate zone, and no endemic species has been recorded from Lake Biwa (Matsubara 1996). *Polyarthra vulgaris* is the dominant species among the rotifers in Lake Biwa. *Polyarthra vulgaris* and *Synchaeta stylata* are observed throughout a year. *Kellicottia longispina* and *Notommata* sp. dominate during April to June, and *Hexarthra mira*, *Trichocerca birostris*, and *Keratella cochlearis* are often observed in summer, and sometimes dominate the rotifer community (Ichise et al. 1998).

2.3 Submerged and Waterside Plant Changes

Etsuji Hamabata

In Lake Biwa, the growth environment of the waterside plants changed a lot after World War II. In Lake Biwa, many swamps and *Naikos* (attached lakes or lagoons) were reclaimed as agricultural land and many aquatic plant habitats were lost. Moreover, the lake and the wet lowland were divided by the construction of banks in the paddy field zones. During the economic growth period subsequent to the 1960s, the north basin changed from being oligotrophic to being mesotrophic, and the south basin changed from being mesotrophic to being eutrophic. In accordance with the eutrophication of the water quality, the dominant species of submerged macrophytes changed from the small rosette type *Vallisneria asiatica* var. *biwaensis*, suitable for oligotrophy, to the large-sized *Hydrilla verticillata*, *Potamogeton maackianus*, and *Elodea nuttallii*. In the south basin, where marked eutrophication occurs, submerged plants hardly existed except near to strandlines. Under these circumstances, the serious shortage of water in the summer of 1994 occurred and the submerged macrophyte beds in the south basin began to recover, with an improvement in the transparency of the water and its quality. However, since the submerged macrophytes are too thick now, it is necessary to find the appropriate measures required for submerged macrophyte management. The serious shortage of water also affected the floating-leaved plants near the shoreline. *Paspalum distichum* and *Paspalum distichum* var. *indutum*, which were introduced into Lake Biwa before the serious shortage of water, covered the strandlines of many lakesides after the shortage, and, as a result, floating-leaved plants, such as *Nymphoides peltata*, rapidly decreased. In addition to these species, the alien species *Alternanthera philoxeroides* was first found at Jinjyo-numa pond, Hikone, in 2004, and *Gymnocoronis spilanthoides* in the east side of the South Basin, near Yabase, Kusatsu, in 2007. These alien species are posing a problem by threatening the native species.

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2.3.1 Submerged Macrophyte Flora and its Long-term Changes

Etsuji Hamabata · Yoshihito Yabu'uchi

Abstract The growing conditions of the submerged macrophyte communities in recent years in Lake Biwa can be divided into three stages: until the 1960s, from 1960 to 1993, and from 1994 onwards. During the first stage, the north basin was oligotrophic, the south basin was mesotrophic, and the dominant species of the submerged macrophyte was the endemic species, *Vallisneria asiatica* var. *biwaensis*. During the second stage, the lake eutrophicated, and the alien species *Elodea nuttallii* and *Egeria densa* invaded and increased dominantly, while the native species decreased. In the southern part of the lake, where marked eutrophication occurs, submerged plants hardly existed. During the most recent stage, after the serious shortage of water in the summer of 1994, the submerged macrophyte bed in the south basin began to recover and there was an improvement in the transparency of the water and its quality. The so-called regime shift of the ecosystem took place mainly around the south basin.

Keywords Submerged macrophyte • Flora • Endemic species • Dominant species • Distribution • Growth environment

Introduction

Submerged macrophyte communities are greatly influenced by eutrophication in lakes. In addition, many swamps in Japan were reclaimed as agricultural land during and after World War II. In the case of Lake Biwa, the coastal areas became the object of reclamation and the areas of *Naikos* (attached lakes), which had been 29 km^2 in the 1940s, decreased to 4 km^2 in 2005 (Nishino and Hamabata 2005). As a result, much of the shallow water areas, which were habitats of the submerged macrophytes, were lost. After that, during the economic growth period subsequent to the 1960s, with the eutrophication in the lake and the associated decline in transparency, the distributive water depth of the submerged macrophytes became shallow and its growth water width decreased. Furthermore, owing to the serious shortage of water in the summer of 1994, when the water level became the lowest level ever recorded since the commencement of water level monitoring in 1874, the submerged macrophyte bed in the south basin recovered, bringing an improvement in transparency, and causing a dramatic change in the ecosystem centered in the south basin. Here, we will mainly discuss the change in the floristic composition of the entire Lake Biwa region, leaving the topic of the change in the submerged macrophyte beds in the south basin after 1994 to be discussed in Sect. 7.2.3.

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Submerged Macrophyte Flora

There have been many reports heretofore concerning the distribution of submerged macrophytes in Lake Biwa [Maeda (1910), Yamaguchi (1943), Ikusima et al. (1962), in addition, Ikusima (1966), Nagai (1975), Kunii et al. (1985), Hamabata (1991), Japan Water Agency (2009)]. *Table 1* lists the names of the submerged macrophyte species mentioned in the above reports. According to the periods when these reports were written, species names differ, so it is not clear whether the same species are being talked about or not, and consequently it is not possible to clarify the exact number of species, although at least 53 kinds of submerged macrophytes have been reported so far. In recent years, the identification of charophytes has progressed, so they are listed as numbers 1–9 in *Table 1*. The authors have also added to the table species, which have been confirmed through field surveys centered around the north basin. There are four kinds of species: *Potamogeton panormitanus*,

Table 1

List of the submerged macrophytes recorded in Lake Biwa

Year of survey		–1910	1935–1943		1953	1962–1965	1974	1982–1983		1986–1987	1997–1998	2002	2007	2006–2009	
Reference number		1	2		3	4	5	6		7	8	8	8	9	
Surveyed site (L: Lake Biwa; N: Naikos [attached lakes])		L	L	N	L	L	L	L	N	L	L	L	L	L	N
	Species name (Japanese name)														
1	*Chara* spp. (Shajikumo spp.)	○	○		○										
2	*C. braunii* (Shajikumo)										○	○	○		
3	*C. corallina* var. *corallina* (Oushajikumo)											○	○		
4	*Nitella* spp. (Furasukomo spp.)		○		○					○			○		
5	*N. flexilis* var. *flexilis* (Himefurasukomo)												○		
6	*N. hyalina* (Otomefurasukomo)										○	○	○		
7	*N. gracillima* var. *robusta* (Onihinafurasukomo)											○			
8	*N. mucronata* (Sakibosofurasukomo)										○				
9	*N. rigida* var. *rigida* (Onifurasukomo)											○	○		
10	*Potamogeton natans* (Ohirumushiro)														○
11	*P. fryeri* (Futohirumushiro)			○											
12	*P. distinctus* (Hirumushiro)	○		○				○						○	
13	*P. malainoides* (Ainokohirumushiro)		○												
14	*P. nipponicus* (Sasaebimo)		○	○			○								
15	*P. octandrus* (Hosobamizuhikimo)			○						○	○	○	○		
16	*P. octandrus* var. *miduhikimo* (Mizuhikimo)			○											
17	*P. perfoliatus* (Hirohanoebimo)	○	○	○	○	○	○			○	○	○	○		
18	*P. dentatus* (Gashamoku)			○	○										
19	*P. malaianus* (Sasabamo)		○	○	○	○	○	○	○	○	○	○	○		
20	*P. crispus* (Ebimo)	○	○	○	○	○	○	○	○	○	○	○	○		

21	*P. oxyphyllus* (Yanagimo)	○		○				○			○	○	○		
22	*P. maackianus* (Senninmo)		○	○	○	○	○	○		○	○	○	○		
23	*P. oxyphyllus*× *P. maackianus* (Yanagimo×Senninmo)									○					
24	*P. leptocephalus* (Hirohanosenninmo)									○	○	○	○		
25	*P. biwaensis* (Sannenmo)		○		○	○				○	○	○	○		
26	*P. panormitanus* (Tsutsuitomo)													○	
27	*P. pectinatus* (Ryunohigemo)			○											
28	*P. anguillanus* (Oosasaebimo)		○					○		○	○	○	○		
29	*Najas marina* (Ibaramo)	○	○	○	○	○	○	○		○	○	○	○		
30	*N. oguraensis* (Ootorigemo)			○						○	○	○	○		
31	*N. minor* (Torigemo)	○	○	○		○									
32	*N. foveolata* (Hirohatorigemo)			○											
33	*N. graminea* (Hossumo)		○	○	○										
34	*Blyxa japonica* (Yanagisubuta)						○								
35	*B. ceratosperma* (Subuta)	○													
36	*Vallisneria denseserrulata* (Kougaimo)	○	○	○	○	○	○	○	○	○	○	○	○		
37	*V. asiatica* (Sekishoumo)	○		○	○		○								
38	*V. asiatica* var. *biwaensis* (Nejiremo)		○		○	○	○	○		○	○	○	○		
39	*Hydrilla verticillata* (Kuromo)	○	○	○	○	○	○	○		○	○	○	○		
40	*Elodea nuttallii* (Kokanadamo)					○	○	○	○	○	○	○	○		
41	*Egeria densa* (Ookanadamo)						○	○	○	○	○	○	○		
42	*Ottelia alismoides* (Mizuoobako)	○		○							○	○			
43	*Schoenoplectus lineolatus* (Himehotarui)										○	○	○		
44	*Cabomba caroliniana* (Hagoromomo)						○	○	○	○	○	○	○		
45	*Ceratophyllum demersum*(Matsumo)	○	○	○	○	○	○	○	○	○	○	○	○		
46	*C. demersum* var. *quadrispinum* (Goharimatsumo)		○	○										○	
47	*Ranunculus nipponicus* var. *submersus* (Baikamo)	○		○											

(continued)

Table 1
(continued)

Year of survey		–1910	1935–1943		1953	1962–1965	1974	1982–1983		1986–1987	1997–1998	2002	2007	2006–2009	
Reference number		1	2		3	4	5	6		7	8	8	8	9	
Surveyed site (L: Lake Biwa; N: Naikos [attached lakes])		L	L	N	L	L	L	L	N	L	L	L	L	L	N
	Species name (Japanese name)														
48	*Elatine triandra* (Mizohakobe)			○											
49	*Myriophyllum verticillatum* (Fusamo)	○	○	○	○		○								
50	*M. spicatum* (Hozakinofusamo)	○	○	○	○	○		○		○	○	○	○		
51	*M. oguraense* (Oguranofusamo)			○											
52	*M. ussuriense* (Tachimo)			○											
53	*M. aquaticum* (Oofusamo)		○				○	○	○						
Total number of species		16	21	29	17	13	17	16	8	20	24	26	26	3	1
			36					35							

1) Maeda (1910); 2) Yamaguchi (1943); 3) Ikushima (1962); 4) Ikushima (1966); 5) Nagai (1975); 6) Kunii et al. (1985); 7) Hamabata (1991); 8) Japan Water Agency (2009); 9) Hamabata & Yabuuchi (in this survey)

Fig. 1
***Vallisneria asiatica* var. *biwaensis*.**

Fig. 2
***Potamogeton biwaensis*.**

P. natans, *P. distinctus*, and *Ceratophyllum demersum* var. *quadrispinum*. The first two species mentioned above are cited for the first time in Lake Biwa and the last two species are the species that had not been found for a long period of time. *P. panormitanus* is widely distributed in the shallow water area off the coast of Kohoku-cho, Nagahana on the northeast side of the north basin. Moreover, when samples of the fruits of the *C. demersum* were taken in the above-mentioned place in August–September 2009, since most had five spines, we considered these samples to correspond to *C. demersum* var. *quadrispinum*. As a result of the authors surveying the habitat of *P. natans*, based on the advice given by Mr. Shinji Fujii (University of Human Environments), we were able to confirm that this species grows in the *Naikos*, into which cold water flows, on the west coast of the north basin. Furthermore, although *P. distinctus* is sparsely distributed in some rivers of the eastern north basin, and not recorded in Lake Biwa since the beginning of 1980, the authors confirmed its growth in one of the small river mouths in Tazuke-cho, Hikone. When we added the above-mentioned four species to the table, the total number of submerged macrophytes growing in Lake Biwa and *Naikos* in recent years increased to 35 (27 species of submerged macrophyte of higher plants and 8 species of charophyta). In the table, two kinds of endemic species, *Vallisneria asiatica* var. *biwaensis* (*Fig. 1*) and *Potamogeton biwaensis* (*Fig. 2*) (see color page 5), and four kinds of alien species, *Elodea nuttallii*, *Egeria densa*, *Cabomba caroliniana*, and *Myriophyllum aquaticum*, are included. In addition, the table includes *Potamogeton dentatus*, which resembles *Potamogeton lucens*, but this species is thought to be extinct now, with no evidence of collection over the last 50 years.

Table 2
Dominance order of submerged macrophyte in Lake Biwa in 1953

Spieces names (Japanese name)
1. *Vallisneria asiatica* Miki var. *biwaensis* Miki (Nejiremo)
2. *Hydrilla verticillata* Casp. (Kuromo)
3. *Vallisneria denseserrulata* Makino (Kogaimo)
4. *Ceratophyllum demersum* L. (Matsumo)
5. *Potanogeton maackianus* Benn. (Senninmo)
6. *Myriophyllum verticillatum* L. (Fusamo)
7. *Najas major* All. (Ibaramo)
8. *Potamogeton malaianus* Miq. (Sasabamo)
9. *Vallisneria asiatica* Miki. (Sekishomo)
10. *Myriophyllum spicatum* L. (Hozakinofusamo)
11. *Potamogeton crispus* L. (Ebimo)
12. *Potamogeton perfoliatus* L. (Hirohanoebimo)
13. *Potamogeton biwaensis* Miki (Sannenmo)
14. *Najas graminea* Del. (Hossumo)
15. Potamogeton dentatus Hagstr. (Gashamoku)
16. *Chara* spp. (Shajikumo spp.)
17. *Nitella* spp. (Furasukomo spp.)

Changes in Dominant Species

Ikusima et al. (1962) shows the dominance ranking of the submerged macrophyte on the basis of the 1952 survey before eutrophication (*Table 2*). Hamabata (1991) conducted a diving survey at 208 points throughout 1986 and 1987, during the ongoing process of eutrophication, and clarified the frequency ranking (*Fig. 3a*).

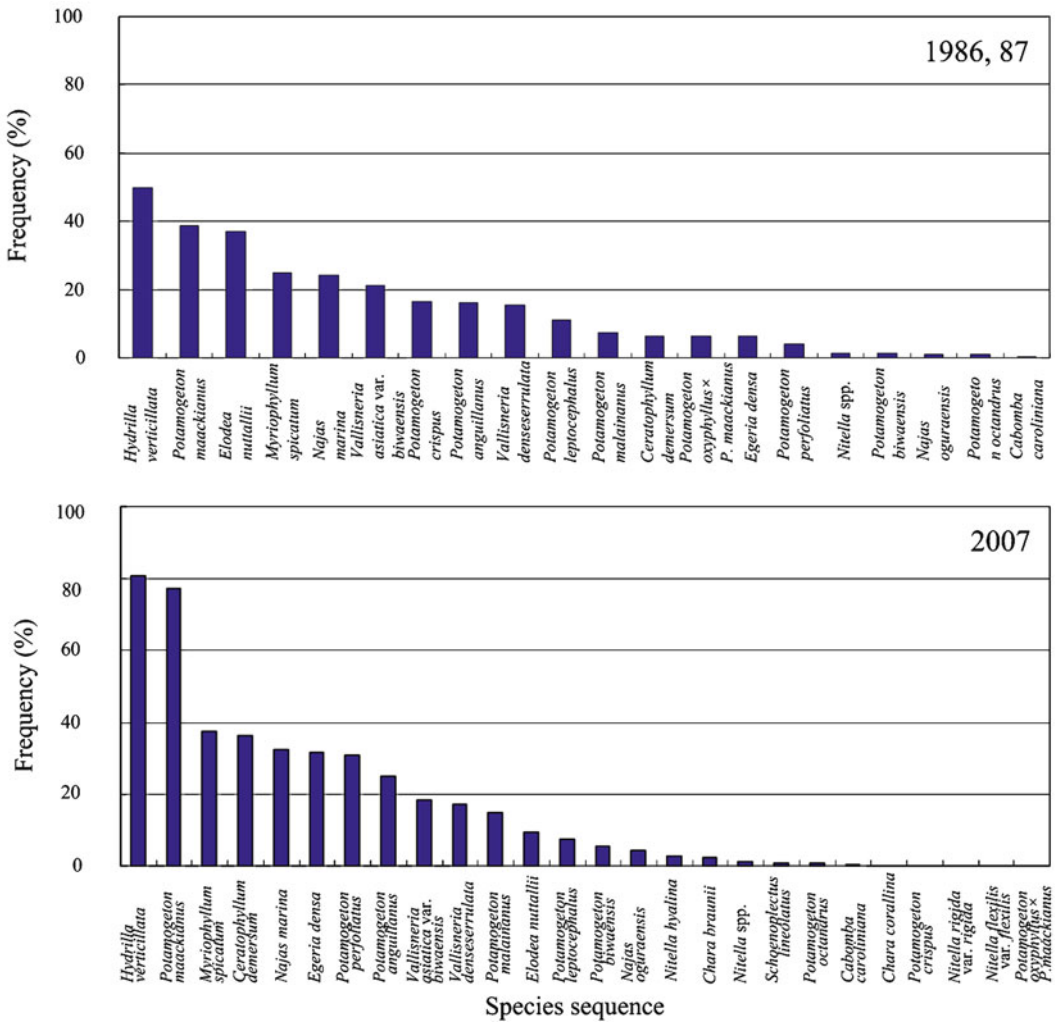

Fig. 3

Frequency of species in descending order of frequency in 1986 and 1987 (a: *upper*), and in 2007 (b: *lower*).

Furthermore, the Japan Water Agency (2009) conducted a substantial diving survey in 1997 and 1998, and subsequently in 2002 and 2007, after the submerged macrophyte bed began to recover following the serious water shortage in 1994. During these surveys, 109 survey starting points were stipulated around the lake shore (*Fig. 4* in Sect. 7.2.3), transect lines were drawn as far as the macrophyte continued into the lake, quadrats—2-m wide and 10-m long—were prepared along the transect lines, and the submerged macrophytes were surveyed length by length by scuba diving. The total number of survey quadrats for each year amounts to around 7,000. The changes in frequency of occurrence are shown in *Fig. 3b*. Before the eutrophication in the 1960s, the dominant rosette type in *Table 2* was *V. asiatica* var. *biwaensis*. But this species became the sixth species in *Fig. 3a*, and *Hydrilla verticillata*, *Potamogeton maackianus*, and *E. nuttallii*, which have long stems, became the dominant species in the mid-1980s (*Fig. 3a*). *H. verticillata* and *P. maackianus* were the dominant species in *Fig. 3b*, with *E. nuttallii* decreasing and becoming the 12th. In addition, since *P. biwaensis* and *Potamogeton leptocephalus* are seldom found, they are thought to be in the process of becoming extinct. Although the latter species has even been recorded in Unagi-ike Pond in Kagoshima Prefecture in 1923 (Osaka Museum of Natural History 1978), it has been extinct in this pond since then, and this species' present habitat is only Lake Biwa, making it very valuable.

Distribution and Growth Environment

The influence of waves differs largely by the position and the water depth in the case of big lakes like Lake Biwa. The northwesterly wind is strong during the winter in Lake Biwa, and the north basin east coast, where the fetch lengthens, receives the strongest waves. There is comparatively little influence from the northwesterly wind on the west coast and on Minami-hama, which is the leeward of Anegawa River's river mouth. Moreover, since there is little influence from waves because the water is deep, a schematic diagram like *Fig. 4* can be drawn. Hamabata (1991) clarified that the habitat was divided into the native macrophyte species and the alien species corresponding to the influence of the waves. The east central shore of the north basin received the strongest northwest wind, except for the area close to Miyaga-hama beach on the leeward of Okishima Island, Omihachiman, where a submerged macrophyte bed is not found (A in *Fig. 4*). Native species began to appear gradually in deeper water where the influence of the wind becomes weaker (B, C), and *E. nuttallii* appears in the weaker areas (D). This alien species can grow even when the water is shallow in the areas where the wind is the weakest (E). The schematic diagram of the community sections from the 1980s is shown in *Fig. 5*. The decrease in the area of *E. nuttallii* is dramatic and it has been replaced now by *P. maackianus* or *H. verticillata*.

There are differences in the dormancy form of native species and alien species. *Hydrilla* have seeds and tubers or turions and *P. maackianus* have seeds and strong underground stem systems, but *Elodea*, found only as male plants in Japan (Kunii 1984), have no dormant organs like seeds, and have spread solely by vegetative propagation, reproducing from the stems from the previous year (Kunii 1984; Hamabata 1997). Their resistance to wave action differs. Toward the end of summer, the shoots of floating masses of detached *Elodea* sink again and settle somewhere on the bottom. Viable shoot tips lying on the bottom may continue to grow for some time during the autumn and over the winter months. Therefore, *Elodea*, in order to photosynthesize, make their habitats in highly transparent water areas where light reaches to the bottom of the lake. Moreover, since the water at the sites where *Elodea* grows is calm, mud accumulates thickly, becoming nutritious substrate. It is generally thought that this species obtains nutrients mainly from the substrate, with the number of stems being about 5,000/m^2 and the standing stock being about 700 g dry weight/m^2 in years when the conditions, as stated in Hamabata (1997), are good. *Elodea* can make a high-density community in the mud substrate and also excels in movement ability. Native species, which have special wintering organs, are able to inhabit places influenced by waves. From the above, it can be concluded that the alien species and the native species inhabit different areas of waters (Hamabata 1991).

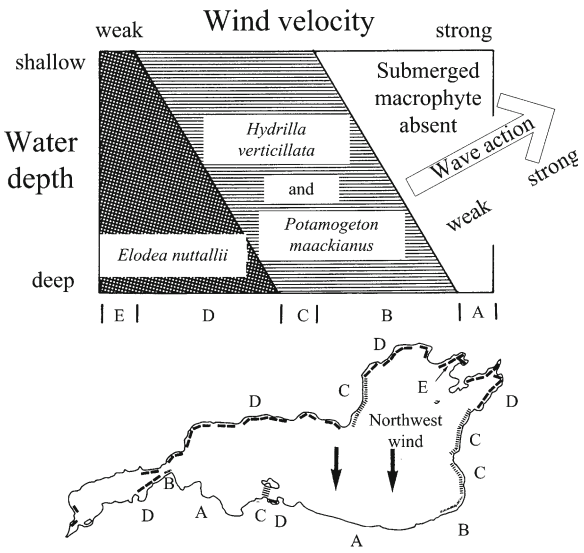

Fig. 4
Diagram showing the distribution of the three most dominant species in relation to prevailing wind direction, wave action, and water depth.

Conclusion

Water plants were harvested from the lake and *Naikos* until the 1950s as fertilizer for agriculture in the form of water plants, causing the wide-scale removal of nutrients from the lake to the land. However, chemical fertilizers were widely used after the 1960s, leading to a disuse of submerged macrophytes. In addition, land reclamation of *Naikos*, which performed the role of deposit ponds, proceeded, with many *Naikos* being lost. With the use of chemical fertilizers, and the furthering of economic activities, the north basin changed from being oligotrophic to being mesotrophic, and the south basin changed from being mesotrophic to being eutrophic, starting in the 1960s and continuing to the early 1970s. In accordance with the eutrophication of the water quality, the dominant species of submerged macrophytes also changed from the small *V. asiatica* var. *biwaensis*, suitable for oligotrophy, to the

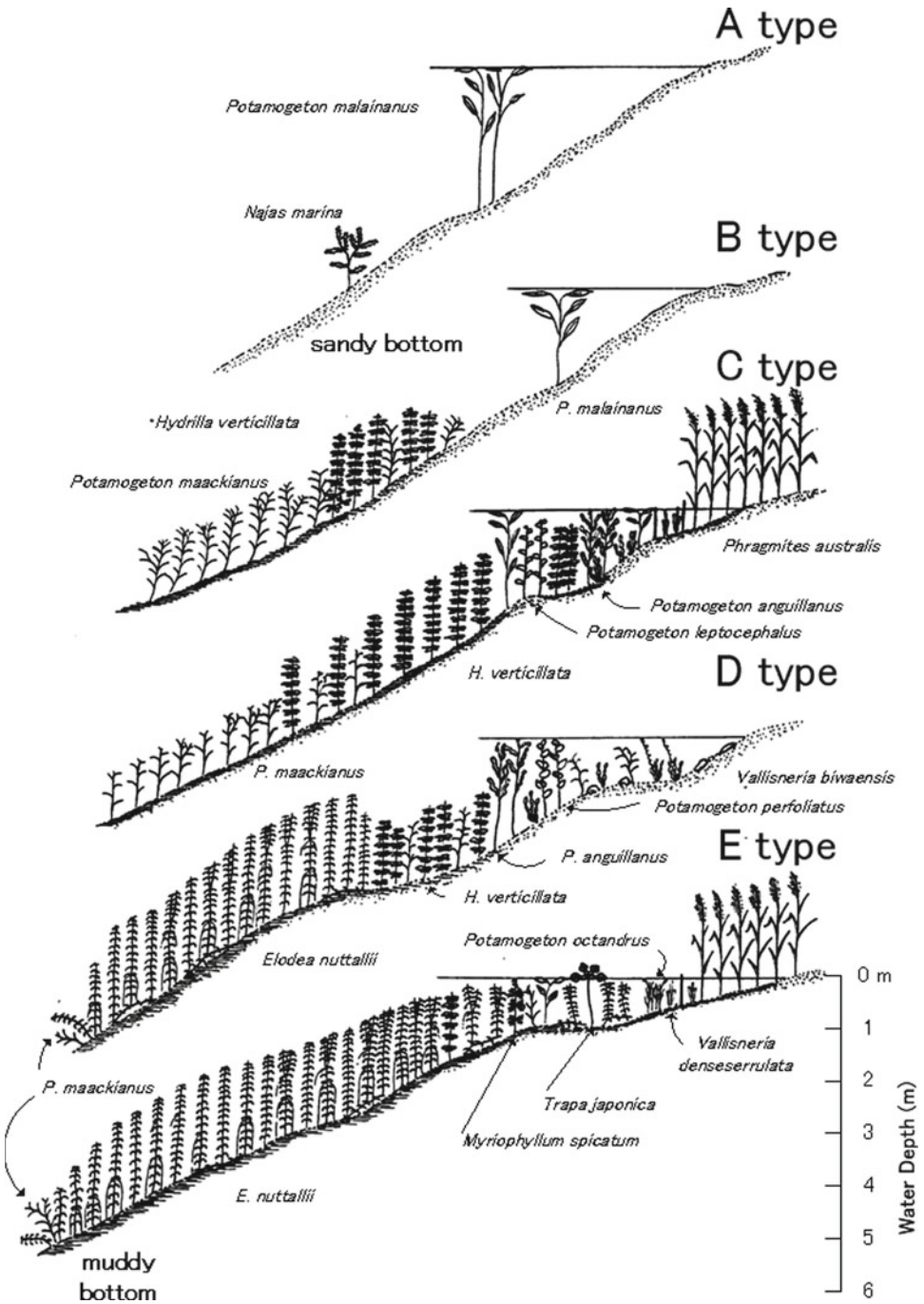

Fig. 5

The community profile of the submerged macrophyte in each lake shoreline area in 1980s (Fig. 4: A–E).

large-sized *H. verticillata*, *P. maackianus*, and *Elodea*. After the serious shortage of water in the summer of 1994, the submerged macrophyte bed in the south basin began to recover and there was an improvement in the transparency of the water and its quality. The species composition of the native species hardly changed after the 1980s, but the alien species *Elodea* decreased dramatically. Although it is not clear why the *Elodea* decreased, the serious shortage of

water in the summer of 1994 happened during the luxuriant growth stage of the native species when the *Elodea* was dormant. Moreover, the water level declines, which occurred frequently after that served as an environment which was not desirable for *Elodea* which prefer a calm environment.

Acknowledgments

We appreciate Associate Professor Lynne Misaki (University of Shiga Prefecture) for her critical reading of an earlier version of the manuscript.

2.3.2 Wetland Plants Growing on the Shore of Lake Biwa: Littoral, Hygrophyte, and Psychrophyte Floras

Shinji Fujii · Yuko Kaneko

Abstract The wetland flora of Lake Biwa is characterized by three major groups: littoral plants, "Genya" plants (rare hygrophytic plants), and psychrophyte relicts. The abundance of inland beaches and wet meadows around the lake provides some explanation of the distribution of such species within suitable habitats. In particular, the area's large-scale floodplains may have contributed toward the high diversity of rare genya and psychrophyte plants. Molecular analyses may further clarify the historical basis for the lake's flora. The psychrophytes in attached lakes are more diverse than those in the main lake area itself. This suggests the importance of the attached lakes for the persistence of these types of plants. Development along the shores, such as reclamation, embankments and road construction, beach restoration, and residential development, has threatened these three important plant groups.

Keywords Flora • Genya plant • Littoral plant • Hygrophyte • Psychrophyte • Sandy beach • Wet meadow

Introduction

Lake Biwa and its surroundings contain a wide variety of habitats and geographical features. Diverse shorelines with vast numbers of rivers and small lakes or marshes characterize the area. Sand or gravel beaches, rocky shores, muddy marshes, wet meadows, and swamp forests are typical natural habitats. The attached lakes, known in Japanese as naikos, are of particular importance as hot spots of wetland species diversity. The wetland flora of Lake Biwa is unique and is categorized into three major groups: 1) littoral plants growing in the sea coast habitats, 2) "Genya" plants, defined by Umehara and Kuribayashi (1991) as rare hygrophytic (growing in wet or moisture habitats) plants with distributions that are concentrated around large water systems such as Lake Biwa and the Yodo River, and 3) psychrophyte relicts inhabiting in cool temperate or subarctic climates. The presence and abundance of each of these relates to the habitats and/or history of Lake Biwa. Littoral plants have been well studied since the nineteenth century (Kitamura 1968); however, the recognition of genya plants and psychrophytes as major floral elements did not occur until after the 1990s (Umehara and Kuribayashi 1991; Fujii 1994b, 2009). Therefore, there is little quantitative information of historical change for the latter two groups. Here, a floristic review on wetlands is conducted and primary threats to shore plants are discussed.

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Inland Species Richness of Littoral Plants

Shores of Lake Biwa are particularly distinctive, as they are inhabited by an abundance of littoral plants (Kitamura 1962, 1968; Fujii 1994b; Murase 2007; Fujii 2009). Characteristic littoral species include *Dianthus japonicus* Thunb. (Callyophyraceae), *Tetragonia tetragonioides* (Pall.) Kuntze (Aizoaceae), *Arabidopsis kamchatica* (DC.) K. Shimizu et Kudoh subsp. *kawasakiana* (Makino) K. Shimizu et Kudoh, *Raphanus sativus* L. var. *hortensis* Backer f. *raphanistroides* Makino (Brassicaceae), *Lathyrus japonicus* Willd. (Leguminosae), *Calystegia soldanella* (L.) R.Br. (Convolvulaceae), *Vitex rotundifolia* L.f. (Verbenaceae), and *Carex scabrifolia* Steud. (Cyperaceae). Lake Biwa has the richest littoral flora of any Japanese inland water system. Most of the littoral species grow in

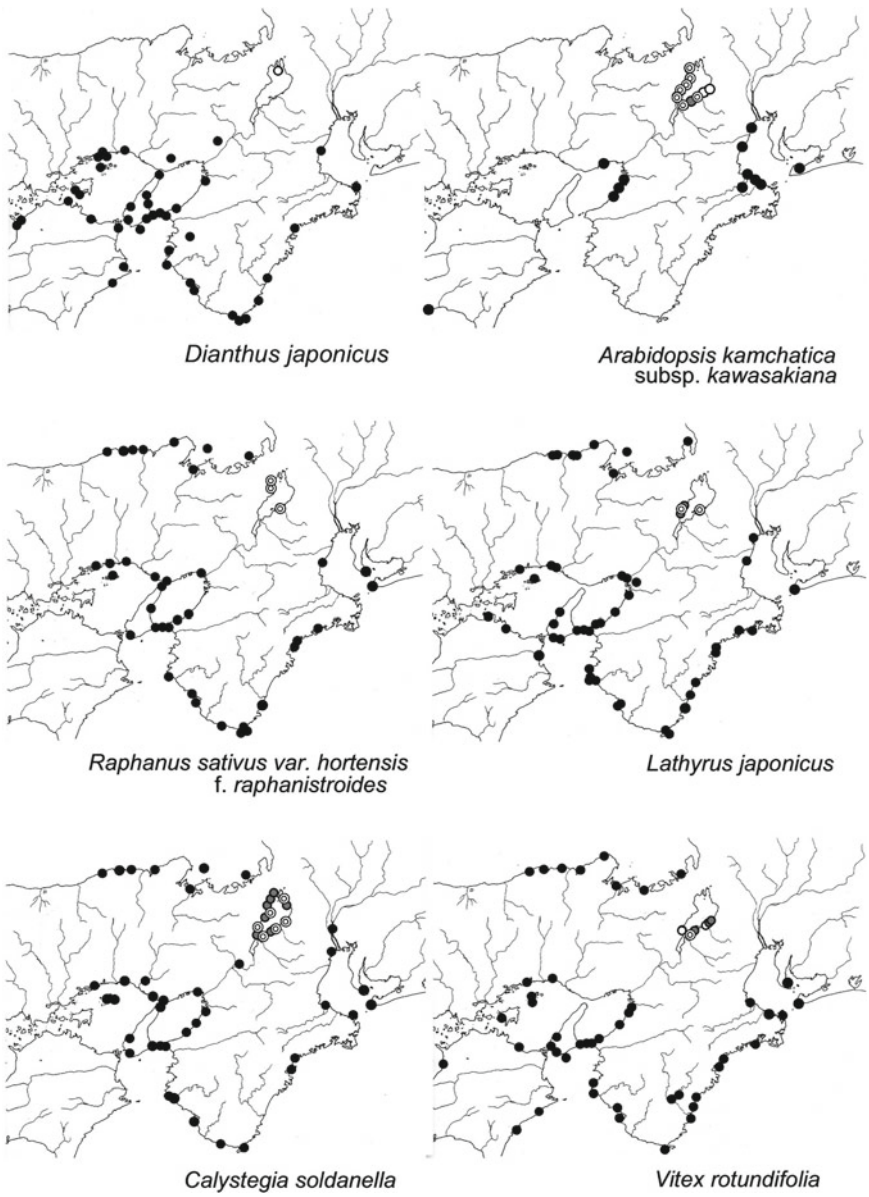

Fig. 1

Distribution of littoral plants in the Kinki region and adjacent regions, based on herbarium specimens. Black circles: localities revised from Fujii (1994b). Around Lake Biwa, double circles: localities known before 2007 (Fujii 1994b and additional survey) and rediscovered in the survey during 2007–2008, white circles: localities known before 2007 but not found during 2007–2008; gray circles: localities newly found during 2007–2008 based on Kaneko et al. (2010), Kaneko et al. (2011), and additional survey.

sandy beach areas (*Fig. 1*), which represent the predominant shore habitat surrounding Lake Biwa (Kitamura 1968; Fujii 1994b, 1999; see *Fig. 2* in Sect. 3.1).

Arabidopsis kamchatica subsp. *kawasakiana* (*Figs. 1* and *2*) is a winter annual or short-lived perennial that grows on sandy beaches in Central Japan (in the Tokai region, which includes Shizuoka Prefecture and Ise Bay, and in Toyama Bay in the Hokuriku Region) and Western Japan (Lake Biwa in the Kinki region, Kochi Bay in the Shikoku region and surrounding the Seto Inland Sea)

Fig. 2
***Arabidopsis kamchatica* subsp. *kawasakiana*, a littoral plant, on Makino Beach, Takashima.**

(Kitamura and Murata 1962; Shimizu et al. 2005; Fujii 1994b). It was previously considered to be the southern littoral-adapted form of *Arabidopsis kamchatica* subsp. *kamchatica*, which usually grows in the mountainous sub-alpine and alpine habitats of Central Japan (Kitamura 1962; Kitamura and Murata 1962). However, a genetic study has strongly suggested that subsp. *kamchatica* and subsp. *kawasakiana* originated by independent polyploidization between *Arabidopsis halleri* and *Arabidopsis lyrata* (Shimizu-Inatsugu et al. 2009). *Calystegia soldanella* (*Figs. 1* and *2*) in the Lake Biwa area has smaller seeds in size than those of coastal populations (Yamada 1992). However, no genetic differences have been reported (Ohsako and Matsuoka 2008), although further genetic studies on this species, as well as *Lathyrus japonicus*, are currently underway (Ohtuki et al., unpublished data).

Although most of the littoral species around Lake Biwa occur on sandy beaches, two species have other habitat preferences. *Dianthus japonicus* grows in rocky habitats (Kitamura 1968) and *Carex scabrifolia* along halophytic marshy shores (Fujii 2010). The diversity of littoral plants around Lake Biwa suggests a strong relationship with the sea coast.

In the early Pleistocene, Lake Biwa was open to the sea, having a broad sea-bound channel with no distinct barriers (Takaya 1963). Despite this, there is no geological evidence of seawater invasion through Lake Biwa's history (Tanaka 1998; Yoshikawa and Yamazaki 1998). With the exception of *Pinus thunbergii* Parl. (Pinaceae), no plant fossil records of littoral elements have been found, and littoral plants, if they existed, were extremely sparse (Takaya 1963). *Calystegia soldanella* and *Vitex rotundifolia* grow along coastal beaches and sometimes occur in dry riverbeds such as Uji River (Lake Biwa and Yodo River system) and Kumano River, which may suggest a historical dispersal upward from the seacoast (Fujii 1994b). However, the halophytic plant *Carex scabrifolia*, which strongly depends on salty habitats, would be unlikely to grow without any seawater connection and the exceptional case was found in Lake Biwa (Fujii 2010). We must also take into account water-level fluctuations, which provide temporal halophilous habitats during the long history of Lake Biwa. To further clarify the invasions and origins of littoral plants into the Lake Biwa area, molecular genetic studies may need to become a focus.

Genya Plant Dependency on Large, Wet Meadows

The water system of Lake Biwa and the Yodo River is the largest in the Kinki region, being about three times larger than the next largest, the Kumano River. Vast floodplains with marshes, wet meadows, swamp forests, and other wetlands are all distinct features. These habitats are especially predominant in and around the small lakes or marshes connected with Lake Biwa, which are collectively referred to as attached lake (*Fig. 3*), and are less associated with the dominant sand beach of the lakeshore.

Hygrophytes, including emergent water plants and some other aquatic plants and trees, inhabit the hyper humid environments of the floodplain, where *Salix* spp., *Phragmites australis* (Cav.) Trin. ex Steud. (Graminae),

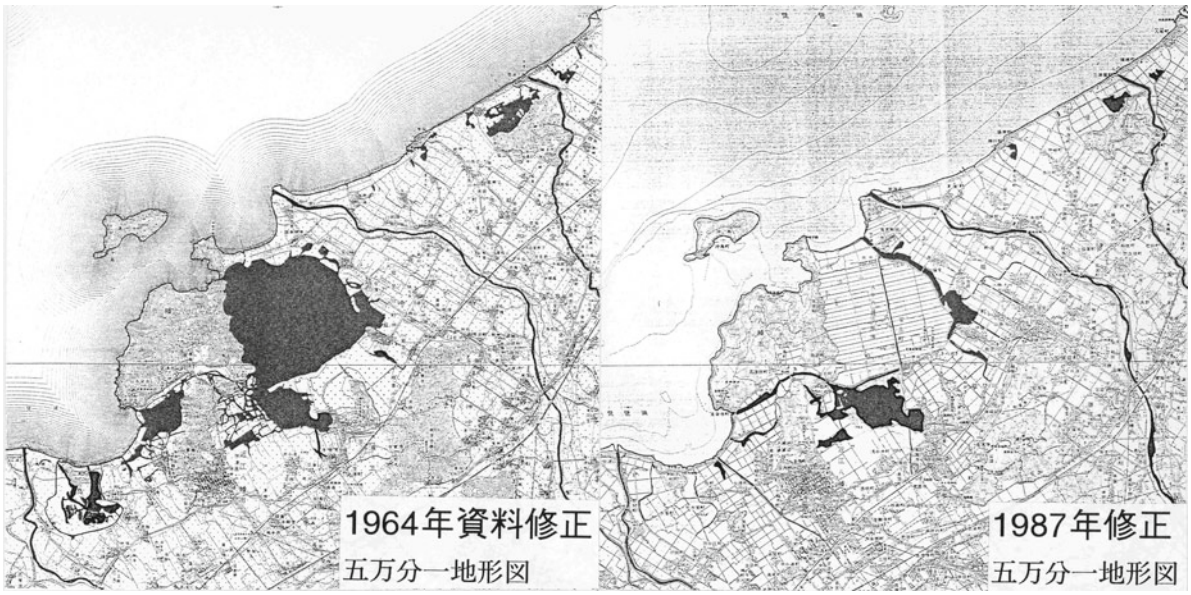

Fig. 3

Example of changing attached lakes (black parts). Eastern region of Lake Biwa in the 1960s (left) and 1980s (right), indicating great reduction of area due to reclamation for agricultural fields.

Typha spp., *Bolboschoenus fluviatilis* (Torr.) Soják subsp. *yagara* (Ohwi) T. Koyama, and *Carex dispalata* Boott (Cyperaceae) are important members of the vegetation communities. Wet meadows contain communities dominated by herbaceous plants rooted in occasionally flooded soils, where temporal flooding excludes terrestrial plants and swamp plants (Keddy 2000). The diverse mosaic of the habitat of wet meadows is caused by disturbances (particularly by flood periods of various frequencies, intervals, and intensities), together with fluctuations in soil moisture levels, underground water levels, nutrient levels, variations in other soil properties, varied topography, and by the coexistence of various succession stages.

Emergent communities of wetlands show a negative correlation between competition intensity, and species richness. However, wet meadows, maintained by intermittent flooding, are clearly associated with the presence of a number of rare plants (Keddy 2000). It is noted by Keddy (2000) that "The larger the watershed area, the larger the amplitude of water-level fluctuations, the broader the wet meadows and the higher the plant diversity." In this viewpoint, some genya plants show a unique distribution pattern clearly associated with the water system of Lake Biwa and the Yodo River (Umehara and Kuribayashi 1991, Fujii 1994b; see *Table 1* and *Fig. 4*).

Table 1

Typical genya plants in Lake Biwa (After Fujii 2009)

Family	Species
Cyperaceae	*Carex maackii* Maxim.
	C. pseudocuraica F. Schmidt
	C. vesicaria L.
Penthoraceae	*Penthorum chinense* Purs
Euphorbiaceae	*Euphorbia adenochlora* C. Morren et Decne.
Polygonaceae	*Persicaria foliosa* (H. Lindb.) Kitag. var. *paludicola* (Makino) H. Hara
	P. hastatosagittata (Makino) Nakai
	P. maackiana (Regel) Nakai
	P. taquetii (H. Lév.) Koidz.
Primulaceae	*Lysimachia thyrsiflora* L.
Apocynaceae	*Vincetoxicum sublanceolatum* (Miq.) Maxim.
Lamiaceae	*Salvia plebeia* R. Br.
Solanaceae	*Solanum megacarpum* Koidz.
Umbelliferae	*Cicuta virosa* L.
Compositae	*Cirsium pendulum* Fisch. ex DC. var. *albiflorum* Makino

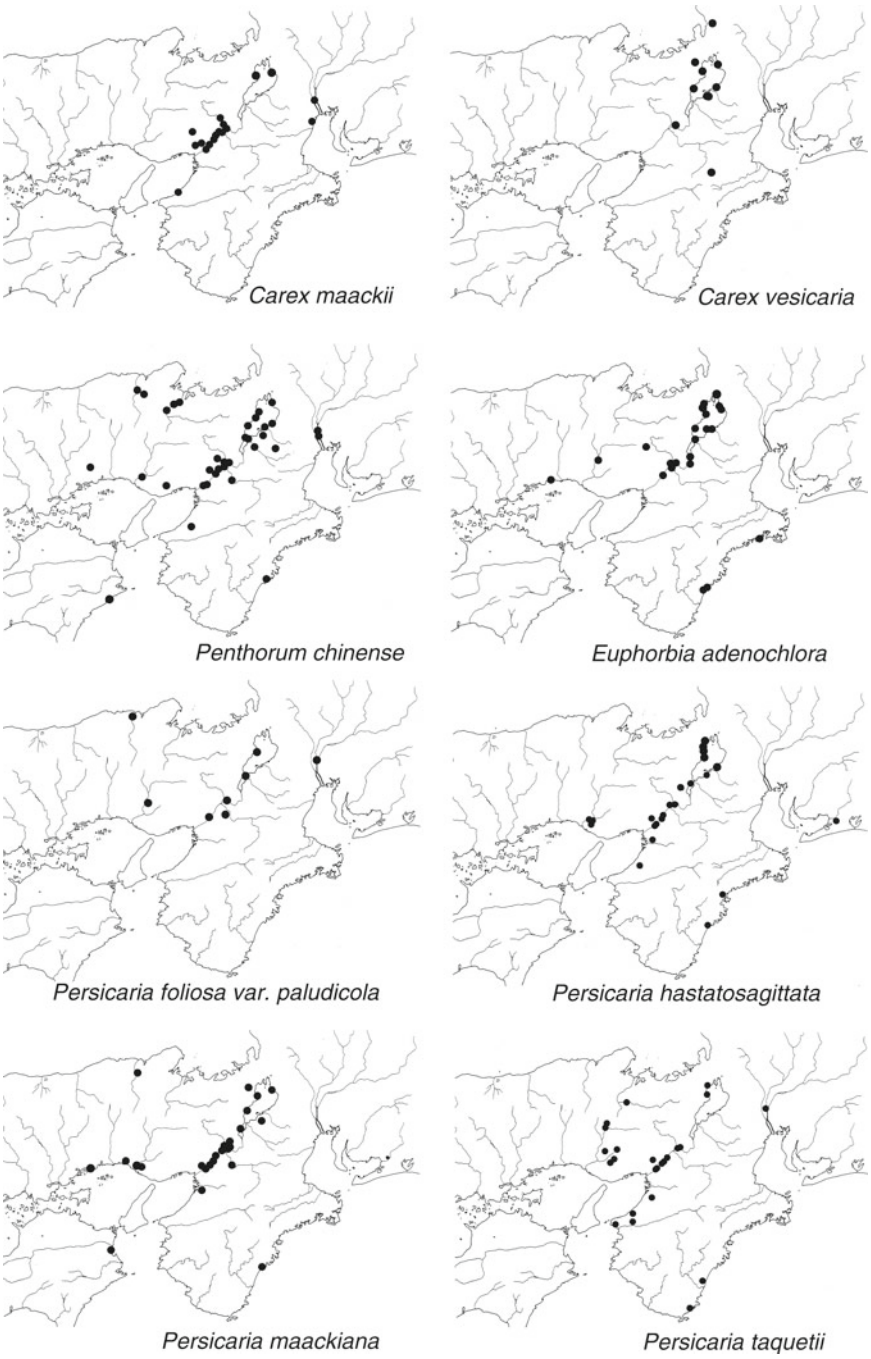

Fig. 4
Distribution of genya plants in the Kinki District and adjacent regions, based on herbarium specimens. *Persicaria taquetii* and *Cirsium pendulum* var. *albiflorum* are added here. Black circles: localities revised from Fujii (1994b, 1994c, 2009) and Umehara (1999). Around Lake Biwa, double circles: localities known before 2007 (Fujii 1994b, c, 2009, and additional survey) and rediscovered in the survey during 2007–2008, white circles: localities known before 2006 but not found during 2007–2008; gray circles: localities newly found during 2007–2008 in Kaneko et al. (2010), Kaneko et al. (2011), and additional survey.

Such plants are abundant around Lake Biwa, but rare in other water systems in the Kinki region. They usually grow in more disturbed habitats or at the edge of *Phragmites australis* and *Carex dispalata* communities, suggesting the importance of reduced competition due to disturbance. The richness of the species, such as the rare or threatened genya plants and the other floodplain-dependent plants, strongly correlates with the size of the attached lakes (Nishino and Hamabata 2004; Hamabata and Nishikawa 2005). This seems to confirm the hypothesis by Keddy (2000) that the broader the wet meadows, the higher the species diversity.

Nishino-ko, which is the largest attached lake with richest flora (Nishino and Hamabata 2004; Hamabata and

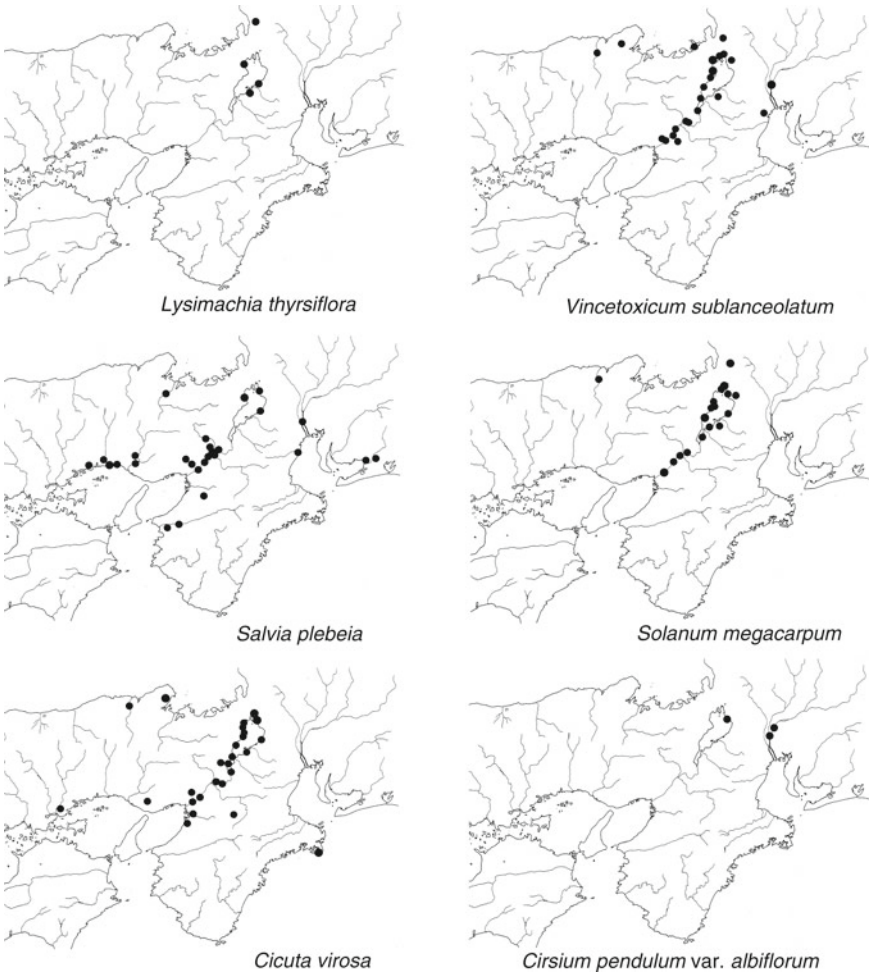

Fig. 4
(continued)

Nishikawa 2005), has extremely large, semi-natural wet meadows, dominated by *Phragmites australis*, which is harvested for industrial products every winter. This is may be a factor that has been attributed to it also being the largest in area. The disturbance factor of the annual reed harvest should be evaluated in future studies to understand its impact on the flora (Fujii 1995, 1998). The effect of semi-cultivation of *P. australis* in wet meadows needs to be studied with respect to species diversity and its conservation. Genetic studies on *Phragmites australis* and other genya plant species such as *Carex vesicaria* L. are currently underway (see Topic 4 and Sect. 7.2.1; Kaneko et al., unpublished data).

Psychrophyte Relicts

Despite the lake being 85.614 m above the Osaka Peil and in a warm temperate climate, many psychrophyte species have been reported from around Lake Biwa and adjacent areas (*Table 2* and *Fig. 5*). A number are also genya plants, and others are notably threatened or rare in the Kinki region. The southwestern limit of the distributions of both *Lysimachia thyrsiflora* and *Carex pseudocuraica* occurs at Lake Biwa (Fujii et al. 1999, 2007). The closest locality of *Carex pseudocuraica* is 400 km apart from Lake Biwa, and *Lysimachia thyrsiflora* was known at Ikenokouchi (Fukui Pref.) and Niigata Pref (*Fig. 5*). Such disjunct distributions and the species richness of psychrophytes may suggest that Lake Biwa represents a refuge in the Kinki region.

Psychrophyte species composition is rather different between Lake Biwa proper (excluding the small lakes and marshes) and the attached lakes. Five species grow in both, two species only along the shore of the main lake, and five species only along the shore of the attached lakes (*Table 2*). *Equisetum palustre*, *Sium suave* var. *nipponicum*, *Lysimachia thyrsiflora*, *Menyanthes trifoliata* L. (Menyanthaceae), and *Carex pseudocuraica* are restricted to attached lakes around Lake Biwa (Fujii 2009), and the

Table 2

Psychrophyte and their growing places in Lake Biwa (Revised Fujii 2009)

Family	Species	Honko [Lake Biwa]	Naiko [attached lake]
Equisetaceae	*Equisetum palustre* L.		○
Cyperaceae	*Carex pseudocuraica* F. Schmidt		○
	Carex vesicaria L.	○	○
Polygooaceae	*Rumex longifolius* DC.	○	
Primulaceae	*Lysimachia thyrsiflora* L.		○
Apocynaceae	*Vincetoxicum sublanceolatum* (Miq.) Maxim.	○	○
Lamiaceae	*Scutellaria dependens* Maxim.	○	○
Solanaceae	*Solanum megacarpum* Koidz.	○	○
Menyanthaceae	*Menyanthes trifoliata* L.		○
Umbelliferae	*Cicuta virosa* L.	○	○
	Sium suave Walter var. *nipponicum* (Maxim.) H. Hara		○
Compositae	*Cirsium pendulum* Fisch. ex DC. var. *albiflorum* Makino	○	

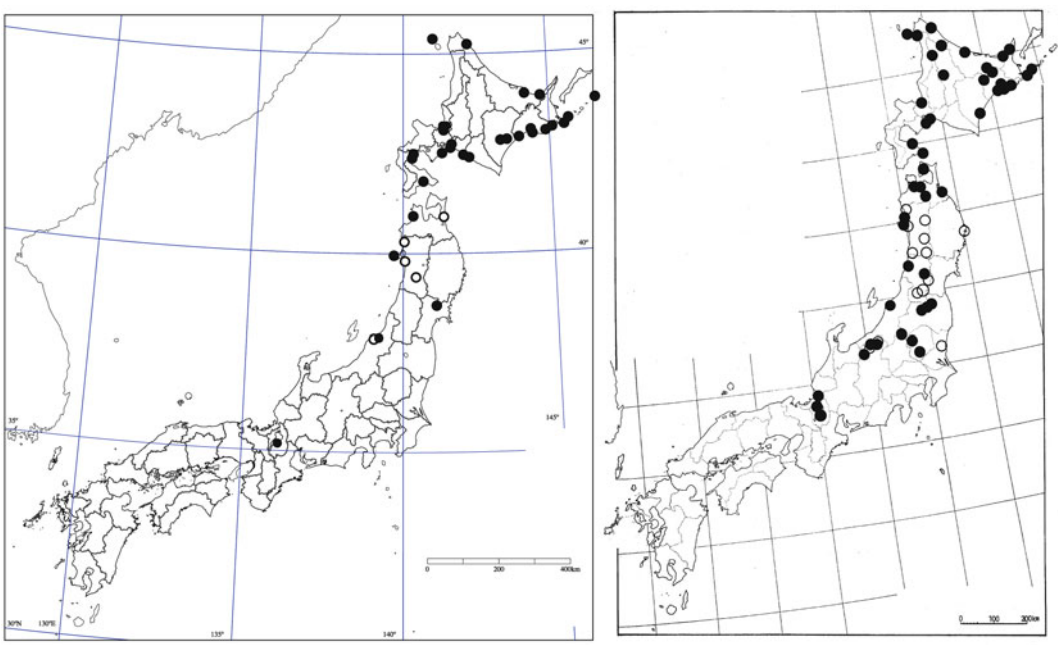

Fig. 5

Distribution of psychrophytes based on herbarium specimens (solid circles) and literature records (open circles). (a) *Carex pseudocuraica* (Fujii et al. 2007), (b) *Lysimachia thyrsiflora* (Fujii et al. 1999).

Fig. 6
Example of restoration of a narrowed beach in Ohmi-shirahama, Takashima.

particularly distinct psychrophyte flora here suggests no alternative habitats for these in the vicinity of the main lake. It is notable that attached lakes contain a high diversity of the species, such as threatened, or rare, genya plants as well as many floodplain-dependent plants (Nishino et al. 2003).

Threats for Wetland Flora

The most significant threats for the littoral plants have been beach development for recreational use and active efforts to prevent beach narrowing. In the latter case, such restorations often involve the dumping of large amounts of sand in areas where beach narrowing has been noted (*Fig. 6*). This buries native plants and may also damage the submerged plant community by muddying the waters (Fujii 1994a, 1999, 2004). The impacts have been varied. *Calystegia soldanella* is the most common and abundant beach plant around Lake Biwa, and has recently been noted to be still growing well (Nakagawara 2005). However, *Arabidopsis kamchatica* subsp. *kawasakiana*, an endangered plant (Environment Agency of Japan 2000), previously abundant to the area with entire beaches reported to be covered with its white flowers (Murase et al. 1995), has seemingly now been greatly reduced. The presence of *Vitex rotundifolia* has only been recorded at a few localities around Lake Biwa. In one of these localities, Wani Beach, it has since disappeared, but at another one, Ayame Beach, it has been conserved at the edge of a swimming area (Fujii 1994a). Many alien plants, such as *Silene gallica* L. var. *gallica*, *Bidens pilosa* L., *Lolium* spp., and *Vulpia myuros* (L.) CC Gmel., have colonized the sandy beaches, but it is as yet unclear whether native plants are threatened or not.

In addition, genya plants, rare hygrophytes, and psychrophytes have suffered great habitat loss due to three major types of development. First, reclamation of attached lakes for agricultural fields started in the 1940s resulting in a 37.8% loss in number and 85.2% loss in area of the attached lakes (Nishino 2003; see also *Fig. 3*). Second, during the 1980s and 1990s, a flood embankment was constructed surrounding the lake, upon which a ring road was placed (Fujii 1994d). This reduced the wet meadow area and formed a physical barrier, both disturbing habitat continuity and disrupting ecotones (Fujii 1999). Third, the development of villas and cottages in the 1980s also reduced the habitats, as does the more recent development threat of continuing construction of shoreline recreational parks (Fujii 1994d). It is important to conserve the shores of both Lake Biwa and its naikos, the latter of which have been exposed to high development pressure because of their inland locations. Invasive plants have not, as yet, become a major issue for the wet meadows, but *Solidago altissima* L. is noted as being the most competitive in drier conditions (Fujii, personal observation). Regulation of water-level fluctuations, obstructing natural flood periods, and cutting off habitat continuity with embankments or roads may also result in the acceleration of terrestrial alien plant invasions.

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2.4 Benthic and Pelagic Invertebrate Fauna of Lake Biwa

Machiko Nishino

About 700 or more species are so far reported from Lake Biwa as benthic invertebrate species, such as Cnidaria, sponges, flatworms, a ribbon worm, oligochaetes, leeches, mollusks, Crustacea, aquatic insects and Bryozoa (see Appendix 2). Other benthic invertebrates, like Tardigrada, Gastrotricha and water mites, also inhabit the lake, but have not yet studied. Protozoan, rotiferan, cladocean and copepod species, as well as phytoplankton, inhabit the pelagic zone of the north basin.

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2.4.1 Diversity and Distribution of Freshwater Sponges (Porifera: Spongillidae) in Lake Biwa

Yoshiki Masuda

Abstract The diversity and distribution of freshwater sponges in Lake Biwa have been studied for decades. To date, 14 species in 8 genera have been recorded from Lake Biwa and its attached lakes. Considering about 150 species of freshwater sponges that have been recorded in the world, it is apparent that Lake Biwa hosts quite a few of them. *Spongilla inarmata*, which is supposed to be the only endemic sponge of Lake Biwa, has not been recorded since a specimen was described as a new species by Annandale in 1918. *Stratospongilla clementis*, which seldom produces gemmules, was widely distributed over the entire lake before the period of Japanese post-war economic development. By the end of the twentieth century, however, only a few were found in some parts of the north basin. *Spongilla lacustris*, which was broadly distributed in the lake and attached lakes, has decreased in number during the last decade. Contrary to this, *Heterorotula multidentata*, which is considered to be an introduced species, began to be frequently found in 1988.

Keywords Freshwater sponges • Lake Biwa, Diversity • Distribution

Introduction

Although freshwater sponges are widespread in ponds, lakes, and rivers, they are not familiar to most people. For years, sponges were considered to be plants because of their shapes and living patterns. They were not clearly recognized as members of the animal kingdom until the nineteenth century and remained as objects of mystery for scientists.

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In Japan, sponges appeared as "shisho-ka" (purplish flower) in the *Wakan Sansai Zue* (Illustrated Sino-Japanese Encyclopedia) published in 1712 during the Edo Period (1603–1868). It said that "shisho-ka can be found in Lake Biwa. It is as small as an ear of reedmace. Its color is yellowish black, almost purple." It also describes the use of "shisho-ka" as a medicine. Annandale and Kawamura (1916) performed the first biological research on freshwater sponges in Lake Biwa in 1914 and 1915. Since then, researchers have dedicated themselves to the study of the taxonomy and distribution of sponges, but in spite of their efforts, a lot of questions about sponges remain unanswered.

History of Research on Freshwater Sponges in Lake Biwa

The first detailed research of freshwater sponges in Lake Biwa was Annandale and Kawamura's (1916) taxonomical and ecological study performed in 1914 and 1915. They recorded seven species belonging to six genera. They reported one of them was *Spongilla aspinosa* in 1916, but in 1918, Annandale reidentified it as *Spongilla inarmata*, an endemic species in Lake Biwa. There have been no reports of this sponge since then. The only sample is the one they collected and recorded as a new species. Gee (1928) studied many samples from the lake and added a new record of *Trochospongilla phillottiana*. Sasaki (1934), who studied the distribution of freshwater sponges in Japan, South Sakhalin, the Kuril Islands, the Korean Peninsula, and Taiwan during the 1930s, researched Lake Biwa in 1933; but in spite of his efforts, no new records were added. Mizuno and Tetsukawa (1965) studied the distribution of sponges in the lake and attached lakes from 1963 to 1965, but did not add any new records. Nishino and coresearchers have been studying the lake and the attached lakes since 1986 and have added records of six species: *Eunapius coniferus*, *Radiospongilla crateriformis*, *Radiospongilla sendai*, *Ephydatia fluviatilis*, *Trochospongilla*

latouchiana, and *Heteromeyenia multidentata* (Nishino 1993). So far, 14 species belonging to 8 genera have been recorded in Lake Biwa (see Appendix 2). Up to now, about 150 species of freshwater sponges have been recorded in the world, including 25 species in Japan. It is apparent that Lake Biwa hosts quite a few of them.

The Taxonomic Problem of Freshwater Sponges in Lake Biwa

Most freshwater sponges create a dormant and resistant internal bud, known as a gemmule, as a result of asexual reproduction. Gemmoscleres, spicules that reinforce the gemmule coat, are the most important morphological characters for classifying sponges, and therefore, there are lots of difficulties in classifying non-gemmulating sponges.

Spongilla inarmata, the only endemic species among the 14 species recorded in the lake, was identified as *S. aspinosa* by Annandale and Kawamura at first. Annandale, however, reidentified it as *S. inarmata*, not as *S. aspinosa* (Annandale 1918). As a result, this became an endemic species in the lake, but there is little information on this because only one specimen was collected. According to Annandale and Kawamura's description, the specimen has no gemmoscleres, and its gemmule coat and other spicules are similar to those of *S. lacustris*. Further specimens are required to clarify the relationship between *S. lacustris* and *S. inarmata*.

Annandale and Kawamura (1916) collected many samples of *Stratospongilla clementis*, but only two specimens, collected in the same dredge sample, had gemmules. They classified their samples of *S. clementis* into three types and described them in detail. One of these types is similar to *S. yunanensis* (Penney and Racek 1968). To clarify its classification, further work is needed, such as molecular and biological studies, and comparisons with non-gemmulating relatives (*Nudospongilla*, *Cortispongilla*, *Potamolepis*, *Lubomirskia*, and *Pacdictyum*).

Most marine sponges do not produce gemmules, while many freshwater sponges do. Gemmules encapsulate archaeocytes and protect them from unbearable environmental stresses, such as dry-up and freezing. When conditions improve, gemmules hatch and archaeocytes develop into adult sponges. Gemmulating is, therefore, considered an adaptive strategy gained during the colonization of freshwaters, which is influenced by seasonal climatic changes. Non-gemmulating sponges, however, are common in ancient lakes such as Lake Tanganyika and Lake Baikal (Masuda 2009). Such sponges may have lost their ability of gemmulating after colonizing habitats, where great volumes of water exist that rarely dry-up or freeze. It is possible that non-gemmulating sponges in Lake Biwa stopped gemmulating for the same reason that sponges in other ancient lakes did.

Distribution of Freshwater Sponges in Lake Biwa

Very few attempts have been made at ecological studies on freshwater sponges in Lake Biwa, and only some studies on their distribution exist. According to Annandale and Kawamura's research in the early twentieth century, every species except *S. clementis* was more abundant in the south basin compared with the north basin; especially, *S. lacustris*, *R. cerebellata*, and *E. muelleri* are abundant (*Fig. 1*). Only *S. clementis* was recorded more in the north basin than in the south basin.

Every species except *S. clementis* showed a depth distribution ranging from 0.6 to 6 m deep, but they were mostly found in areas less than 3 m deep. *S. clementis* was found in areas of 2–45 m deep (Annandale and Kawamura 1916). Mizuno and Tetsukawa (1965) revealed that *S. clementis* could be found in the north basin, while only a few were found in the south basin. According to Masuda's research since 1979, there was no record of *S. clementis* in the south basin and only a few could be found in the north basin. The number of *S. lacustris* in the south basin showed a decrease recently (Masuda, unpublished).

A study of the depth distribution of *S. lacustris* in the north basin shows that it is colored green in shallow water, while it is red at 20 m depth. It is supposed that the difference of colors results from different kinds of symbionts. Red symbionts can capture energy from even faint sunlight (Masuda, unpublished).

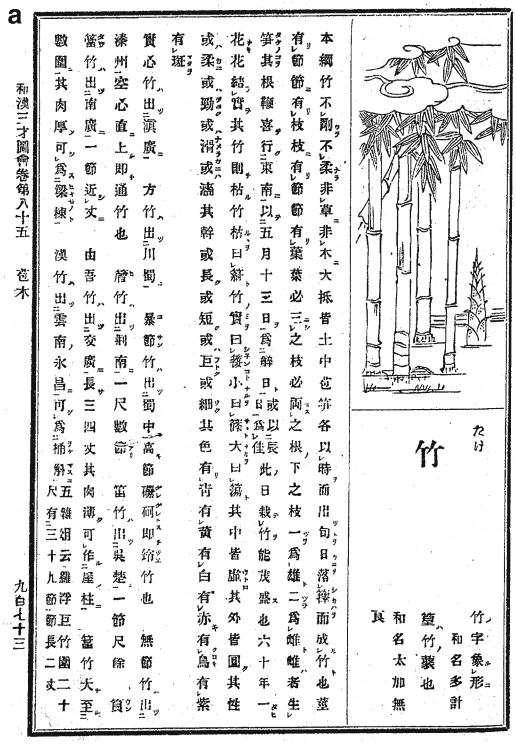
Relationship between People and Freshwater Sponges in Lake Biwa

Freshwater sponges of Lake Biwa are described as a medicine in many books published during the Edo Period, such as *Wakan Sansai Zue* (Illustrated Sino-Japanese Encyclopedia 1712), *Yoyaku Suchi* (Necessary Knowledge about the Use of Medicine 1726), *Senchu-fu* (Illustrations of a Thousand Insects 1811), and *Nanso Satomi Hakkenden* (Eight Dog Chronicles 1814–1842) (*Fig. 2*). Sponges were believed to be effective for erectile dysfunction and rejuvenation. Today, freshwater sponges have been studied pharmacologically, but useful chemicals have not been found yet.

Fig. 1

***Spongilla lacustris*, the most abundant freshwater sponge in Lake Biwa. Though it is distributed broadly, it began to decrease in number recently.**

a



和漢三才圖會卷第八十五　芭木

本綱竹不剛不柔非草非木大抵皆土中位笋各以時而出旬日落籜而成竹也蓋有節節有枝枝有節節有葉葉必三之枝必兩之根下之枝一爲雄二爲雌雌者生笋其根糞宜行東南以五月十三日爲解日或以長佳此日栽竹能茂盛也六十年一花花結實其竹即枯竹枯曰薪竹實曰䉡小曰篠大曰簜其中者謂其外者圍其性或柔或勁或滑或澁其幹或長或短或巨或細其色有青有黃有白有赤有烏有紫有斑

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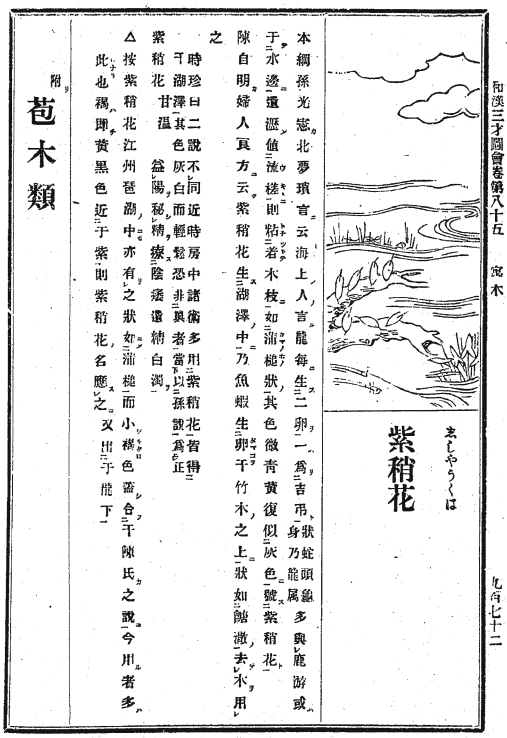

和漢三才圖會卷第八十五　寓木

本綱孫光憲北夢瑣言云海上人言龍每生二卵一爲吉弔狀蛇頭鹿多與鹿游或于水邊遇值樓則黏著木枝如湔槌狀其色微青黃復似灰色號紫稍花隊自明婦人眞方云紫稍花生湖澤中乃魚蝦生卵于竹木之上狀如醃漬去水用之

時珍曰二說不同近時房中諸術多用紫稍花實得于湖澤其色灰白而輕恐非眞者當以孫說爲正

紫稍花甘溫益陽秘精療陰痿遺精白濁

△按紫稍花江州琵琶湖中亦有之狀如湔槌而小穗色蓋合千隊氏之說今用者多此也禍即黃黑色近于紫則紫稍花名應之又出于能下

附　苞木類

ましやうくは

紫稍花

九百七十二

Fig. 2

(a) "Shisho-ka" in old books. Terajima Ryoan, *Wakan Sansai Zue* (1712) (from the collection of the National Diet Library). (b): Kurimoto Tanshu, *Senchu-fu* (1811) (from the collection of the National Diet Library).

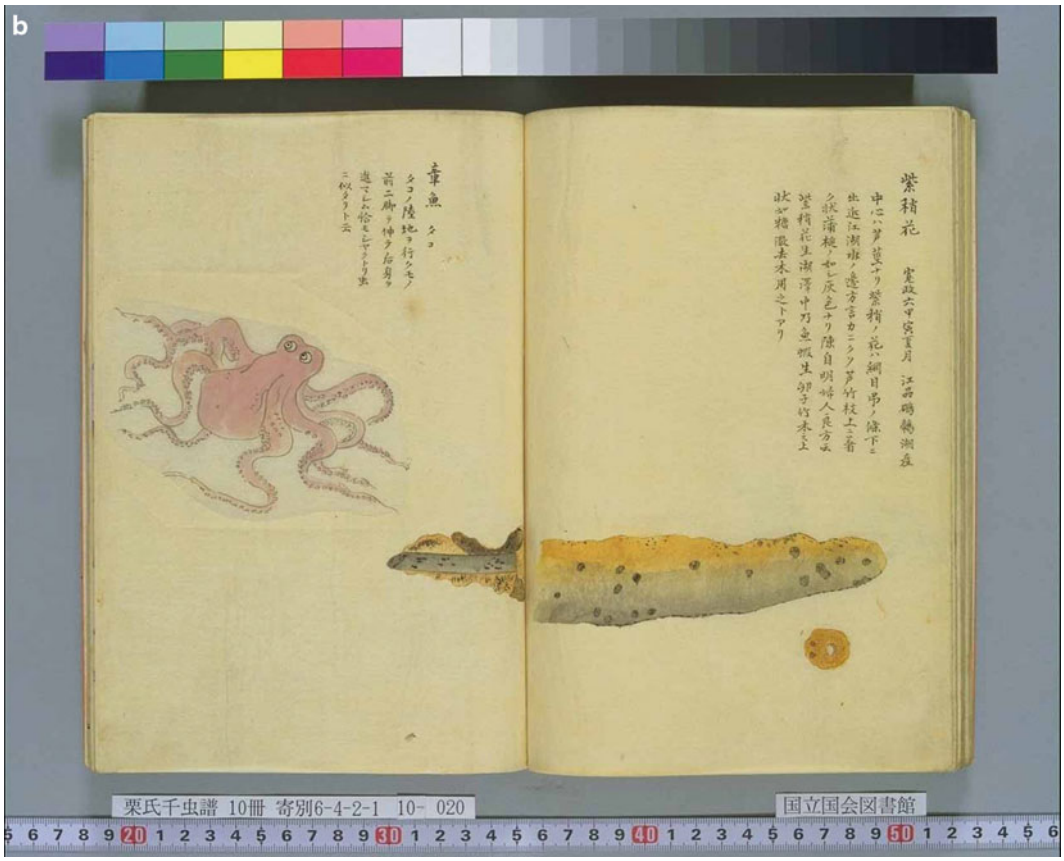

Fig. 2
(continued)

Freshwater sponges are sessile animals, and they are easily found attached to the stems of reeds and other plants. There are some old books that described them as eggs of crucian carps or nests of shrimps. Pearl farmers of attached lakes called sponges "Sobu" (attached organism) together with algae and bryozoans. In recent years, most attached lakes have been drained for farmland and reed beds have decreased rapidly in area because of the construction of roads around the lake. Fewer structures remain for sponges to attach to. However, the most influential factor of their decline is the change in water quality. As the human population around the lakeshores increased, sewage and industrial pollution caused a deterioration of the lake's water quality. By the end of the twentieth century, many pearl farmers gave up the culture of pearls using the freshwater pearl mussel (*Hyriopsis schlegeri*) because of poor growth of mussels. Sponges, especially *S. lacustris* and *Eunapius fragilis*, used to be found on cages of *H. schlegeri* and piles. It is suspected that changes in water quality caused the rapid decrease of freshwater sponges. To the contrary, *H. multidentata*, which is an introduced species from Australia, has been increasing in numbers. It first appeared in the lake in 1988 as a by-product of human movements (Masuda, unpublished).

Water quality changes directly affect freshwater sponges in particular, as they are sedentary animals, unable to move away from deteriorating conditions. Improvements in lake water quality are the focus of conservation projects currently underway, and once achieved, it is possible that even *S. clementis* will be found in the south basin.

2.4.2 Flatworms ("Turbellarians") and Ribbon Worms (Nemerteans) of Lake Biwa

Masaharu Kawakatsu · Machiko Nishino

Abstract In the groups of so-called microturbellarians living in Lake Biwa, 8 orders, 9 families, 3 genera, and 21 species are known. The genus *Microstomum* with five species is the dominant group. A temnocephalidan species, *Scutariella japonica* (Matjašič, 1990), is also known. In the triclad planarians, *Bdellocephala annandalei* Ijima et Kaburaki, 1916 and *Phagocata kawakatsui* Okugawa, 1956 are known from the bottom of the northern basin of the lake. Although *Dugesia japonica* Ichikawa et Kawakatsu, 1964 occurs commonly in epigean streams around Lake Biwa, it has a scanty of occurrence in beaches of the lake. *Girardia tigrina* (Girard 1850), an exotic cosmopolitan species, is found in shallow beaches of Lake Biwa and became naturalized about 10 years ago. *Prostoma ohmiense* Chernyshev, Timoshkin et Kawakatsu, 1998, a nemertean species, is recorded from shallow littoral stations of the lake.

Keywords *Stenostomum* • *Microstomum* • *Microdalyellia* • *Scutariella* • Tricladida • Continenticola • *Prostoma*

Flatworms: A Short History of the Study of "Turbellaria" in Lake Biwa

In 1915, the first turbellarian species from Lake Biwa was collected by T. N. Annandale (Indian Museum of Calcutta) and T. Kawamura (Kyoto Imperial University) (cf. Annandale 1922). Their specimens from a dredged sample were described as *Bdellocephala annandalei* Ijima et Kaburaki, 1916. This true lake-dwelling planarian is known as an endemic species of the lake (cf. Nishino 1993; Kawakatsu and Nishino 1993, 1994; Kawakatsu et al. 2001).

So-called microturbellarians from Japanese freshwater habitats were studied at first by Nassonov (1929), followed by Okugawa (1930). Later, Okugawa (1953) listed 31 species belonging to the groups of "Rhabdocoela" and "Alloeocoela" in Japan. Among them, 14 species (7 families and 8 genera according to a classical taxonomic system employed at that time) were recorded from Lake Biwa and its epigean water basin.

For a taxonomic revision and additional records of Lake Biwa microturbellarians, see Mori (1970), Mori and Miura (1980, 1990), and Kawakatsu and Nishino (1993, 1994). The latest record of Lake Biwa microturbellaria is that of *Prorhynchus stagnalis biwaensis* Timoshkin, Grygier et Kawakatsu, 2004. According to the present taxonomic system of this group, 8 orders, 9 families, 3 genera, and 21 species (including one subspecies) are known from Lake Biwa (see the Taxonomic List of Platyhelminthes at the end of this volume). The genus *Macrostomum* (Order Mesostomida, Family Macrostomidae), with five species, is the dominant group in the lake (cf. Kawakatsu 1998a).

A temnocephalid species from Lake Biwa, an ectocommensal animal of a shrimp (*Partya compressa* Kemp, 1917), was studied by Kobayashi (1935) and Honjo (1937). At that time, they used an erroneous name of the animal as "*Caridinicola indica* Annandale, 1912." The Lake Biwa temnocephalid species is now known as *Scutariella* japonica (Matjašič 1990) (Order Temnocephalida, Family Scutariellidae). Cf. Kawakatsu (1998a, b); Kawakatsu et al. 1999, 2007a).

Freshwater planarians (i.e., so-called paludicolen triclads) are now classified in the Order Tricladida and Suborder Continenticola Carranza, Littlewood, Clough, Ruiz-Trillo, Baguñà and Riutort, 1998 (cf. Sluys et al. 2009; Kawakatsu et al. 2009). *Bdellocephala annandalei* (the endemic species mentioned earlier) is a member of the Superfamily Planarioidea, Family Dendrocoelidae, Genus *Bdellocephala*. *Phagocata kawakatsui* Okugawa, 1956, a

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member of another genus in the Family Planariidae, is also found on the bottom (depth, 3–70 m) at the southern part of the northern basin of Lake Biwa (cf. Kawakatsu et al. 2000; Kawakatsu and Ohtaka 2008).

Occurrences of two dugesiid species in shallow lakeside areas (Suborder Continenticola, Superfamily Geoplanoidea, Family Dugesiidae) are known. One of them is *Dugesia japonica* Ichikawa et Kawakatsu, 1964 (cf. Kawakatsu et al. 1967). Another is *Girardia tigrina* (Girard, 1850), an exotic species that is now naturalized in shallow beaches of the lake (cf. Nishino et al. 2002; Kawakatsu et al. 2007b, 2008; Sluys et al. 2010).

D. japonica and the other two species of freshwater planarians are distributed in the plains and mountainous districts around the lake. *D. japonica* is common both in many lowland streams and in brooklets of mountainous areas (below the altitude of about 950 m in the Hira Mountains, which are located along the southeastern and northeastern sides of the lake). *Phagocata vivida* (Ijima and Kaburaki 1916) is rather common in the cold-water areas of the Hira Mountains (altitude range, 120–950 m) (cf. Kawakatsu et al. 1967). A population of *Bdellocephala brunnea* Ijima et Kaburaki, 1916 is known from a locality downstream of the Amagase Dam, Uji-gawa River (approximately 18 km downstream from the outlet of Lake Biwa), Uji City, Kyoto Prefecture (cf. Kawakatsu et al. 2001).

The Population Density of *Bdellocephala annandalei*

This endemic species was rather common on the profundal muddy bottom of the northern basin of the lake (30–80 m or more in depth) (cf. Kawakatsu and Nishino 1994: 97–100, figs 4–6). According to the results of dredging investigations of the lake during the past 30 years or more, there has been a rapid change of the population density of *B. annandalei* (see color page 7). In the beginning of the 1980s, the species was collected from various localities of the profundal bottom (30–90 m in depth). By the beginning of the 1990s, this benthic planarian population had diminished remarkably. The 1991–1992 dredging investigation obtained animals from only a few localities (50–90 m in depth). After 2000, however, the population of *B. annandalei* increased again.

This endemic planarian is now ranked as a Critical Endangered Species (CR + EN) according to the Revised Red List (Ministry of the Environment of Japan) (cf. Kawakatsu 2010).

Ribbon Worms (Nemerteans)

Only a single species of nemertean, *Prostoma ohmiense* Chernyshev, Timoshkin et Kawakatsu, 1998, is currently known from the lake, along the northwestern slope (off Komatsu and off Shin-Asahi-cho, Takashima-gun; ca. 2m in depth) (cf. Chernyshev et al. 1998).

Prostoma ohmiense is the first Japanese freshwater nemertean species identified according to correct procedures. As was already pointed out by Chernyshev et al. (1998: 60–64), all previous records of *Prostoma* from Japan should be cited as *Prostoma* sp. (or spp.?). Previous taxonomic descriptions of Japanese *Prostoma* species are insufficient for the correct species identification (see also Kajihara 2007; Kajihara et al. 2008).

2.4.3 Diversity and Distribution of Aquatic Oligochaetes (Annelida, Clitellata) in Lake Biwa

Akifumi Ohtaka · Machiko Nishino

Abstract Diversity and distribution of aquatic oligochaetes in Lake Biwa are summarized. To date, 49 valid species belonging to 5 families of oligochaetes have been recorded from Lake Biwa and its attached lakes (*Naiko*). The lake is characterized by the wide distribution of *Branchiura sowerbyi* Beddard, 1892. A variant form of *B. sowerbyi*, which is almost devoid of posterior gill filaments, is found in the profundal zone, and is regarded to be endemic to the lake. It has specialized not only morphologically, but also physiologically to be able to live in the constantly cool environment. The lake's fauna is categorized into four groups on the basis of depth distribution patterns, of which the highest diversity is found in littoral zone. The oligochaete fauna in the attached lakes (*naiko*) is richer in small-sized naidines, while poorer in other groups compared with those in Lake Biwa, and basically can be regarded as an extension of the fauna of Lake Biwa's littoral zone. In recent decades, research could not find lumbriculids and a biwadrilid from the profundal zone, both of which were recorded in the earliest oligochaete research in 1917, suggesting some recent environmental changes in the lake.

Keywords Oligochaetes • Lake Biwa • Diversity • Distribution • Branchiura sowerbyi • Rhyacodrilus hiemalis

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Introduction

In freshwater habitats, about 1,100 valid species of oligochaetes are known in the world (Martin et al. 2008), and 77 freshwater valid species, belonging to 9 families, have been recorded from Japan. On the basis of the freshwater oligochaete fauna, the Amur-Japanese freshwater zoogeographical subregion (Timm 1980), which is transitional between the Holarctic and Sino-Indian zoogeographical regions, is regarded to be more related to the Holarctic region (Timm 1997). However, the Japanese islands stretch a long way north to south with a corresponding heterogeneous climate, and a recent faunal study in Lake Biwa in central Japan suggested a closer relationship with the more southern Indo-Malayan subregion in the Sino-Indian region (Ohtaka and Nishino 2006).

Among Japanese lakes, Lake Biwa has been most intensively studied for oligochaetes. In this article, we briefly summarize the diversity and ecology of Lake Biwa oligochaetes.

Overall View of Lake Biwa Oligochaetes

The first taxonomic study of Lake Biwa oligochaetes was conducted by Stephenson (1917) based on Annandale's samples collected in 1915 (cf. Annandale 1922). He described three new species along with several unidentified species. To date, 49 valid species belonging to 5 families have been recorded from Lake Biwa and its attached lakes (*naiko*) (Stephenson 1917; Yamaguchi 1964; Ohtaka 1995; Ohtaka and Nishino 1995, 1999, 2006; Torii and Ohtaka 2007; Martin and Ohtaka 2008; Blakemore 2008). The present list of Lake Biwa oligochaetes is made up primarily of widely distributed species, but also includes Asiatic, circum Pacific, and Japanese species (see Appendix 2).

However, research on oligochaete diversity in the lake is still insufficient, especially in the littoral zone (shallow areas of the lake) and in the family Enchytraeidae, and many additional species will be discovered in the future.

Astacopsidrilus ryuteki Martin et Ohtaka, 2008 was recently described based on a single specimen from the 90 m depth of the profundal zone (the deep part of the lake where there is effectively no light penetration) in the north basin of Lake Biwa. This species belongs to the Family Phreodrilidae, which originated in the ancient supercontinent Gondwana, and the majority of species of this family now occur in the southern hemisphere (Martin et al. 2008). *A. ryuteki* is postulated to have been introduced into Japan from the southern hemisphere, because any hypothesis of a former zoogeographical connection between Japan and any Gondwanan originated regions is unsupported by any other biogeographical data (Martin and Ohtaka 2008). Several other recorded species have been suspected as alien too, although their invasions cannot be verified due to the long break in research of the lake's oligochaete fauna until recent years.

Endemicity of Lake Biwa Oligochaetes

There have been five nominal species which were originally described only from Lake Biwa: *Chaetogaster annandalei* Stephenson, 1917, *Kawamuria japonica* Stephenson, 1917, *Criodrilus bathybates* Stephenson, 1917, *Peloscolex yamaguchii* Brinkhurst, 1971, and *Astacopsidrilus ryuteki*. Several of them had once been considered to be endemic to the lake; however, later taxonomic revisions and additional records from other localities have led to the conclusion that there are no oligochaetes confined to the lake at the specific level. At present, an infraspecific variant form of *Branchiura sowerbyi* Beddard, 1892, noted below, is regarded as the only endemic oligochaete in Lake Biwa.

The endemicity of the oligochaete fauna is lower in Lake Biwa than in several other ancient lakes, for example, Russian Lake Baikal (111 species out of 207 are endemic), African Lake Tanganyika (9 species out of 16 are endemic), and Balkan Lake Ohrid (5 species out of 23 are endemic) (Martin 1996). This could be due mainly to the relatively short and complicated history of Lake Biwa. Martin (1996) suggested that the disappearance of the precursors of Lake Biwa is responsible for the low extant diversity, but no evidence to support this hypothesis is available for oligochaetes.

Variant Form of *Branchiura sowerbyi*

Lake Biwa is characterized by the eurybathyal occurrence of *Branchiura sowerbyi*, of which the profundal population that lack posterior gills was previously regarded as a separate species, *Kawamuria japonica* (Stephenson 1917). The development of the gill filaments is correlated with water depth in the lake (*Fig. 1*; *Table 1*). In the profundal region of the north basin at depths deeper than 30 m, almost all individuals were devoid of gill filaments (*Fig. 1b*) and only a few individuals had vestigial gills (*Fig. 1c*). In the littoral region of the north basin, worms with small developed gills occurred, but more than half of the individuals were still devoid of gills (*Fig. 1d, e*). In the shallow south basin, worms with gills surpassed in number those without gills; however, the number and length of gill filaments were few and short (*Fig. 1f*). On the other hand, all worms in the attached lakes (naiko) had developed gills (*Fig. 1g, h*) as well as those in surrounding rice paddies (*Fig. 1a*).

Along with the lack of posterior gills, the profundal population also differs from other *B. sowerbyi* populations in eastern and southeastern Asia in having fewer and shorter hairs, and simple-pointed chaetae, or short bifid (forked) chaetae with parallel teeth, in dorsal bundles of chaetae (Ohtaka and Nishino 1999). In addition, although *B. sowerbyi* is typically a warm-water oligochaete, and reproduction usually occurs in spring in temperate regions (Ohtaka and Kikuchi 1997), continuous reproduction was found in the profundal zone of Lake Biwa (unpublished), the bottom water of which is almost constantly 6–8°C throughout the year. Such temperatures are lower than the threshold value for embryonic development of *B. sowerbyi* estimated at 10°C by Bonacina et al. (1994). Consequently, it is highly probable that the profundal population of *B. sowerbyi* has specialized not only morphologically, but also physiologically to be able to live in the constantly cool environment. A recent study using molecular characters has recognized a great phylogenetic diversity among southeast and East Asian populations of *B. sowerbyi*, and the profundal Lake Biwa population can be regarded as a distinct lineage compared to other lake Biwa populations as well as to world populations outside Lake Biwa (Lindström et al., unpublished).

Distribution of Oligochaetes in the Lake

Among 42 oligochaete species so far recorded from Lake Biwa excluding the attached lakes (*naiko*), 31 (73%) species are distributed in the north basin, which covers 91%

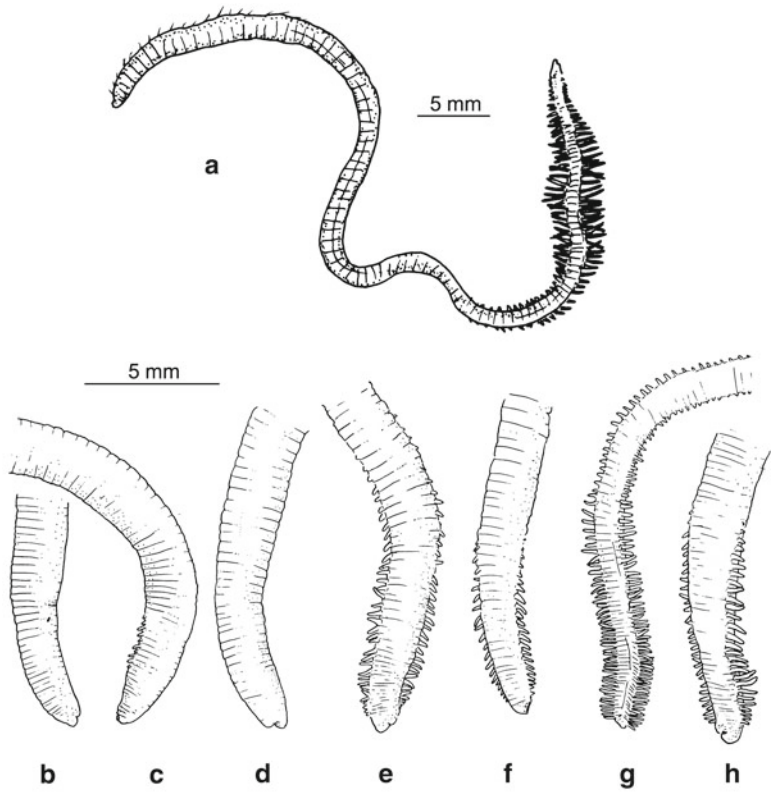

Fig. 1
Whole body (a) and posterior ends (b–h) of *Branchiura sowerbyi* from Lake Biwa and adjacent areas. a, from an adjacent paddy field; b, from the north basin, 90 m depth; (c) from the north basin, 70 m depth; (d) from the north basin, 30 m depth; (e) from the north basin, 5 m depth; (f) the south basin, 4 m depth; (g) and (h) an attached lake (*naiko*) (Modified from Ohtaka and Nishino 1999).

Table 1
Development of posterior gill filaments in *B. sowerbyi* in Lake Biwa and the attached lakes

Locality	Depth (m)	No. specimens	Without gills	With gills	No. gills paired	
			%	%	Mean	Range
The north basin	>90	152	100	0	–	–
	90 > > 70	440	99	1	7.3	6–10
	70 > > 50	147	99	1	8.0	8
	50 > > 30	52	100	0	–	–
	30 > > 10	51	53	47	14.0	7–26
	<10	179	69	31	24.1	6–60
The south basin	<5.5	52	15	85	17.1	5–56
Attached lakes	<1	24	0	100	68.0	38–105

of the whole area of the lake. On the other hand, 38 (90%) species live in the south basin, though it covers only 9% of the whole lake area. They can be categorized into four groups on the basis of deep distribution patterns in the lake, that is, littoral (0–10 m deep, covering the whole area of the shallow south basin; 26 spp.), littoral to sublittoral (0–30 m; 3 spp.), sublittoral to profundal (> 30 m; 3 spp.), and eurybathyal (13 spp.) (Nishino et al. 1999; Ohtaka, unpublished). The highest oligochaete diversity was found in the littoral zone, where more than 90% of the entire Lake Biwa fauna was found (Nishino et al. 1999). The littoral zones of Lake Biwa are also characterized by being rich and abundant in naidines. This could be due to the heterogeneous nature of the habitats, which include various kinds of substrates, rich aquatic vegetation, as well as large seasonal changes in water temperatures (Nishino et al. 1999).

Profundal bottoms harbored 16 species. Most of them are eurybathyal, but a phreodrilid, *A. ryuteki*, was found only from the profundal zone, and two tubificines, *Tubifex tubifex* (Müller 1774) and *Limnodrilus profundicola* (Verrill 1871), are restricted to sublittoral and profundal zones.

Forty-four species of aquatic oligochaetes were recorded from 20 small attached lakes (*naiko*) adjacent to Lake Biwa, based on a 2001–2002 survey (Ohtaka and Nishino 2006). No distinctive oligochaete fauna can be seen in individual naiko, but as a collective body they maintain a rich fauna. The naiko's fauna was richer in naidines, while poorer in other groups of oligochaetes than those in Lake Biwa, and basically can be regarded as an extension of the fauna of the littoral zone of Lake Biwa. Epiphytic oligochaetes were more diverse and more abundant in the naiko than those in the littoral zone of Lake Biwa, probably due to higher temperatures, denser aquatic vegetation, and higher primary production. The oligochaete species composition in the naiko changed seasonally; the summer assemblages were predominated by *Stylaria fossularis* Leidy, 1852 and include several species characteristic of subtropical and tropical Asia, for example, species of the genera *Pristina*, *Allonais*, *Dero*, and *Aulophorus*.

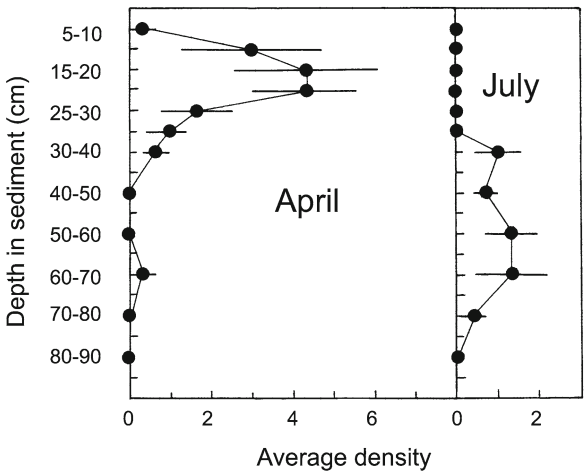

Fig. 2

Average densities of *Rhyacodrilus hiemalis* at various depths of sediment in April (16 and 23) and June (4 and 23) 1984. Average density indicates the number of specimens in an area of 119 m² of sediment of each section. Sediment samples were sectioned at 5 cm intervals to 30 cm, and 10 cm intervals below 30 cm (Modified from Narita 2006).

Ecological Aspects of Oligochaetes

As in many other lakes, oligochaetes are one of the most abundant zoobenthos in Lake Biwa, especially in the profundal zone (e.g., Miyadi 1932; Mori 1978). In a 1992–2000 survey of the deep profundal zone of the lake (50–90 m), annual mean density and annual mean biomass of oligochaetes were recorded as 5,000–15,000/m² and 8–15 wet g/m², respectively (Nishino and Ohtaka, unpublished). Samples were dominated by *T. tubifex* in number (70–85%) and *B. sowerbyi* in biomass (54–75%).

Peculiar summer aestivation (i.e., dormancy of animals in summer) in deep layers of sediment was studied in *Rhyacodrilus hiemalis* Ohtaka, 1995 (Rhyacodrilinae) in Lake Biwa (Narita 2006). In the south basin, the worms migrated downward from April, and almost all worms remained deeper than 30 cm (up to 90 cm) in mud and aestivated there between June and September (Narita 2006) (*Fig. 2*). They returned to the sediment surface from October and grew rapidly and bred during the winter season there. *R. hiemalis* is annual and breeds only once during its lifetime. They attach their cocoons to solid surfaces on the sediment, mostly shells of bivalves and gastropods (Narita 2001). A very similar ecology was observed in the same species from other localities in Japan, such as Lake Kitaura (Ohtaka 1995; Ohtaka and Kikuchi 1997) and Lake Suwa (Takada et al. 1992, under the name of *Rhyacodrilus* sp.). The summer migration to deeper layers of sediment is believed to be an avoidance behavior against high temperatures in the top layers of sediment. The life-history traits of seasonal vertical migration and summer aestivation can arise as an adaptation to the warm water conditions accompanying the geographically north origin of *R. hiemalis*, and they also serve to minimize predation risk during summer when most benthivorous fishes are active (Ohtaka and Kikuchi 1997; Narita 2006). The life histories of other Lake Biwa oligochaetes have not been studied.

Long-Term Changes in Oligochaete Fauna

Our knowledge of the oligochaete fauna in Lake Biwa is mostly restricted to studies conducted in the last few decades, and faunal changes cannot be detected in detail. Nevertheless, some distributional changes can be noted for some species. In particular, Stephenson (1917) once recorded unidentified lumbriculids and a criodrilid (*Biwadrilus bathybates*) from the profundal zone of the

lake. However, recent repeated surveys since 1986 have not been able to confirm their occurrences in such deep habitats (Nishino et al., unpublished). The disappearance of such profundal fauna might be caused by some recent environmental changes in the lake.

Acknowledgments

We wish to thank Dr. R. J. Smith of Lake Biwa Museum, Japan, for his critical reading of the manuscript.

2.4.4 Mollusca of Lake Biwa and its Long-Term Changes

Machiko Nishino

Abstract Of 56 indigenous mollusc taxa, that is, 36 gastropods and 20 bivalves that have been reported from Lake Biwa so far, 29 species and/or subspecies are endemic. The pleurocerid snail *Semisulcospira* (*Biwamelania*) comprises 15 endemic species, and is regarded as the sole species flock in the lake. The annual shellfish catch reached 7,500 tons in 1958, about three times larger than the fish catch of the lake. However, it has decreased rapidly since 1960, by the inflow of pesticides and overfishing in subsequent years. Comparison of the mollusc biomass from 1953 to 2002 revealed that the large endemic bivalves such as *Cristaria plicata clessini* and *Hyriopsis schlegeri*, and *Corbicula sandai* had greatly decreased from 1953 to 1969, and a gastropod *Sinotaia quadrata historica* and small bivalve *Unio douglasiae biwae* had increased from 1969 to 1995. The latter two prefer a muddy substratum, which actually increased in 1995 and 2002. Thus, the dominant species shift reflects the substratum changes. The decrease of unionid mussels caused the decrease of the indigenous bitterling fishes, through their symbiotic relationships.

Keywords Species flock • Endemic species • Shellfish catch • Long-term changes • Symbiotic relationship

Relation between Man and Molluscs

The largest freshwater shell mound in Japan is located at the south end of Lake Biwa, called "Awazu Lake Site." It was formed during the Jyomon Period, about 5,000 years ago (BC 3000) (Sect. 4.1.1). "The Third Shell Mound at Awazu Lake Site" has an area of 100 × 70 m and is located on the bottom in water at 2.5–3 m deep of the outlet Seta River. The major shell species composing the mound is an endemic corbiculid bivalve called "Seta-shijimi" (*Corbicula sandai*). Other kinds of shells were also found from the mound, such as a gastropod *Heterogen longispira*, *Semisulcospira* spp., and bivalves *Anodonta lauta*, *Unio douglasiae biwae*, *Lanceolaria oxyrhyncha*, *Cristaria plicata clessini*, *Inversiunio reinianus*, and *Corbicula leana*, but not so many.

At the beginning of the nineteenth century, the first issue of the Lake Biwa fauna was published by a samurai, Mr. Yoshie Kobayashi, who lived in Hikone in the northeast of Lake Biwa (Kobayashi 1805). In his old document "Kogyoko," he introduced more than 30 kinds of fishes, four decapods, five molluscs, two amphibians, and a reptile that inhabited Lake Biwa, attached lakes, and rivers flowing into the lake, along with their distribution, habitat, and their relations with human life. He also mentioned that *Corbicula* spp. were collected commercially at Seta River around the mound.

Since Meiji Era (more than a hundred years before present), a lot of molluscs have been caught commercially and nourished by the people inhabiting the lake and its adjacent areas. The annual shellfish catch was up to 7,500 tons in 1958, which was about three times larger than the fish catch of the lake. Artificial freshwater production method for cultivating an endemic unionid mussel, *Hyriopsis schlegeri*, was established about 80 years ago, and had continued until recent years. Quite diverse mollusc fauna of Lake Biwa and high productivity of molluscs supported these large commercial demands.

Rich Mollusc Fauna of Lake Biwa

A total of 56 indigenous mollusc species or subspecies, of which 36 are gastropods and 20 bivalves, have so far been reported from Lake Biwa (Appendix 2-14). The mollusc fauna of Lake Biwa account for about 40% of the total freshwater mollusc fauna of Japan (Nishino 2009).

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However, there are several genera whose taxonomic study have not been conducted more than 50 years, such as a gastropod genus *Gyraurus* and two bivalve genera *Sphaerium* and *Pisidium* (Mori 1933, 1938a, b). Further taxonomical examination is required for these genera in Japan and its adjacent areas.

As pointed out by Nishino and Watanabe (2000), molluscs exhibit quite high endemicity in the lake. A total of 29 endemic molluscs, that is, 20 out of 36 gastropod and 9 out of 20 bivalve taxa, respectively, are endemic, comprising nearly half of the endemic taxa (61 species). Besides, 58% of the mollusc species are endemic. Among the three endemic genera that have been reported from Lake Biwa, two genera are molluscs: a gastropod *Heterogen* and a bivalve *Oguranodonta*, but both contain only one species. For most endemics consisting not only of molluscs, but also of other taxa of the lake, only one or two endemic species or subspecies have been reported from the lake for each genus or subgenus. The sole exception is the gastropod subgenus *Semisulcospira* (*Biwamelania*), composed of 15 endemic species (Nishino and Watanabe 2000).

Fossil Records

A total of 13 contemporary mollusc species, among which ten species are endemic, have been found from the Katata Formation of Paleo-Lake Biwa Group (0.4–1 million years ago), located west of the south basin. They are three gastropods, that is, *Cipangopaludina japonica*, *H. longispira*, and *Semisulcospira* (*Biwamelania*) *habei*, and ten bivalves, that is, *H. schlegeri*, *Anodonta calipygos*, *Oguranodonta ogurae*, *C. plicata clessini*, *L. oxyrhyncha*, *U. douglaceae biwae*, *Inversidens brandti*, *I. reinianus*, *C. Leana*, and *C. sandai* (Matsuoka 1987). These species have evolved and survived over more than 0.4–1 Ma. No fossil of the present mollusc species was found from the Paleo-Lake Biwa Group older than the Katata Formation.

Distribution of Molluscs in Lake Biwa

Most of the molluscs in Lake Biwa are distributed in the littoral area of the south and north basins in depths shallower than 10 m. Three species of the subgenus *Semisulcospira* exhibit limited distribution within the littoral of the lake, whereas the subgenus *Biwamelania* is represented throughout the littoral (Watanabe and Nishino 1995). Some *Biwamelania* species such as *S.* (*B.*) *niponica* and *S.* (*B.*) *morii* are restricted to rocky and/or gravel substrates, while others, such as *S.* (*B.*) *reticulata* and *S.* (*B.*) *arenicola*, occur only on the sandy and/or muddy areas. Some species, for example, *S.* (*B.*) *habei* and *S.* (*B.*) *decipiens*, are widely distributed throughout the littoral area irrespective of substratum type (Watanabe and Nishino 1995). Another species such as *S.* (*B.*) *ourense*, *S.* (*B.*) *fluvialis*, and *S.* (*B.*) *dilatata* are distributed in a quite restricted area of the littoral.

Nishino and Watanabe (2000) regarded the subgenus *Biwamelania* as a sole species flock, and assumed that *S.* (*B.*) *habei*-like ancestor had evolved in the lake, and adaptive radiation had followed there. As all the 15 species belonging to the subgenus *Biwamelania* were endemic and distributed widely in the littoral areas, *S.* (*B.*) *habei* was distributed in the littoral irrespective of the substratum, and only *habei* was found in the Katata Formation of the Paleo-Lake Biwa Group.

Three endemic bivalves, *U. douglasiae biwae*, *H. shlegeri*, and *C. sandai*, are also distributed in the sublittoral, that is, in depths of 10–30 m, of the north basin, but their density is quite low (Nishino 1991; Hayashi 1972a, b). Only two tiny endemic molluscs, a gastropod *Valvata biwaensis* and a bivalve *Pisidium kawamurai*, are distributed throughout the lake, from littoral to the deep profundal (Nishino 1991b). There was no mollusc species that inhabited only at the profundal of the lake.

Symbiotic Relations between Bivalves and Fishes in Lake Biwa

Freshwater unionid mussels exhibit a unique reproductive habit (Kondo 2008). Males discharge spermatozoa into the water as sperm spheres, and females inhale them through their inhalant siphons. After fertilization, females release glochidia larvae, which are entirely immobile, into the lake water through exhalant siphons. Waiting to make contact with the host fish on the substratum or while drifting in the water, glochidia attach to the fins or gills of some fishes, like the endemic oily minnow *Sarcocheilichthys variegatus microoculus*, field gudgeon *Gnathopogon elongatus*, and the indigenous pale chub *Zacco platypus*, pile gudgeon *Pseudogobio esocinus*, and common freshwater gobies *Rhinogobius* spp. During the metamorphosis from glochidia into juvenile mussels, they begin to digest and absorb body fluid of the host fishes and leave the hosts when metamorphosis was completed.

Opposite parasitism is known between the bivalves and the indigenous bitterling fish such as *Acheilognathus* spp., *Tanakia lanceolata*, and minnow *Sarcocheilichthys* spp. Female bitterlings lay eggs on the unionid gills by penetrating their ovipositor into the inhalant and exhalant siphons

of the bivalves. *Sarcocheilichthys* females also lay eggs on the unionid and corbiculid mantles through the bivalve's inhalant siphons. However, there is no report that the unionid glochidia attach to the bitterling fish. Anyway, during their early life unionid mussels depend on several fishes, such as *Sarcocheilichthys* and *Gnathopogon*. Reproduction of the bitterling fishes and *Sarcocheilichthys* are dependent on the unionids. Moreover, some bitterling species exhibit host specificity. For example, *T. lanceolata*'s host is *Pronodularia japanensis*, and that of *Acheilognathus rhombeus* is *U. douglasiae biwae*. This indicates that the decrease in the *Sarcocheilichthys*, *Gnathopogon*, *Zacco*, and *Rhinogobius* densities should inevitably damage the early life of the mussels. Should unionid decrease, the bitterling fishes and *Sarcocheilichthys* would fail to reproduce. Actually, the decrease in the unionid mussels is one of the major threats to the four indigenous bitterling fishes, such as *T. lanceolata* and *A. rhombeus* in Shiga Prefecture (Nishino 2009).

Long-Term Changes in the Molluscs of Lake Biwa

As stated above, shell fish catch reached the maximum of 7,500 tons in 1958, but suddenly decreased afterwards (*Fig. 1*). In 1960, a lot of water containing high concentrated herbicide (pentachlorophenol) flew into the lake, due to the heavy rain just after farmers had spread the chemicals on the paddy fields around the lake. Then, many fishes and mussels died on the fishing grounds. Shellfish catch has dropped rapidly since the following year. To respond to the rapid decrease in the catch, fishermen have begun to explore more effective catching methods since 1964 using boats with more horsepower, which inevitably led to overfishing. Shellfish catch has decreased rapidly since then. Annual catch was only 59 tons in 2007, less than a hundredth of that in 1958.

The littoral benthic animals and submerged macrophytes were surveyed four times, in 1953, 1969, 1995, and 2002, by Shiga Prefectural Fishery Experiment Station. Total shell biomass in the lake was estimated at 25,100 tons in 1953, but greatly decreased to 10,850 tons in 1969 (*Fig. 2*). A great decrease in large unionids and corbiculids and an increase in large gastropods were observed, but no information on species was available in the report of 1953. I'domoto (2001) supposed that *C. plicata clessini* and *H. schlegeri* constituted large unionids and *C. sandai* corbiculids, and that large gastropods in 1953 were composed of an endemic *H. longispira*, but that large gastropods in 1969 were composed of another snail *Sinotaia quadrata historica*.

Subsequent change in the shellfish biomass was relatively small, that is, 7,020 and 10,270 tons in 1995 and 2002, respectively. However, the changes in the dominant species had occurred between 1969 and 1995, that is, a further decrease in *C. plicata clessini*, *C. sandai*, *H. Longispira*, and *Semisulcospira* spp., and an increase in *U. douglasiae biwae*, *Anodonta* spp., and *S. quadrata historica* in 1995 and 2002, respectively. As the latter species prefer muddy substratum,

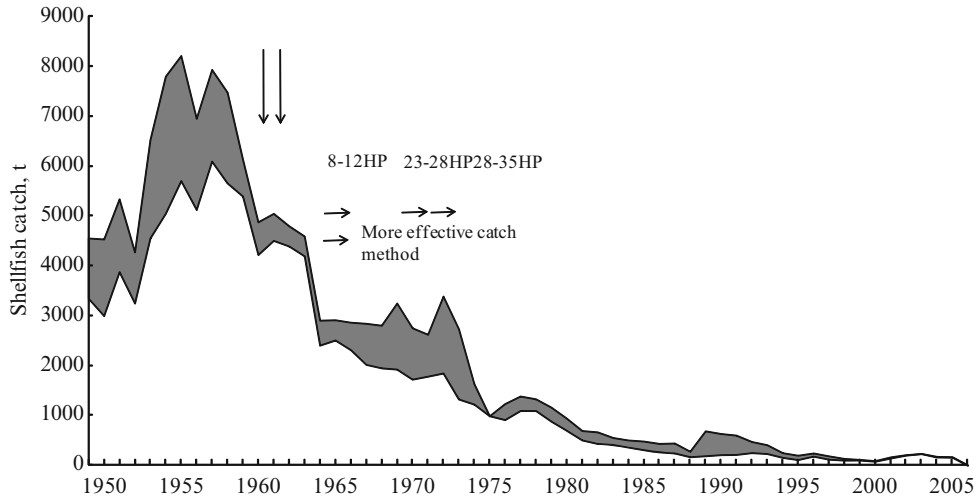

Fig. 1

Long-term changes in the shellfish catch in Lake Biwa. White: *Corbicula sandai*, Gray: other molluscs. Vertical *arrows* indicate the inflow of herbicide in 1960 and 1961. Horizontal *arrows* show the horsepower (HP) of fisherman's boats and more effective catch methods.

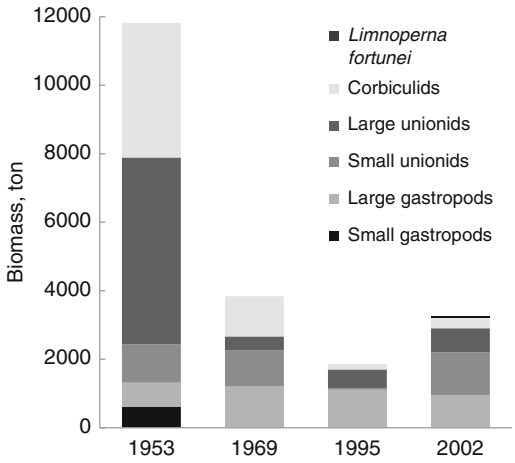

Fig. 2

Molluscan biomass of Lake Biwa in 1953, 1969, 1995, and 2002 (Data derived from Shiga Prefectural Fishery Experiment Station 1972, 1999, and 2005).

which actually increased from 1969 to 1995 (Shiga Prefectural Fishery Experiment Station 1999), the dominant species shift may reflect the substratum changes.

Mollusca in the Red List

As shown in Appendix 2, a total of 32 species, that is, 5, 7, and 20 mollusc species are designated as Critically Endangered + Endangered, Vulnerable, and Near Threatened species in the Red List of the Ministry of the Environment of Japan. In the Red Data Book 2006 of Shiga Prefecture, a total of 26 species, that is, 5, 9, and 12 species are listed as Critically Endangered, Endangered, and Rare (Nishino 2009). Both lists clearly show that almost half of the indigenous molluscs are threatened.

According to the Red Data Book 2006 of Shiga, Nishino (2009) concluded that the threats to the most numerous indigenous mollusc species were the artificial lake water level control, then lake shore improvement, water pollution, river improvement, and readjustment of paddy fields (*Fig. 3*). No mollusc was regarded as threatened by alien species. However, biomass of the Invasive Alien Species (IAS) *Limnoperna fortunei*, first found in Lake Biwa in 1992 (Sect. 3.1.4; Uenishi and Matsuda 1992), was already estimated up to 28 tons in 2002 (*Fig. 2*); alien molluscs would become threat to the indigenous species in the near future.

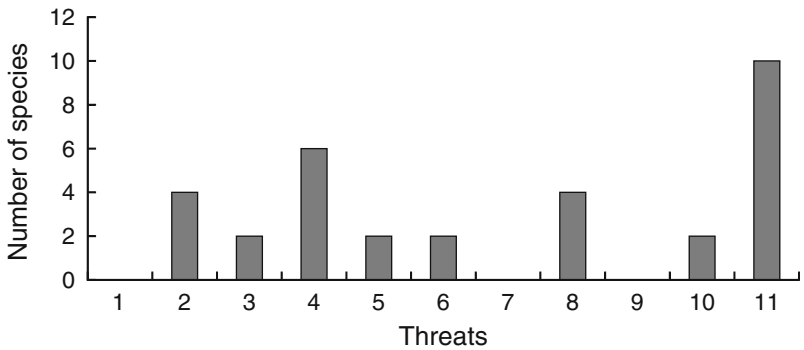

Fig. 3

Threats to respective mollusc species of Lake Biwa, designated as Critically Endangered, Endangered, and Rare in the Red List of Shiga Prefecture of 2006 (Nishino 2009). Threats are: 1; alien species, 2; construction of dikes on the shoreline, 3; river improvement, 4; artificial control of the lake water level, 5; paddy field improvement around the lake, 6; soil inflow into the rivers or the lake, 7; organic pollution or eutrophication of the rivers in the prefecture or the lake, 8; water pollution of the rivers in the prefecture or the lake, 9; destruction or loss of cold spring, due to human development, 10; overfishing, 11; other threats or threats unknown. Several threats were overlapping in a single species.

2.4.5 Crustacea of Lake Biwa

Machiko Nishino

A total of 145 crustacean species, that is, 55 cladocerans, 33 copepods, 40 ostracods, 1 branchiopod, and 16 malacostracans, are so far reported from Lake Biwa (see Appendix 2). Four endemic species are known, a planktonic *Daphnia biwae* and three benthic gammarid such as *Jesogammarus* (*Annanogammarus*) *annadalei*, *J.* (*A.*) *naritai*, and *Kamaka biwae*, and 16 ostracod species have been recorded only from Lake Biwa. A cladocera and four malacostracan species are alien.

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2.4.5(1) Cladocera of Lake Biwa

Susumu Tanaka

Abstract Sixty-six cladoceran species have been recorded from Lake Biwa, most of which were found in the littoral zone. Of the planktonic species, *Daphnia galeata* is the most important in relation to the landlocked dwarf ayu-fish. The taxonomic status of *Daphnia biwaensis*, an endemic species of the lake, is also discussed.

Keywords Cladocera • Plankton • meiobenthos • *Daphnia galeata* • *Daphnia biwaensis*

Cladocera, which has no taxonomical significance, is a group of small-sized branchiopod crustaceans. Their total lengths are commonly 0.5–5 mm. Cladocera occur widely in freshwater and marine habitats, and they are grouped into 4 orders, 19 families and 102 genera. About 620 species are currently known in the world (Forró et al. 2008), and about 90 species have been reported from freshwater habitats of Japanese Islands (Tanaka, unpublished data). From Lake Biwa, 66 species have been recorded until now (Tanaka et al. 2004). But, the record includes several species must be re-examined. The numbers of species both in Japan and in Lake Biwa will increase in future if we advance the investigation of cladoceran fauna actively.

Most of cladoceran species recorded from Lake Biwa are recognized ecologically as meiobenthos, which are collected from the littoral zone of the lake (Dodson and Frey 1991). On the other hand, relatively a few plankton species have been collected from pelagic zone of Lake Biwa. The plankton species of Lake Biwa are represented by four species, *Daphnia galeata*, *Diaphanosoma macrophthalma*, *Bosmina longirostris*, and *Leptodora richardi*. Especially, *Daphnia galeata* occurs abundantly in pelagic zone, and it is known as a good prey for planktivorous fishes represented by the landlocked dwarf ayu-fish (Kawabata et al. 2002).

The pelagic species of the genus *Daphnia* were also confused with regard to their taxonomic status and their assignment. The species had long been recorded under various names such as *D. longispina* (Narita & Okamoto 1984), *D. longispina hyalina* (Uéno 1934, 1937), *D. hyalina* (Uéno 1973), *D. longispina galeata* (Uéno 1937), and *D. galeata* (Uéno 1973a). But, the detailed morphological investigation showed that only one species, *Daphnia galeata* Sars, existed in the limnetic zone of Lake Biwa (Tanaka 1992).

Another species, *Daphnia biwaensis*, was, however, recorded from limnetic zone of Lake Biwa. It was explained as a race of *Daphnia pulex* (Uéno 1934). Uéno (1934) wrote as follows: of many races examined, the one living in Lake Biwa was ecologically a very peculiar form which was probably a heritably fixed biotype and represented so far a race endemic in this lake. Uéno (1934) also wrote this was a rather large *Daphnia* with an extremely hyaline broad valve and with well-developed combs on the terminal claws of the postabdomen. He also pointed out that *D. Biwaensis* was the only pelagic race of Daphnia pulex found in Japanese lakes. This race was recognized as a biotype fixed genetically (Uéno 1934) and established as a species, *Daphnia biwaensis*, by Uéno (1965).

The population size of *D. biwaensis* seemed to be very small at that time (Uéno 1939). Since then, unfortunately, we have no information on *D. biwaensis*. And, some problems exist concerning on the *Daphnia biwaensis*; first Uéno (1934 or 1965) have not designated the type specimens and given the incomplete description of the species, and secondary there are no specimens confirmed now. Monograph on genus *Daphnia* recently published (Benzie 2005) did not list *D. biwaensis*, and the recent checklist of Cladocera (FADA database: Kotov 2009) treated *D. biwaensis* as *species inquirenda*. We need to search the specimens of *Daphnia biwaensis* and to re-describe the species based on type specimens.

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In the winter of 1999, *Daphnia pulicaria* Forbes, which belonged to the *D. pulex*-group similar to *D. biwaensis*, suddenly emerged in the limnetic zone of Lake Biwa. Then, its population disappeared in the autumn of that year leaving ephippial eggs. *D. pulicaria* were commonly distributed in the lakes or ponds of Europe and North America, but they were not distributed naturally in Japan. The population of *D. pulicaria* in Lake Biwa was genetically related to the populations inhabited the western regions of North America (Urabe and Ishida 2003). The occurrence of such an invaded species indicates possible occurrence of another cladoceran species to the lake fauna may always happen in Lake Biwa.

2.4.5(2) Pelagic Copepods

Keiichi Kawabata

Abstract Three species of planktonic copepods have been recorded from the pelagic area of Lake Biwa: one calanoid, *Eodiaptomus japonicus*; and two cyclopoids, *Mesocyclops dissimilis* and *Cyclops kikuchii.*

Their ecology is reviewed, with particular attention to population dynamics in the late twentieth century and ontogenetic niche shifts. The pelagic food web of Lake Biwa is also discussed as regards the trophic relationships of these copepods.

keywords • *Eodiaptomus japonicus* • *Mesocyclops dissimilis* • *Cyclops kikuchii* • Population dynamics • Predation • Vertical distribution

Introduction

Three species of planktonic copepods have been described from the pelagic area of Lake Biwa: one calanoid, *Eodiaptomus japonicus*; and two cyclopoids, *Mesocyclops dissimilis* and *Cyclops kikuchii* (Fig. 1).

Two copepod species were collected from Lake Biwa on 26 October 1898. Burckhardt (1913) firstly described them as *Diaptomus japonicus* n. sp. and *Cyclops leuckarti* Claus 1857, respectively. They are now classified as *Eodiaptomus japonicus* (n. gen. Kiefer 1932) and *Mesocyclops dissimilis* Defaye et Kawabata 1993, respectively. The third species, *Cyclops kikuchii* Smirnov 1932, has been treated as *C. vicinus* (Ishida 2002). The other 12 cyclopoid species are confined to the littoral zone, and they have not been collected from the pelagic area of the lake (Ishida 2002).

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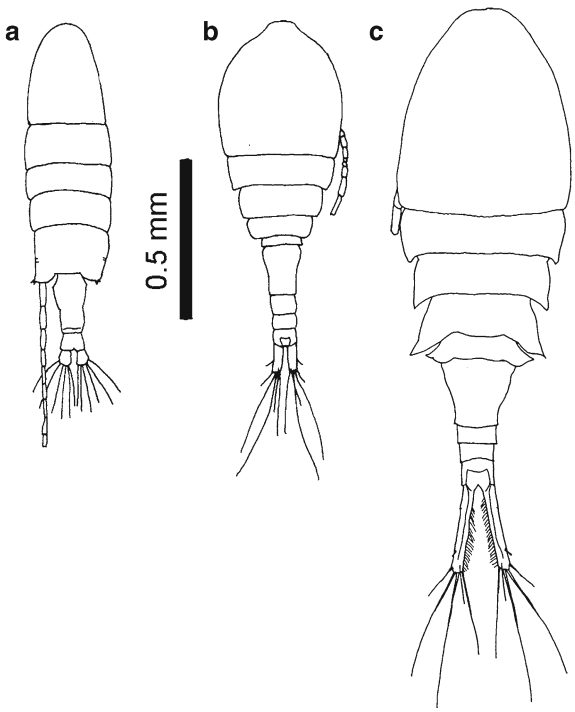

Fig. 1
Adult females of *Eodiaptomus japonicus* (a), *Mesocyclops dissimilis* (b), and *Cyclops kikuchii* (c).

Population Ecology

The following three groups of researchers studied the zooplankton abundance in the north basin in different periods of the late twentieth century: Narita and Okamoto (1984) from April 1974 to April 1975, Kawabata (1987, 1989) from January 1984 to December 1986, and Yoshida et al. (2001) from April 1997 to June 1998. Although the abundance of other zooplankters fluctuated, *E. japonicus* was the most dominant species in all periods. The dry mass density of *E. japonicus* (g/m^2) showed the following

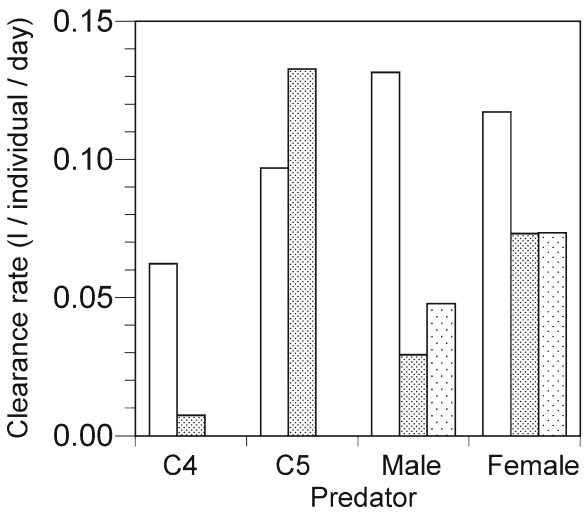

Fig. 2
Clearance rate of C4, C5, adult male and female *Mesocyclops dissimilis* on *Eodiaptomus japonicus* in N2/3 (clear), N5/6 (shaded), and C2/3 (dotted) (Modified from Kawabata 2006).

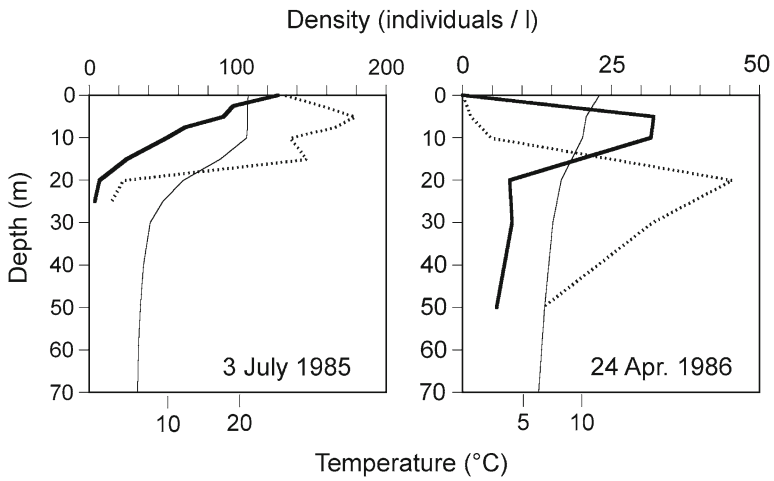

Fig. 3
Vertical distribution of *Eodiaptomus japonicus* (bold), *Mesocyclops dissimilis* (3 July 1985, dotted), *Cyclops kikuchii* (24 April 1986, dotted), and water temperature (fine) (Modified from Kawabata 1987, 1989).

peak value in each period: 1.2 in July 1974, 10.0 on 5 November 1986, and 5.0 in early April 1998. Thus, zooplankton mass seems to have increased after the 1980s.

Community Ecology

Copepods develop through six naupliar (N1–N6) and five copepodid (C1–C5) stages up to adulthood with showing ontogenetic niche shifts. As for their feeding ecologies, all copepods in Lake Biwa consume planktonic algae and protozoa, and the two cyclopoids also prey on rotifers and crustaceans in the late developmental stages. In the epilimnion of the stagnation period, C4-adult *M. dissimilis* is one of the most important predators of juvenile *E. japonicus* (Kawabata 2006).

The clearance rate of *M. dissimilis* upon *E. japonicus* increased with the development of predators and decreased with that of prey (*Fig. 2*). Assuming a clearance rate of 0.1 l/individual/day, 10 predators in 11, a common density in Lake Biwa (cf. *Fig. 3*), consume all prey within the volume in a day. This ability of predators to reduce prey population ascertains the predator–prey cycle of *M. dissimilis* and *E. japonicus* in April–June of 1984 and 1985 (*Fig. 4*). The ecology of *C. kikuchii* has been, however, seldom studied.

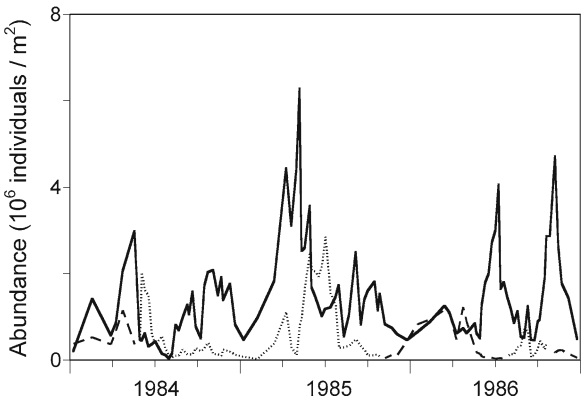

Fig. 4

Temporal changes in abundance of *Eodiaptomus japonicus* (solid), *Mesocyclops dissimilis* (dotted), and *Cyclops kikuchii* (broken) (Modified from Kawabata 1987, 1989).

Conclusion

Of three pelagic copepods in Lake Biwa, *E. japonicus* has been the most dominant species during the late twentieth century. Recently, eutrophication, climate change, and invasion of alien species in the lake have been changing aquatic environment of the lake. Therefore, the dynamics of the keystone species, *E. japonicus*, should be continuously studied. In addition, the complex relationships among living organisms surrounding *E. japonicus* should also be investigated in conjunction with the epistemological and methodological renovations.

2.4.5(3) Malacostraca

Machiko Nishino

Abstract A total of 16 malacostracan species have so far been reported, of which three amphipod species are endemic. A widely distributed shrimp *Palaemon paucidens* in Lake Biwa exhibits egg size and genetic differences from other populations in Japan, suggesting the genetic and phenotypic differentiation of Lake Biwa population. Among the four alien species that have been reported, two species were transplanted more than 70 years ago, and another two have recently invaded.

Keywords *Palaemon paucidens* • Egg size • Genetic differences • Unintentional invasion

Origin of the Endemic Species

Of the total of 16 malacostracan species so far reported from Lake Biwa, three amphipod species, *Jesogammarus* (*Annanogammarus*) *annandalei*, *J.* (*A.*) *naritai*, and *Kamaka biwae* are endemic. Based on the cladistic analysis of morphology, Morino (1994) postulated that *J.* (*A.*) *annandalei* and *J.* (*A.*) *naritai* had evolved from different ancestors: *annandalei* from an ancestor distributed over Korea and Japan and which invaded the lake about 100,000 years ago, and *naritai* was from an ancestor distributed in Japan like *J.* (*A.*) *suwaensis* in Nagano Prefecture, and which invaded afterwards. Based on the phylogenetic analysis with mitochondrial COI and 12S sequences for 16 *Jesogammarus* species, Tomikawa et al. (2007) found that the subgenus *Annanogammarus* including both species was monophyletic as Morino (1994) suggested, but *suwaensis* and *naritai* showed a close affinity. Thus, they assumed that *suwaensis* was the synonym of *naritai*, and that *naritai* had been transplanted from Lake Biwa to Lake Suwa recently. As they did not analyze the *Jesogammarus* in Korea, further studies are required to examine Morino's hypothesis.

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On the origin of *K. biwae*, several scientists supposed marine glacial relict. Akiyama (2007) compared its morphology with the newly described *Kamaka morinoi* widely distributed in the freshwater and brackish areas in Honshu and Kyushu. As morphology of both species are closely resembled, he supposed that *biwae* was derived from *morinoi*. In order to identify its origin, genetic analysis is inevitable, as in *Jesogammarus*.

Intraspecific Variation of *Palaemon paucidens*

A striped shrimp *Palaemon paucidens* is widely distributed in Japan and Sakhalin, and females in Lake Biwa bear more numerous and much smaller eggs than those in other populations (Nishino 1980). Nishino (1984) compared the larval development of three lake populations and found that it took 2 more months for metamorphosis for the larvae in the Lake Biwa population than in the rest populations. Through electrophoretic analysis of the 20 geographical populations of this species, Chow et al. (1988) showed that this species could be divided into two types: the A-type included the Lake Biwa population and 11 populations from all over Japan, inhabiting lakes, ponds and rivers, whereas B-type was found only in rivers in East Honshu. The A-type populations exhibit great variation both genetically and in egg size, whereas little variation is seen among the B-type populations. Based on the mating experiments, they concluded that the A- and B-types are different biological species. As Lake Biwa population differs greatly both genetically and in egg size from other geographical populations of A-type, it is supposed to have undergone genetic and phenotypic differentiation.

Alien Species

A total of four alien species are reported from Lake Biwa, in which two species are translocated for the fisheries stock enhancement: red swamp crayfish *Procambarus clarkii* from the USA in mid-1930s, and a caridean shrimp *Macrobrachium nipponense* from Kasumigaura Lake in

Ibaragi Prefecture during 1910s-1930s. Another two species were introduced into the lake unintentionally. An alien *Crangonyx floridanus* was firstly found in an attached lake, Nishino-ko, in 2006 and in Lake Biwa next year (Nishino 2007). This amphipod settled in the late 1980s into Tokyo or Yokohama, where large-scale importation ports have been historically developed, then spread rapidly in Japan. Morino et al. (2004) supposed that these species have been transported accidentally with imported freshwater organisms like aquatic plants. Another caridean shrimps *Neocaridina* spp. were firstly detected in the lake in 2001 (Nishino and Niwa 2004). This species lives in a very shallow areas, where the alien largemouth bass *Micropterus salmoides* and bluegills *Lepomis macrochirus* do not visit (Nishino 2008). This is the reason why this shrimp has successfully invaded and settled in all over Japan, as the alien fishes often feed on the indigenous shrimps such as *P. paucidens* and *Paratya compressa compressa*.

2.4.5(4) Ostracods of Lake Biwa

Robin J. Smith

Abstract Forty species of ostracods have been reported from Lake Biwa, including 12 species of the genus *Fabaeformiscandona* and five species of the genus *Limnocythere*. Sixteen species are only known from Lake Biwa, but due to the lack of studies of lake ostracods in other parts of Japan, it is unknown how many of these are endemic. The shallow depths of Lake Biwa support the highest diversity, with diversity rapidly decreasing below the summer thermocline. Only three species are found in the deepest parts of the lake, with one of these species restricted to the deep zone.

Keywords Crustacea • *Fabaeformiscandona* • *Limnocythere* • depth • thermocline.

Introduction

Ostracods (seed-shrimps) are small crustaceans, typically 0.4–2 mm in length, which live in many types of aquatic environments, including the sea, rivers, springs, lakes, temporary puddles, rice fields, and even wet leaf litter. They have an excellent fossil record, stretching back about 450 million years, due to their hard, calcitic shells that readily fossilize. The shell consists of two valves that are hinged along the back and precisely fit together to protect the body and appendages (*Fig. 1*). Experiments have shown that their shells can even protect them from fish predation; 26% of specimens of *Cypridopsis vidua* (Müller 1776) fed to bluegill sunfish (*Lepomis macrochirus* Rafinesque, 1819) in an aquarium survived passage through the fish's guts unharmed (Vinyard 1979). This species of ostracod and bluegill are both very abundant in Lake Biwa.

Inside the shell, the limbs typically number eight pairs, each pair with a different shape and function. The limbs are protruded through the opened shell to swim, walk, feed, and reproduce. Male cypridoidean ostracods have two sexual organs, eight testes and two powerful sperm pumps, producing a copulatory system that can take up a significant volume within the shell (McGregor and Kesling 1969). Both sexual organs are used simultaneously during copulation, paired with twin vaginal openings in the females. Each species has differently shaped male sexual organs, an ostracod species' equivalent of an identity "mug shot" for the researchers studying them, particularly useful for the numerous *Fabaeformiscandona* species living in Lake Biwa. Some other groups, however, lack males altogether, such as the darwinulid ostracods found in Lake Biwa. These species consist of all female populations that reproduce by cloning themselves, a feat made possible by the infection of the eggs with parasitic bacteria.

In the lake, ostracods typically live on or in the top layers of sediments, from fine mud through to coarse sands and gravels. Some groups have appendages equipped with long setae used for swimming from place to place, while others that lack such long setae are restricted to walking. Even species capable of swimming spend a long time on the bottom rather than in the water column, and are therefore not plankton. Little is known about the feeding habits of ostracods, but they are generally considered to be opportunistic, consuming organic detritus, algae, and dead plant and animal matter.

Research of Lake Biwa's Ostracod Fauna

Research of Lake Biwa's ostracods started late compared with other animal groups. Only in 1990 was the first ostracod reported, a new species named after the lake, *Physocypria biwaensis* Okubo, 1990. Over a decade later, the second species was reported, the cosmopolitan *Darwinula stevensoni* (Brady and Robertson 1870), and in 2004 a further six named species were reported, plus another eight species not identified to the species level (Okubo 2001, 2004). Surveys carried out mostly between 2005 and 2007 revealed a total of 40 species living in the lake, and of these, 16 species were newly described (Smith and Janz 2008, 2009; Smith et al. 2011). However, it is unlikely that this represents the entire ostracod fauna of

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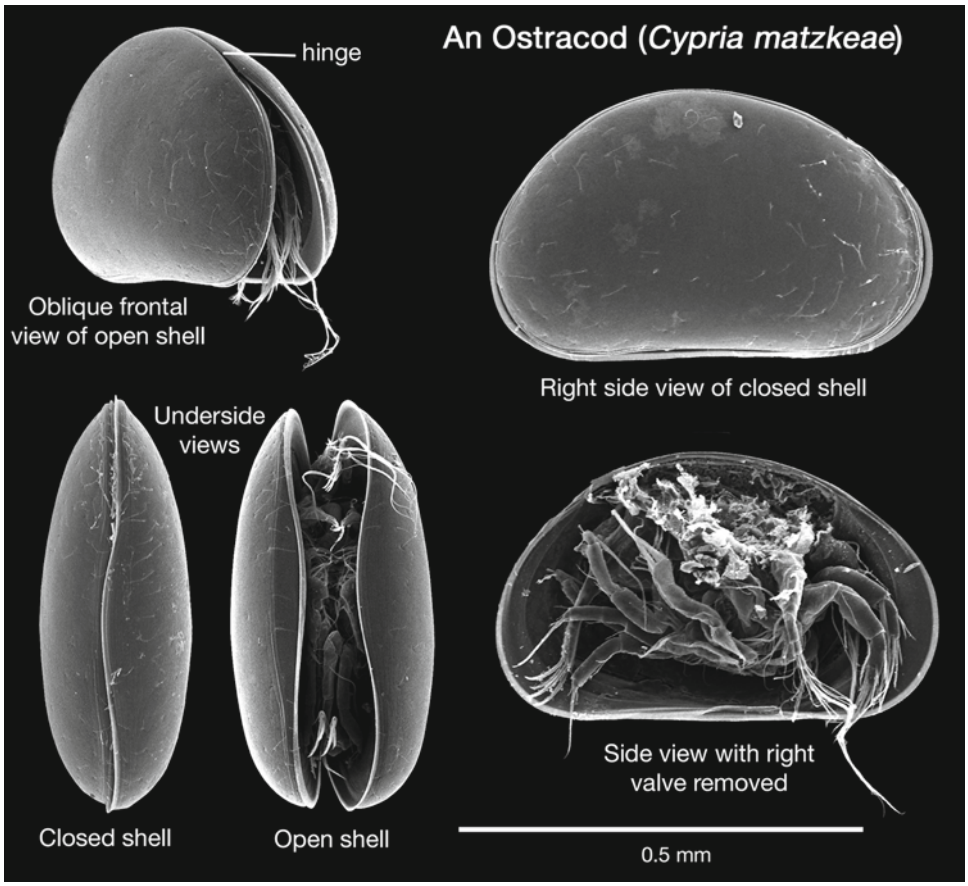

Fig. 1
The ostracod *Cypria matzkeae* from Lake Biwa.

the lake, and there are probably other ostracod species yet to be discovered.

Of the 40 species known, the majority belongs to the Family Candonidae of the Superfamily Cypridoidea, including 12 species of the genus *Fabaeformiscandona* (*Fig. 2*). Nine of these *Fabaeformiscandona* species are currently only known from Lake Biwa. Research on the morphology of the appendages and the male sexual organs suggests that there are at least three, maybe five lineages of this genus in the lake, indicating that this genus repeatedly invaded the lake basin and is not the result of one species diversifying there (Smith and Janz 2008). The second most diverse genus in Lake Biwa is *Limnocythere* (Superfamily Cytheroidea, Family Limnocytheridae), represented by five species (*Fig. 2*). One of these, *Limnocythere stationis* Vávra, 1891, is found in Europe, Russia, and Africa, but the other four have so far only been found in Lake Biwa (Smith and Janz 2009). How many species are endemic in the lake is a question that cannot be answered at present as other lakes in Japan have yet to be investigated for comparisons.

The shallow depths support the highest diversity of ostracods in Lake Biwa, with 34 species (87.5% of the total) found between 0 and 5 m depths during recent surveys (*Fig. 3*) (Smith et al. 2011). During the summer an internal boundary, termed a thermocline. develops at approximately 10–20 m depth, separating a warm top layer and a much cooler, hence denser, lower layer. Due to the differences in densities, these two layers cannot mix, until the winter, when the cooling of the upper layer allows the two layers to intermingle. The number of ostracod species decreases with depth, so that below the thermocline,

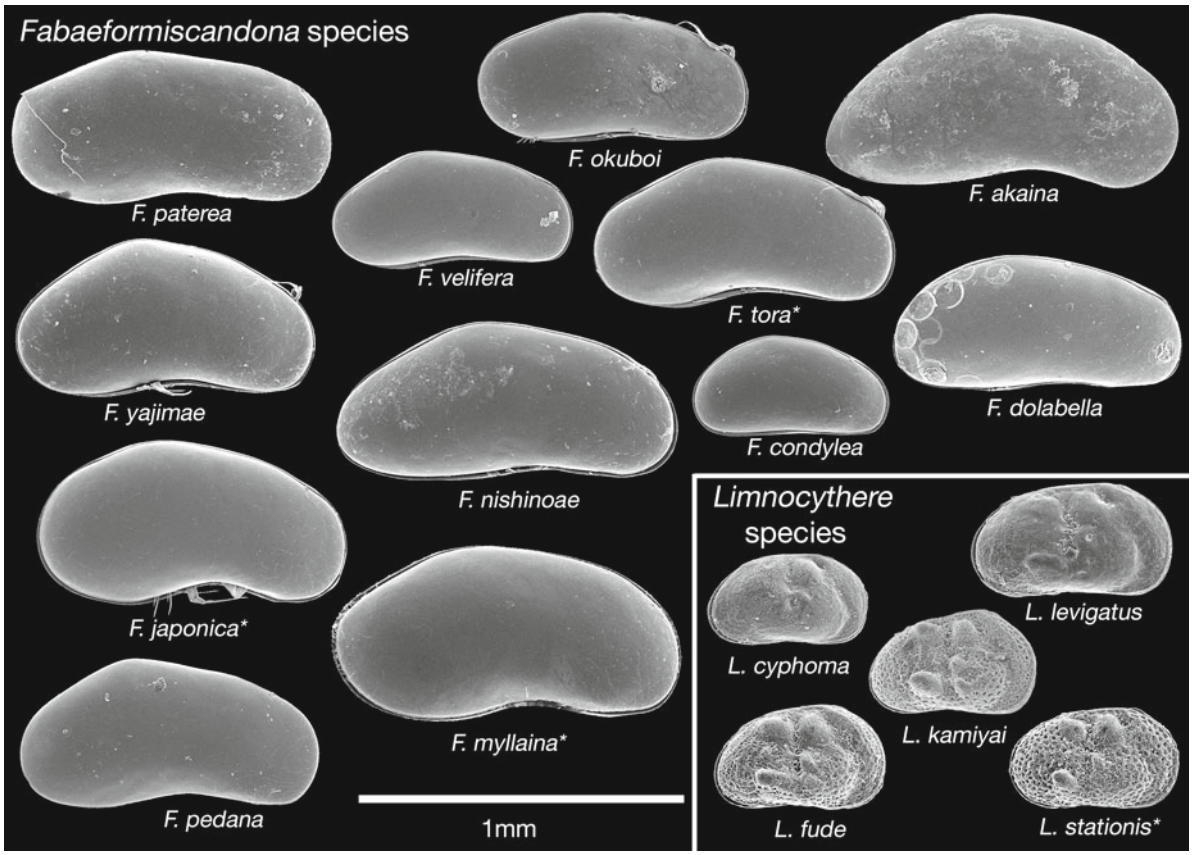

Fig. 2
Right views of the shells of the two most diverse ostracod genera in Lake Biwa. *Indicates species also found outside of Lake Biwa.

at a depth of 20–25 m, only 11 species were recovered. Deeper still, the diversity reduces further to two species at 50–60 m depth, but below this the diversity increases by one, due to the presence of *Fabaeformiscandona nishinoae* Smith & Janz, 2008, a species that was only found below 66 m depth.

Some of the shallow water species found in Lake Biwa are also found in rice fields, and it is not clear at present if such species have permanent breeding populations in the lake. Water from Lake Biwa is used to fill rice fields, and water from surrounding rice fields is drained into the lake basin. It is possible that rice fields are the source of some species, producing temporary, albeit re-occurring populations along the lakeshores. If this is the case, then human activity is directly influencing the ostracod fauna in the lake.

Future Research

It is recognized that ostracods have a high potential to act as bio-indicators of environmental changes, although such research has yet to be fully exploited (e.g., Holmes and Chivas 2002). The documentation of the ostracod species found in Lake Biwa is the first stage in utilizing this potential in Shiga Prefecture and Japan and can act as a benchmark for future studies. Ostracods can be used for various environmental studies, because they are sensitive to numerous pollutants (e.g., Sancho-Bayer 2006). Some ostracod species found in Lake Biwa may be useful in monitoring changes in the deep-lake environment. *Cytherissa lacustris* (Sars 1863), a species found between 25 and 87 m in Lake Biwa, has been used in Europe as a bio-indicator of deteriorating deep-lake conditions; if

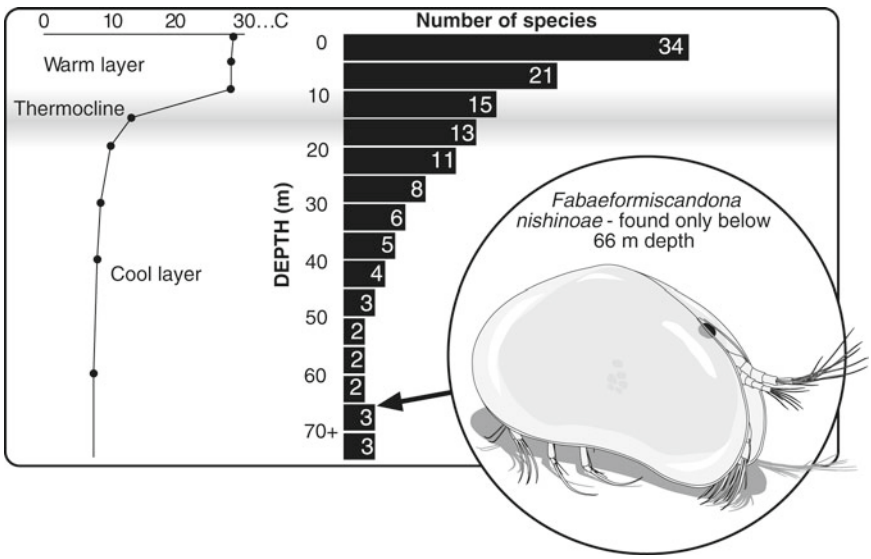

Fig. 3
Number of ostracod species found at depths of 5 m intervals, and the temperature of the water during August (temperature data was measured on 17 August 2000 by the Lake Biwa Environmental Research Institute). Inset: illustration of *Fabaeformiscandona nishinoae* in oblique lateral view.

oxygen levels decline, the species' abundance also declines (Danielopol et al. 1990).

On a longer time-scale, variations in the shell chemistry of ostracods have been used in Europe and North America to deduce changes in isotopic composition of lake water over time, which is linked to climatic changes (e.g., von Grafenstein 2002; Ito 2002). Additionally, differences in species composition have been used to indicate long-term environmental and climatic changes, for example, in the Lake Titicaca region (e.g., Mourguiart and Montenegro 2002). Such research techniques have not yet been applied to the ostracods of Lake Biwa, but this group has a potential to be a useful tool in future environmental studies of Shiga Prefecture and Japan.

2.4.6 Aquatic Insects

Machiko Nishino

More than 310 insect taxa have so far been reported from Lake Biwa and its adjacent water bodies (see Appendix 2). It consists about 29% of Ephemeroptera (27 out of 142 species), 25% (54 out of 214) of Odonata, 15% of Trichoptera (55 out of ~350), 15% of Chironomidae (158 out of ~1,000) of species recorded in Japan (see Chap. 2, Appendix 2). As some taxa such as Hemiptera, Coleoptera, and Diptera excluding Chironomidae have not well been studied taxonomically, their species number is unknown. Chironomidae is the most species-rich family among all animals and plants in Lake Biwa and occupied more than half species of the aquatic insects in the lake (Nishino 2001; Sect. 2.4.6(3)).

In contrast to the species richness, endemicity of aquatic insects is quite low. Only two species are recognized as endemic, that is, a mayfly *Ephoron limnobium* and a caddisfly *Apatania biwaensis*. Another two mayfly and seven chironomid species have never been reported other than Lake Biwa, and some of them may be regarded as endemic in the future.

Most of the aquatic insects inhabit the littoral areas. Their species richness reflects the diverse habitat of the littoral, that is, rocky shore, pebble shore, sandy shore, and vegetated shore covered with the reed *Phragmithes* spp. (Sect. 3.1.1, Topic 7). For example, a mayfly *Ecdyonurus yoshidae*, a stonefly *Neoperla geniculata*, and a beetle *Eubrianax ramicornis* are distributed only in the rocky or pebble shore, whereas the endemic *E. limnobium* and a caddisfly *Dipseudopsis collaris* inhabit in the sandy or vegetated shore in the north basin (Nishino 1992, Sect. 2.4.6(2). Most of the inhabitants of the rocky and pebble shores also live in streams and rivers surrounding the lake. The endemic caddisfly *A. biwaensis* is also distributed in the rocky or pebble shores and considered to be derived from the congeneric river species *A. tsudae* (Nishimoto 1994). Another example is the species in lentic waters, such as a mayfly *Cloeon dipterum* and a beetle *Rhantus pulvelosus*, which are distributed in the vegetated shore. Various kinds of littoral habitat of Lake Biwa may support the diversity of aquatic insects.

On the other hand, not so many aquatic insects were found in the sublittoral or profundal bottoms, most of which are chironomids. No species was recorded only in the sublittoral or profundal bottoms of the lake.

The faunal change and decrease of aquatic insects in the lake is apparent (see Sects. 2.4.6(2), 2.4.6(3) and 2.4.6(4)). The endemic hemipteran *A. kawamurae* lived in the bottom of Lake Biwa as well as in the sandy bottom of the Lake Biwa Canal (Topic 21). Since 1960s, it has never been found, and is designated as Critically Endangered in the Red List of the Ministry of Environment. As of little information on its ecology, the reason of its disappearance is unclear. But the major reason of the decrease of indigenous aquatic insects is considered to be the reclamation of the attached lakes or *naiko*s, eutrophication, construction of levees on the shore and decrease of water levels in the long run since 1960s, and the summer drought caused by the water level control since 1992 (see Sects. 2.4.6(2), 3.1).

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2.4.6(1) Mayflies of Lake Biwa

Shin-ichi Ishiwata · Machiko Nishino

Abstract Eighteen species (taxa), 14 genera, and 9 families of mayflies have been recorded from the Lake Biwa region, of which the nymphs of 11 species (taxa) are lake inhabitants. The nymphal habitats are described citing previous records. The diversity of the genus *Ephoron* is discussed. The distinguishing characters and mating behavior of the endemic mayfly *Ephoron limnobium* are described. The population dynamics of a mayfly is reported, suggesting some recent environmental changes in the lake.

Keywords Mayfly • Distribution • *Ephoron limnobium*

Introduction

Over 3,000 species of mayflies (Order Ephemeroptera), in 400 genera and 42 families, have been described worldwide (Barber-James et al. 2008). From Japan a total of 142 species, 39 genera, and 13 families of mayflies have been reported (Ishiwata and Takemon 2005). Mayflies are one of the most common and important members of the freshwater community since most species form a fundamental link in the freshwater food chain and have proven to be very useful in the analysis or biomonitoring of water environments. In spite of their importance, there is a lack of understanding of their taxonomy, biology, and ecology. The purpose of this study is to determine the composition on the mayfly fauna of the Lake Biwa region and to provide a summary of their ecology.

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Overall View of Lake Biwa Mayflies

Mayfly nymphs of Lake Biwa have been investigated by Kawamura (1918), Kawabata (1963), Takao (1964), Kumode (1965), and Mori and Miura (1980). A summary of previous investigations, as well as the original data of nymphs and adults with notes on ecology, were published by Kobayashi and Nishino (1992); their list of mayfly species includes 16 species (taxa). The most recent list of mayflies in Lake Biwa included 9 families, 14 genera, and 18 species (taxa) (Kaneko et al. 2010). Judging from the nymphal habitats and occurrences along the margin of Lake Biwa, we designate 11 species (taxa) as lake inhabitants; other species with littoral zone inhabitants near stream inlets and quiet areas along the stream margins (see Appendix 2). A total of 142 species of mayflies have been recorded from Japan (Ishiwata and Takemon 2005), the Lake Biwa fauna represents 13% of the total Japanese fauna which includes about 8% of all Japanese species that inhabits Lake Biwa.

Features of the Lake's Mayfly Fauna

Outside of Lake Biwa, there are only four mayfly species that have been reported from each of the following lakes on Honshu Island, the main island of Japan: *Ephemera orientalis*, *Ephacerella longicaudata*, *Cloeon dipterum*, and *Ecdyonurus yoshidae*: Towada Lake (Kato et al. 1999, Uéno et al. 1999), Ashinoko Lake (Ishihara 1982), and Kizaki Lake (Yoshida and Uenishi 2001). The nymphs of these four species and the other lake-inhabiting species of Lake Biwa, with the exception of two species, are common mayflies that are poorly adapted for swift water and are almost always found in quiet portions of streams. The two exceptions are *Ephoron limnobium* (*Fig. 1*), which is endemic to Lake Biwa and occurs in the northern part of the lake, and *Potamanthus* (*Potamanthus*) *huoshanensis*, which is a rare mayfly species. These two mayflies have

Fig. 1
Image of male *Ephoron limnobium* attracted to light, Lake Biwa, Hariehama.

not been collected from any locality in Japan since the reports by Yokkaichi-city (1990) and Kobayashi and Nishino (1992).

From mid-May to the end of May in the beginning of the Japanese Showa era (1920s), numerous adults of *Ephemera orientalis* were attracted to lights from residential housing every night along the shorelines of Lake Biwa near Otsu-city. Roads were covered with many mayflies, resembling a layer of snow in the mornings following rainy days (Miyadi, 1963). A large number of these mayflies have also been observed around Lake Biwa during May and between August and September (Imanishi 1940; Uéno 1959). Although the nymphs of this species have been collected throughout Lake Biwa (Kobayashi and Nishino 1992) the adults have not been so abundant in light trap collections in more recent periods; less than 100 individuals were collected in the 2.5 h after sunset during surveys carried out from 1997 to 1999. It is difficult to measure a standing crop of mayfly quantitatively; however, it seems that the population is now declining. Mayflies constitute one of the major components of aquatic systems and are an important source of animal-food in Lake Biwa. A fuller understanding of the role of species diversity in aquatic systems is urgently needed. In order to determine the population changes in detail, it will be necessary to investigate macroinvertebrates continually.

Diversity of Genus *Ephoron* and Endemic Species *Ephoron limnobium*, Identification and Mating Flight

The genus *Ephoron* is one of the most conspicuous and common mayflies because of their large body size and mass flight. The members of the genus *Ephoron* are widespread on several continents; eight species of the genus are known from the Holarctic region, two species from North America, three species from Europe to Eastern Russia, and three species from Japan (Ishiwata 1996). Species diversity of the Japanese mayfly fauna is not so high compared with other regions: 622 species and 68 genera in North America (Edmunds et al. 1976) and 300 species and 35 genera in the Russian far east (Tshernova, et al. 1986); however, the diversity of Japanese genus *Ephoron* may be high.

The endemicity of the mayfly fauna is low in Lake Biwa as well as other lakes in the Palaearctic region, including other ancient lakes, for example, Lake Hövsgöl (the one species out of 13 that was previously considered to be endemic (Erbaeva et al. 2006) is now considered to be a junior synonym of another, non-endemic species (Kluge 2007)) and Lake Baikal in Russia (no endemic and no lake-inhabiting species; Kozhova and Izmest'eva 1998).

The shape and chorion sculpture of the eggs are useful characters to distinguish species of *Ephoron* (Ishiwata 1996). Eggs of *Ephoron limnobium* are easily distinguished from those of the other known species in the genus by the ring-like depression on the chorion (*Fig. 2*). These characteristics can be easily identified through the use of a scanning electron microscope, but it is also easy to distinguish them with a light microscope.

Emergence and swarming occurred almost at the same time after sunset. Adults were attracted to lights and a great number of individuals could be collected at one time from the end of July to September. Males did not form the typical swarming cluster of mayflies, but flew rapidly back and forth about 0.5 m above the water searching for females (Ishiwata, unpublished). The adult behavior of this species is similar to that of *Ephoron shigae* except for its seasonal emergence (emergence of *E. shigae* from September to October; Watanabe et al. 1993).

Acknowledgments

We wish to thank Dr. Robin James Smith (Lake Biwa Museum) for the critical reading of the manuscript.

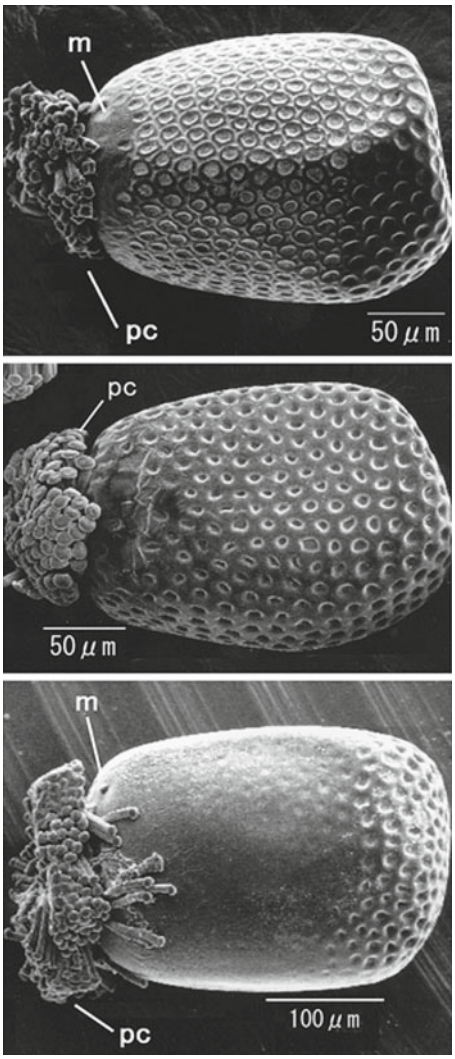

Fig. 2
Scanning electron microscope photographs of the eggs of *Ephoron limnobium* (*above*), *Ephoron shigae* (*middle*), and *Ephoron eophilum* (*below*), m: micropyle; pc: polar cap.

2.4.6(2) Order Trichoptera

Makoto Uenishi · Kazumi Tanida

Abstract The Trichoptera or caddisfly fauna of Lake Biwa was intensively studied by Tsuda from 1940 to 1960. We could confirm about 30 lentic species from the lake through our research during 1983 and 1996, but we could not find 6 species recorded by Tsuda's study. Among the endemic species, *Apatania biwaensis* Nishimoto was discovered, which was derived from a stream species, *A. aberrans* Martynov. A *Mystacides* species (undescribed) is also probably endemic to the lake. *Dipseudopsis collaris* McLachlan, *Ecnomus yamashironis* Tsuda, *Hyalopsyche sachalinica* Martynov, and *Ceraclea nigronervosa* (Retzius) (*s. l.*) are still abundant in the lake but are very rare or absent in other waters in Japan. *Georgium japonicum* (Ulmer) and *Leptocerus biwae* (Tsuda) were extremely abundant in the lake from 1940 to 1960, but there is no reliable record of these two species in recent times. Eutrophication of the lake together with the reclamation of marginal lagoons or inlets has probably reduced the Trichoptera fauna of Lake Biwa.

Keywords Endemic species • Checklist • Zoogeography • Leptoceridae • Ecnomidae

Introduction

Trichopera (caddisflies) is one of the major groups of freshwater macroinvertebrates. Close to 13,000 species have been recorded from the world (Holzenthal et al. 2007), of which more than 350 species from Japan (Morse 2010). Almost all species are inhabitants of freshwaters and have evolved in many kinds of habitats such as cold springs, streams, rivers, ponds, marshes, and lakes. Some ancient lakes, such as Lakes Tanganyika, Baikal, Vopsvolg, and Titicaca, have peculiar endemic species.

Lake Biwa has the richest species of lentic caddisflies among Japanese lakes. The first study of benthic fauna in the lake was conducted by Kawamura (1918) and two species of caddisfly larvae were recorded. The Trichoptera larvae and adults of the lake were intensively studied by Iwata (1927) and Tsuda (1942a, b) more than six decades ago. Tsuda (1971) erroneously designated some caddis species as endemic to Lake Biwa, but most of them were also recorded from the continent (Botosaneanu 1970; Yang and Morse 1988, and others) and from the other waters in Japan (Uenishi et al. 1993; Gyotoku et al. 1994). To provide a more reliable and up to date checklist of Trichoptera of the lake, we conducted a series of surveys on Trichoptera adults and larvae (Nishino 1987b; Tanida and Nishino 1992; Tanida et al. 1999) allowing us to provide a more reliable faunal list and regional distribution patterns of Trichoptera species in the lake. We also consider their ecological and geographical distribution in the lake.

Although Lake Biwa is an unusually important lake for its biodiversity and wetland conservation, eutrophication of its waters and sediments, reclamation of marginal lagoons, and road construction along its shores have severely destroyed the environment of benthic animals. Such activities have probably caused some regional extinction of Trichoptera species and caused others to become endangered. We will reveal such changes by comparing the data from six decades ago (Iwata 1927; Tsuda 1942a, b; Tsuda 1971) with our more recent study (Tanida et al. 1999).

Data Source

We adopted several data sources from collections during 1983 and 1996, most of which were obtained by several projects of Lake Biwa Institute, Lake Biwa Museum of Shiga Prefecture, Monbu-sho (Ministry of Education, Culture and Science, Japan), and the River Fund. The projects covered more than 40 points along the lake shore including some islands in the lake and some inlet and outlet streams. Here we principally use records of adult

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Trichoptera collected by light traps or sweeping by entomological nets. We also use larval collections taken from shores, and deeper zones by dredges, SCUBA or skin diving, to determine which species live in the lake. The published data checked by ourselves are also included (Tanida and Nishino 1992; Nishimoto 1994). There are many published and unpublished records of Trichoptera larvae of the lake, but they are less reliable than adults ones. Thus we decided to use mainly adult material from the lake.

Endemic Species of Lake Biwa

Based on adult collections of Trichoptera at a shore locality in the south basin (Tsuda 1942b), Tsuda (1971) listed 11 species that spent their larval stages in the lake: *Dipseudopsis collaris* (as *stellata*: misidentification), *Georgium japonicum* (as *Rhabdoceras japonicum*: junior homontym), *Molanna moesta* (as *falcata*: junior synonym), *Triplectides misakiana* (as *magna*: misidentification), *Ceraclea nigronervosa* (in the genus *Leptocerus*), *Mystacides* sp. (as *longicornis*: misidentification), *Oecetis yukii*, *Oecetis morii*, *Leptocerus biwae* (in the genus *Setodes*), and *Ecnomus tenellus* (as *omiensis*: junior synonym). He presumed *Leptocerus biwae*, *Oecetis yukii*, and *Oecetis morii* were endemic species to the lake and also suggested that *Dipseudopsis collaris* was not recorded from other waters in Japan.

Our study also reveals that none of these species are endemic to the lake. *Leptocerus biwae* has also been recorded from Hokkaido to Kyushu in Japan (Uenishi 1993; Schmid 1987) and from China (Tsuda 1943 (as *Setodes biwae*); Schmid 1987). *Oecetis yukii*, *O. morii* and *Dipseudopsis collaris* were also recorded from northern Kyushu (Uenishi 1993; Uenishi et al. 1993).

Mori and Miura (1980) listed 16 species of Trichoptera from Lake Biwa in the list of plant and animal species of the lake, and designated *Dipseudopsis collaris* (as *stellata*), *Ceraclea albimacula* (as *Athripsodes biwaensis*), *Leptocerus biwae* (as *Setodes*), *Oecetis morii*, and *Oecetis yukii* as endemic species to the lake. As already mentioned, all of these species are not endemic to the lake. In their revised version (Mori and Miura 1990), they listed 36 species of Trichoptera, only four species are considered to be endemic to the lake.

Nishimoto (1994) described an endemic species from rocky shores in the north basin, *Apatania biwaensis*. He also made an intensive study of Apataniidae of Japan, but no other locality has been known, Lake Baikal has up to 14 species of endemic Apataniidae and also some endemic genera (Ivanov and Menshutkina 1996). It is noticeable that Lake Biwa, a younger lake than Lake Baikal, also has an endemic species of Apataniidae.

Mystacides sp. is another possible endemic species to the lake. It had been erroneously identified as *M. longicornis* (Tsuda 1942a, and others), but its male genitalia are undoubtedly different from *longicornis*. Although we need a more comprehensive taxonomic study on this species and other *Mystacides* species in the northeastern Asia, this would be the candidate of second endemic caddisfly species to the lake.

Within Japan, *Hyalopsyche sachalinica*, and *Neucentropus mandjuricus* seem to be restricted to the Lake Biwa-Yodo River system at the present time, but they have also been recorded from the continental parts of northeastern Asia. *Ecnomus tenellus* is abundant both in lotic and lentic waters on the Japanese Islands and in other zoogeographical regions. *Ecnomus yamashironis* is abundant in Lake Biwa and some streams in Kyoto (Tsuda 1942b, c, and others). This species is not endemic to the lake, but other localities in Japan are very limited. This is also common to the continental part of northeastern Asia.

Characteristics of the Trichoptera Fauna of Lake Biwa

In total, we recorded 47 species of Trichoptera from around Lake Biwa, not including uncertain species (*incertae sedis*) and presumed misidentifications. Among them, larvae of 30 species probably live in the lake. The larvae of other species live in streams flowing into the lake or a river flowing from the lake. Since there are not any comprehensive lists of Trichoptera from other lakes in Japan, it is difficult to compare the fauna of Lake Biwa with other lentic waters in Japan. When comparing the fauna with those of streams and rivers in Japan, Lake Biwa has a high species richness and abundance of individuals in Leptoceridae, Polycentropodidae, Psychomyiidae, Dipseudopsidae, and Ecnomidae, all of which are also abundant in lowland rivers and streams in northeastern Asia (Tanida 1993; Vshivkova and Tanida 1995; Tanida 1998).

The species, *Ecnomus tenellus*, *E. yamashironis*, *Hyalopsyche sachalinica*, *Neucentropus mandjuricus*, *Cheumatopsyche brevilineata*, *C. infascia*, *Potamyia chinensis*, *Macrostemum radiatum*, *Limnephilus fuscovittatus*, *L. orientalis*, *Nemotaulius admorsus*, *Molanna moesta*, *Ceraclea albimacula*, *C. nigronervosa*, *C. superba*, *C. lobulata*, *Mystacides azureus*, *Oecetis nigropunctata*, *O. tripunctata*, and *Leptocerus biwae*, are common in the continental part of northeastern Asia. Therefore, 30 of the 47 species are

common ones between the continent and the lake. Among these species, *H. sachalinica*, *E. yamashironis, N. mandjuricus, C. superba, and C. nigronervosa* are abundant in Lake Biwa, but other populations of these species are rare and geographically very restricted on the Japanese archipelago. Thus, the Trichoptera fauna of Lake Biwa is quite peculiar in Japan and has a close similarity with the fauna of rivers and streams (also lakes) in northeastern continental Asia (Yang and Morse 1988; Tanida et al. 1999).

To clarify this similarity, further research should be conducted on the Trichoptera fauna of continental lakes and rivers more thoroughly. Although most large lowland rivers in Japan are degraded by water pollution, artificial embankments, and other human-related activities, we should research the Trichoptera fauna of larger rivers, as well as lakes, in Japan to compare with the Lake Biwa fauna and that of the continent.

Ecological Distribution of Trichoptera in Lake Biwa

The shores of Lake Biwa can be classified into 4 types: rocky or pebble shores, sandy or muddy shores, reed zones, and unnatural shores (Nishino 1987a). From the Trichoptera distribution along with our observations on larval habitat, we can characterize the lake's caddisflies as follows:

1. Inhabitants of rocky or pebble shores: *Apatania biwaensis*, *Ceraclea nigronervosa*, *Oecetis tsudai*, *Oecetis nigropunctata*, *Triaenodes unanimis*.
2. Inhabitants of sandy or muddy shores: *Dipseudopsis collaris*.
3. Inhabitants of the reed zones: *Limnephilus orientalis*, *L. fuscovittatus*, *Nemotaulius admorsus*, *Mystacides azureus*, *Mystacides* sp.
4. Inhabitants of rocky pebble shores, but tolerant to artificial embankments (unnatural shores): *Paduniella tanidai, Ceraclea albimacula*.
5. Inhabitants of rocky or pebble shores, also in surrounding lotic waters: *Neucentropus mandjuricus*, *Ecnomus tenellus*, *E. yamashironis*, *Cheumatopsyche brevilineata*, *Lepidostoma* spp., *Goera japonica*, *Nothopsyche* spp., *Apatania tsudai*, *Gumaga orientalis*, *Molanna moesta*.
6. Surrounding lotic waters: *Cheumatopsyche infascia*, *Macrostemum radiatum*, *Potamyia chinensis*, *Ceraclea complicata*.
7. Larval habitat unknown: *Hyalopsyche sachalinica*, *Ceraclea superba*, *Oecetis morii*, *Oecetis tripunctata*.

Rocky or pebble shores (types 1, 4, and 5), especially in the northern basin, are the richest in species number and larval abundance. Most of the inhabitants also live in streams and rivers surrounding the lake. They may come from lotic environments (rivers and streams) to the lake shores and are mostly confined to littoral zones of the lake. However, their original habitats in lotic waters are quite variable. *Cheumatopsyche brevilineata*, along with an abundant heptagenid mayfly *Ecdyonurus yoshidae* Takahashi (*s. l.*), lives mostly in riffle areas of streams and rivers. *Lepidostoma* spp. and *Goera japonica* have wide distribution in streams from rapids to stagnant pools. *Ecnomus tenellus*, *Nothopsyche* spp., and *Gumaga orientalis* live in more marginal or in stagnant areas in streams.

Among the genus *Apatania*, the larvae of *A. tsudai* are abundant in streams fed by subsurface water. In the lake, this species is confined to shores with groundwater seepage from small spring runs. *Neucentropus mandjuricus* lives abundantly in the water ways that lead from the lake to an electric power plant. From the distribution of this species in the lake, we guess that the larvae also live in the littoral zone of the lake.

Ceraclea nigronervosa and *C. albimacula* live mostly along rocky shores in the lake. Both species feed on freshwater sponges that are not common in streams surrounding the lake, and thus are scarce in streams. Considering the diversity of original lotic habitats of Lake Biwa species, it is hardly possible to answer the following questions at present: How could they invade the lake? Why did only limited numbers of species colonize the lake?

Recent Faunal Changes

Tsuda (1942a, b, 1971) listed the species collected from a shore in Otsu City, in the south basin of Lake Biwa, and Mori (1946) and Mori and Matsutani (1953) also conducted an interesting study on flying (swarming) behavior of adult caddisflies. In the 1940s and the early years of the 1950s, up to 18 species were commonly found along the shore of the south basin close to the downtown area of Otsu City. Our study confirmed 13 species from the south basin, but *Georgium japonicum*, *Triplectides misakiana*, *Oecetis yukii*, and *Leptocerus biwae* were not collected from the lake, and *Phryganea japonica* now seems to be absent from the south basin. The abundances of other species were also significantly decreased in the south basin compared with previous studies.

During the period between 1940 and 1950, *Ceraclea nigronervosa* (*s. l.*) was the most dominant caddisfly species

during the early emergence season of aquatic insects of Lake Biwa (Tsuda 1942b; Mori 1946; Mori and Matsutani 1953), but this large, beautiful caddisfly species, the larvae of which feed on freshwater sponges, seems to now be completely absent from the south basin.

Tsuda (1942b) mentioned that *Dipseudopsis collaris*, *Georgium japonicum*, and *Leptocerus biwae* were extremely abundant even in the south basin, along with *Ceraclea nigronervosa*. *Georgium japonicum* has also become a very rare and endangered species in other waters in Japan. *Dipseudopsis collaris* still occurs in the lake, but its abundance has significantly declined, similar to other areas in Japan, where it has also declined in numbers or become locally extinct. *Leptocerus biwae* has also become a threatened species. We have no reliable record of *Triplectides misakiana* in Lake Biwa after Tsuda's period, and this is another endangered species in Japan.

From the beginning of the 1960s, Lake Biwa has had serious problems of eutrophication of its waters and sediments. The eutrophication of the south basin is much more severe than the north basin, since the former is much shallower and has a larger human population living around it. The channel between the two basins is constricted and there is not enough water change between the two basins. Land reclamation has been carried out at various lagoons of the lake, which has resulted in the destruction of important habitats for lentic caddisflies. Roads constructed along the shores have destroyed natural shore habitats and have severed the connection between the aquatic and the terrestrial ecosystems. These construction works have probably decreased the species richness and abundance of Trichoptera of the lake.

Tanida (1997a) claimed that within Japan there were two biodiversity hot spots for freshwater fauna that need to be conserved. One of them is the Ryukyu Islands, which have a highly endemic Trichoptera fauna (Tanida 1997b; Kuranishi 1997) and are situated at the boundary between the Palaearctic and the Oriental regions. The other one is Lake Biwa. The endemism of Lake Biwa is lower than in the Ryukyu Islands or other ancient lakes in the world, but the lake has a prominent freshwater biota including interesting endemic species or subspecies. It should be stressed that both of these areas have a long geological history up to several millions of years. Not only the speciation in these areas, but also the zoo-geographical relationships to the continental part of East Asia in the scale of some dozens of millions of years should be studied from various viewpoints using modern systematic and taxonomic tools.

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2.4.6(3) Chironomid Fauna (Diptera: Chironomidae) of Lake Biwa, with Emphasis on the Changes in Recent Years

Eiso Inoue · Tadashi Kobayashi · Machiko Nishino

Abstract In order to clarify the current status of the chironomid fauna of Lake Biwa, we collected adults and immature stages, mainly near the shoreline, from April 2006 to November 2007. A total of 122 species were identified, of which 61 were new records from Lake Biwa. As a result, a total of 158 species have so far been recorded from Lake Biwa. *Psectrocladius aquatronus* and *Cricotopus sylvestris* were collected along the entire shoreline, similar to previous studies, and their adults frequently emerged from water plant samples. *Chironomus plumosus* and *Propsilocerus akamusi* were the major nuisance species until the 1990s, but only a few adults were collected in our study. The most drastic change from previous studies was a newly recorded species, *Corynoneura lacustris*. We collected numerous adults of this species especially along the shoreline of the south basin. These results suggest a large change in the species composition of chironomids in Lake Biwa in recent years.

Keywords Chironomidae • Diversity • Species composition • Distribution • Long-term change • Aquatic insects

Introduction

Chironomidae is the most widely distributed, frequently the most abundant, and the most species-rich group in freshwater benthic communities (Pinder 1986; Cranston 1995). The larvae and pupae of chironomids are aquatic and are found in all kinds of freshwater habitats. Therefore, species diversity and composition of chironomids have been considered to be one of the most useful indicators of various environmental factors, for example, water quality (Sæther 1979; Kawai et al. 1989), catchment urbanization (Roy et al. 2003), and past environmental change (Walker 1995). Due to their ubiquity and abundance, chironomids exhibit an important role in ecosystems as food organisms for benthic macroinvertebrates, fish, terrestrial insects, birds, and bats, etc. (Armitage 1995). Approximately 10,000 species belonging to 11 subfamilies have been recorded worldwide, of which more than 1,000 species belonging to 7 subfamilies were recorded from Japan (Yamamoto 2004).

Sasa and Kawai (1987) systematically investigated the chironomid fauna of Lake Biwa and recorded 71 species from 1985 to 1986. Kitagawa (1997) recorded 75 taxa of chironomid larvae, but the species names were not determined. The most recent systematic study was conducted in 1994 by Kawai et al. (2002b), in which 64 species were recorded. Including other studies (Sasa and Nishino 1995, 1996; Kawai et al. 2002a; Kiyashko et al. 2004), a total of 97 species have been recorded from Lake Biwa until 2006, so the Chironomidae is the most species-rich family among all animals and plants in Lake Biwa (Nishino 2001). Seven species, that is, *Biwatendipes biwamosaics*, *Paratanytarsus biwatertius*, *Tanytarsus kirai*, *Cricotopus biwannulatus*, *Hydrobaenus biwagrandis*, *Orthocladius biwaniger*, and *Orthocladius biwainfirmus*, have so far been recorded only from Lake Biwa. This fact suggests that these species are endemic to Lake Biwa, except *B. biwamosaics*, which may be a junior synonym as a gynandromorph (an individual that contains both male and female characteristics) of *Biwatendipes motoharui*. In relation to human life, outbreaks of chironomid adults often occur around eutrophic lakes and rivers, so the nuisance attraction of the adults to houses and commercial facilities causes economical

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damage. Two large species, *Chironomus plumosus* and *Propsilocerus akamusi*, are the most well-known nuisance midges around the shores of Lake Biwa, especially from the 1970s to 1990s (e.g., Nishino 2001).

During the last couple of decades, various environmental changes have been reported in Lake Biwa, for example, dramatic spread of water plants in the south basin (Nishino and Hamabata 2005), increase of filamentous sulfa-oxidizing bacteria, *Thioploca* spp., in the profundal zone (Nishino et al. 1998), and estrangement between biological oxygen demand (BOD) and chemical oxygen demand (COD) values (Ito et al. 2007). However, no systematic investigation has been conducted after the 1994 study by Kawai et al. (2002b). Therefore, we started an investigation of the chironomid fauna of Lake Biwa in 2006 and have been continuing collecting specimens to clarify the current status and changes in the species composition during recent years (Kaneko et al. 2010).

Methods of Chironomid Collection and Identification

We collected chironomids qualitatively from April 2006 to July 2009 at a total of 343 sites (including the same sites sampled in different seasons and years) in Lake Biwa. The dates of collection cover almost all seasons from early spring to early winter. The study sites were mainly near the shoreline of Lake Biwa and cover its entire basin with various environmental conditions, but also include several sites from littoral to profundal (deep) areas. Adults were collected only at shoreline sites by net sweeping and, when possible, light trapping at several sites. As for the larvae and pupae collection, we sampled bottom substrates and macrophytes, and scraped materials attached to stones and rocks, and all residues were washed through a hand net (0.25 mm mesh). An Ekman-Birge sediment grab and a dredge were used for collection from littoral to profundal sites. Immature specimens were transported to our laboratory while being gently cooled and aerated. The samples were put into a container, covered with a nylon net, and aerated at room temperature (10–25°C). All emerging adults were collected every day for at least 50 days until the emergence ceased.

All adults were preserved in 70% ethanol until mounting on microscopic slides with gum chloral under a dissecting microscope, following the methods of Sasa et al. (1980). Males were used for identification of species, but females and immature stages were also identified when possible, using mainly the taxonomical keys of Wiederholm (1989), Sasa and Kikuchi (1995), and Langton and Pinder (2007).

In this chapter, the results of our chironomid sampling until November 2007, based on Kaneko et al. (2010), are compiled with several corrections and updates.

Species Diversity of Chironomids in Lake Biwa

A total of 122 species belonging to 5 subfamilies were identified and of which 61 species were new records from Lake Biwa (Kaneko et al. 2010). Chironominae was the most species-rich subfamily represented by 65 species (28 new records), followed by Orthocladiinae (40 species; 22 new records), Tanypodinae (12 species; 8 new records), Diamesinae (3 species; 3 new records), and Prodiamesinae (2 species) (*Table 1*). An extremely rare subfamily in Japan, Podonominae, and a marine subfamily,

Table 1

Number of chironomid species recorded by Sasa and Kawai (1987), Kawai et al. (2002b), Kaneko et al. (2010), and the total records

Subfamily (tribe)	Number of species			
	Sasa and Kawai (1987)	Kawai et al. (2002b)	Kaneko et al. (2010)	Total records[a]
Chironominae	47	38	65	88
(Chironomini)	(31)	(27)	(45)	(58)
(Tanytarsini)	(16)	(11)	(20)	(30)
Orthocladiinae	18	20	40	51
Tanypodinae	5	5	12	14
Diamesinae	0	0	3	3
Prodiamesinae	1	1	2	2
Total	71	64	122	158

[a]Include other studies related to Lake Biwa

Telmatogetoninae, were not collected as well as in the previous studies. Combining our results with previous results, a total of 158 species belonging to 5 subfamilies have now been recorded from Lake Biwa. The number of species recorded in our study is much higher than Sasa and Kawai (1987) and Kawai et al. (2002b), but this may be mainly due to the difference in the frequency of sampling, that is, they collected at a total of 28+ and 30? sites, respectively. As a whole, the proportion of the subfamilies is typical of temperate regions (Lindegaard and Brodersen 1995). Both lentic and lotic species were included, and this, together with the high species richness, indicates the diverse habitats in Lake Biwa.

Current Status of the Chironomid Fauna in Lake Biwa

Psectrocladius aquatronus was the most frequently collected species and was found distributed along the entire shoreline of Lake Biwa. *Cricotopus sylvestris* was also frequently collected and the distributions of these two species were similar to the results of Sasa and Kawai (1987) and Kawai et al. (2002b). During larval rearing, these two species mainly emerged from water plant samples, suggesting that their major larval habitat is aquatic plant communities. On the other hand, *Stictochironomus akizukii* was mainly collected along the north basin and emerged from sand samples. *Rheotanytarsus aestuarius* was collected along rocky shores of the north basin, and this may be due to the fact that the filter-feeding habit of the larvae requires waves to enable feeding on suspended organic matter. *Orthocladius glabripennis* was frequently collected from autumn to spring, especially in December. Its larvae were mainly collected along the shore where the substrates were composed of sand, gravel, pebbles, and/or cobbles.

In the profundal areas, *Stictochironomus pictulus* was the most abundant species. We could obtain emerging adults by rearing the larvae collected at depth down to 90 m. The larvae show high tolerance to oxygen depression and feed on methanotrophic bacteria (Kiyashko et al. 2004). A few adults were collected at several shoreline sites in May 2008, suggesting that this species emerges during the spring in Lake Biwa.

There were remarkable differences in the chironomid fauna compared with previous studies. *Chironomus plumosus* and *Propsilocerus akamusi* were the major nuisance species until the 1990s, but only a few adults were collected in this study. In addition, nine species, including *Chironomus biwaprimus*, *Chironomus circumdatus*, *Chironomus nippodorsalis*, and *Glyptotendipes tokunagai*, recorded both by Sasa and Kawai (1987) and Kawai et al. (2002b) were not collected by Kaneko et al. (2010). These results are related to the improvements in water quality of Lake Biwa, because the above species mainly occur in eutrophic waters, that is, waters rich in nutrients, often derived from fertilizers, household waste, etc. (e.g., Tabaru et al. 1987). The species that showed the most drastic change in its distribution from previous studies was *Corynoneura lacustris* (Fig. 1). This species is newly recorded from Lake Biwa, but originally it was described from England (Edwards 1924). In this study, numerous adults were collected especially along the shoreline of the south basin. The adults are very small, about 1 mm in body length, and are found walking restlessly on concrete, rocks, and plants near the shore. It is not clear when this species first occurred in Lake Biwa, but the dramatic increase in water plants in the south basin after 1994 is probably one of the major causes of these changes in the chironomid fauna.

Fig. 1
***Corynoneura lacustris*, male (*left*) and female (*right*) adults.**

Conclusions

The chironomid fauna in Lake Biwa is characterized by high species richness that reflects the diverse habitat types along the shores, for example, mud, sand, rocks, and water plants. It is difficult to compare the abundance and distribution of all chironomid species in Lake Biwa between previous studies and our own, but it is clear that at least several species decreased sharply and a newly recorded species, *C. lacustris*, increased rapidly in recent years. Improvements in water quality and dramatic increases of water plants are suggested as the major causes of these changes.

In Japan, knowledge of taxonomy and species composition of chironomids has developed rapidly during the last 30 years. Data collected in the past that can contribute to the analysis of the long-term changes in the chironomid fauna of Lake Biwa are quite limited. Because many Japanese species are common to other regions of the world, it is difficult to judge whether the newly recorded species in our study, for example, *C. lacustris*, are alien species or not. Molecular analyses would be useful to compare genetic differences between localities. In addition, taxonomical problems in identification of the larvae and pupae have often prevented ecological studies of Japanese species (e.g., Inoue et al. 2004). Even with the adults, synonymic updates have been continuously reported (e.g., Kobayashi and Endo 2008). We have to overcome these difficulties, and the microhabitats and dynamics of chironomid larvae should also be clarified to help conserve the ecosystem and biodiversity of Lake Biwa.

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2.4.6(4) The Dragonfly and Damselfly Faunas of Lake Biwa and their Long-term Changes

Kazuhiro Masunaga

Abstract The dragonfly and damselfly faunas in Lake Biwa are summarized. Ninety-nine species were recorded in 2000 from Shiga Prefecture, which surrounds the lake. Five species are treated as endangered, six as vulnerable species, and five as near threatened species in the 2005 edition of the Red Data Book Shiga. Ongoing threats to these insects, particularly their aquatic young, include deteriorating water quality, loss of aquatic habitats, and predation by nonnative species of fish.

Keywords Odonata • Dragonfly • Damselfly • Diversity • Red Data Book Shiga

Introduction

Shiga Prefecture is blessed with nature, and this is especially true for the aquatic environment including Lake Biwa and its surrounding attached lakes, rivers, and rice fields. In addition, it has a low human population density compared with neighboring prefectures. In this undeniably favorable setting, the Odonatological Society of Osaka investigated the dragonfly and damselfly faunas at about 3,000 localities in all the cities, towns, and one village of Shiga Prefecture in conjunction with the establishment of the Lake Biwa Museum (The Odonatological Society of Osaka 1998). Such a detailed investigation had not been previously conducted in any other prefecture.

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Species Diversity in Lake Biwa

Dragonflies and damselflies (comprising the insect order Odonata) in Japan are represented by 197 species and 17 subspecies according to the most recent review (Sugimura et al. 1999). The Odonatological Society of Osaka conducted thorough investigations of the Odonata in Shiga Prefecture from 1993 to 1997, as a result of which 98 species were confirmed to occur there (The Odonatological Society of Osaka 1998). In addition, one species was added to the record later (Yahiro 2000). In Lake Biwa and its attached lakes, the young stages of 54 of these species (nymphs of dragonflies and naiads of damselflies) have been confirmed (The Odonatological Society of Osaka 1998).

None of these 54 confirmed species is endemic to Lake Biwa, but 11 of them are endemic to Japan. It is remarkable that many species and populations of the dragonfly family Gomphidae inhabit Lake Biwa. Nymphs of this family more typically inhabit flowing water, such as rivers, but not ponds or other still water bodies. It has been suggested that their young can live in this large lake because more oxygen is dissolved in its water than in typical ponds due to wave action. Lake Biwa is also significant as a place where the Japanese endemic species *Stylurus oculatus* (Asahina, 1949) is particularly abundant (*Fig. 1*).

There are at least four reasons for the occurrence of so many species of Odonata in the Lake Biwa basin: (1) the diverse topography consisting of mountains surrounding plains around Japan's largest lake; (2) the diverse aquatic environment, including many large and small rivers, creeks, attached lakes, and Lake Biwa itself; (3) Lake Biwa's long history as an ancient lake; and (4) the low human population density around Lake Biwa compared to nearby urban places such as Kyoto and Osaka.

Fig. 1
Male of *Stylurus oculatus*.

Changes in the Species Composition

Despite the apparent richness of species, Odonata have been recently decreased in Shiga Prefecture. In the Red Data Book Shiga 2000, one species of this group was treated as endangered (EN), one species as vulnerable (VU), and four species as near threatened (NT) (Shigaken Ikimono Chosa I'inkai 2000). Five years later, however, in the Red Data Book Shiga 2005, five were treated as EN, six as VU, and five as NT (Shigaken Ikimono Chosa I'inkai 2006). The reasons behind this decrease in certain species may include the following: deteriorating water quality, loss of aquatic habitats, changes in the methods of rice cultivation (completely draining the water from the rice fields and thus allowing the ground surface to dry during the summer), and predation by nonnative species such as largemouth bass (*Micropterus salmoides*) and bluegill sunfish (*Lepomis macrochirus*). Furthermore, it has been reported that emerging dragonflies are drowned by the wake of jet skis (Yoshida 2006).

2.5 Characteristics of the Ichthyofauna of Lake Biwa, with Special Reference to its Long-term Changes

Masayoshi Maehata

Abstract There are 46 indigenous fish species and subspecies in Lake Biwa, and 17 of them are endemic to the lake. More than half of these endemic species and subspecies are offshore dwellers, while several of them live around rocky shores, in the reed zone, and in attached lakes around Lake Biwa. Some are important targets of the lake fisheries. Native lacustrine fishes, including endemic ones, have dramatically decreased during the past several decades, and this is thought to be due to devastation of spawning and nursery grounds, damage to the fishes' food supply, and/or competition with two alien fish species introduced from the USA, largemouth bass, *Micropterus salmoides*, and bluegill sunfish, *Lepomis microoculus*. Overfishing and water pollution are also considered to be involved in the decline of the native lacustrine fishes. Moreover, it is feared that the hypoxic conditions observed near the bottom of the northern basin of the lake in recent years might accelerate this decline.

Keywords Endemic • Indigenous • Nursery grounds • Non-indigenous fish • Fisheries • Hypoxia

Introduction

Lake Biwa, one of the most ancient lakes on earth, has been nurturing ichthyofauna and other endemic species over a long geological period of time. In the past 40–50 years, however, many of the fishes in this lake have suffered decreases mainly because of human activities (Nakai 1999; Maehata 2003), and similar stories are also reported from several other ancient lakes of the world, such as Lakes Victoria, Titicaca, and Lanao (Witte et al. 1999; Ashiya et al. 1997; Taki 1993).

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In this chapter, the characteristics of the ichthyofauna of Lake Biwa are first described, and the causes of the decline of the lacustrine fishes are then discussed.

Diversity of Fish Species

Many articles have described the features of the fish fauna of Lake Biwa (e.g., Horie 1984; Tomoda 1978; Kawanabe 1996, 1999). According to them, there are 46 indigenous fish species and subspecies in the lake, including warm-water and cold-water fishes (see Appendix). Among these, 17 species and subspecies are considered to be endemic to the lake basin, although several of these have not yet been formally described (*Table 1*). Although not shown here, five additional species are considered to be sub-endemic to the lake.

These 17 endemic fishes are categorized into relicts and those that evolved in and around the lake (Kawanabe 1999). The former includes two species and subspecies, namely Biwa culter (*Ischikauia steenackeri*) and Sugo gudgeon (*Squalidus chankaensis biwae*), each of which has relatives in China and the Korean peninsula. The latter includes 12 species and subspecies: Biwa salmon (*Oncorhynchus masou* subsp.), Biwa ayu (*Plecoglossus altivelis* subsp.), willow minnow (*Gnathopogon caerulescens*), deep-bodied crucian carp (*Carassius cuvieri*), round crucian carp (*C. auratus grandoculis*), oily minnow (*Sarcocheilichthys biwaensis*), Biwa minnow (*S. microculis*), Biwa catfish (*Silurus biwaensis*), rock catfish (*S. lithophilus*), Biwa goby (*Gymnogobius isaza*), Biwa yellow gill goby (*Rhinogobius* sp. BW), and Biwa sculpin (*Cottus reinii*) (Kawanabe 1996) (*Table 1*). Regarding the remaining three endemic species, namely Yodo gudgeon (*Biwia yodoensis*) and two species belonging to the genus *Cobitis*—large striated striped loach (*Cobitis* sp. L) and Biwa striated spined loach (*C.* sp. S), their evolutionary history is not yet clear (Kawanabe 1996; Kawase and Hosoya 2010). Most of the endemics are offshore or rocky-shore dwellers that are considered to have become

Table 1

Endemic fish species and subspecies of Lake Biwa (and its outlet the Yodo River) and their habitats

English name (Jaganese name) Scientific name	Habitat in/around Lake Biwa
Biwa ayu[a] (Biwa-ko-ayu) *Plecoglossus altivelis* subsp.	Offshore
Biwa salmon[a] (Biwa-masu) *Oncorhyncus masou* subsp.	Offshore
Biwa culter[a] (wataka) *Ischikauia steenacheri*	Reed zone to attached lakes
Willow minnow[a] (Hon-moroko) *Gnathopogon caerulescens*	Offshore
Yodo gudgeon (Yodo-zezera) *Biwia yodoensis*	Southern part of the lake
Biwa minnow[a] (Biwa-higai) *Sarcocheilichthys variegatus microculis*	Rocky shore to reed zone, attached lakes
Oily minnow[a] (Abura-higai) *Sarcocheilichthys biwaensis*	Rocky shore
Sugo gudgeon[a] (Sugo-moroko) *Squalidus chankaensis biwae*	Offshore
Round crucian carp[a] (Nigoro-buna) *Carassius auratus grandoculis*	Reed zone to offshore, attached lakes
Deepbodied crucian carp[a] (Gengoro-buna) *Carassius cuvieri*	Offshore
Large striated striped loach[a] (Sujishima-dojyo-ogatashu) *Cobitis* sp. L	Sandy coast to stony coast
Biwa striated spined loach[a] (Suji-shima-dojyo-kogatashu-Biwa-kogata) *Cobitis* sp. S type Biwa	Waterways flowing into the lake
Biwa catfish[a] (Biwako-o-namazu) *Silurus biwaensis*	Offshore
Rock catfish[a] (Iwa toko-namazu) *Silurus lithophilus*	Rocky shore
Biwa goby[a] (Isaza) *Gymnogobius isaza*	Offshore; muddy bottom
Biwa yellow-gill[a] (Biwa-yos hinobori) *Rhinogobius* sp. BW	Offshore; stony bottom
Biwa sculpin[a] (Utsusemi-kazika) *Cottus reinii*	Pebbly coast

[a]Cited from Kawanabe (1999)

differentiated from relatives that lived in and around the lake, after the lake had become deeper and larger 40,000 years ago (see Chap. 1). Regarding the detailed evidence for the relict or in situ-evolved status of the endemic species mentioned above, other articles may be consulted (Tomoda 1978; Horie 1984; Nishida 1985; Kawanabe 1996, 1999).

Most of these endemic species and subspecies have also been very important targets for the lake fisheries, namely Biwa ayu, the two crucian carps (round crucian carp and deep-bodied crucian carp), willow minnow, Biwa goby, Biwa salmon, and others (*Fig. 1*).

Long-Term Changes of Ichthyofauna

Faunal changes with respect to Lake Biwa fishes over the past 40–50 years can be symbolically illustrated by the changes in the total annual catch of indigenous fishes (Shiga Statistics and Information Offices 2010), and the number of lacustrine fishes listed in the Red List by the Ministry of Environment of Japan (2007). The total annual catch does not necessarily mirror the actual fish stock since it varies with catch per unit effort, but it still indirectly implies the quantity of lacustrine fishes as indicated by Nakai (1999). The catch was more than 2,000 tons annually in 1954–1993, peaking at ca. 3,700 tons in 1983; however, it has turned downward since 1994, and fell off to 1,100–1,200 tons in 2005–2006 (*Fig. 1*). On the other hand, the number of threatened fishes, especially critically endangered (CR) and endangered (EN) species and subspecies, in and around the lake increased from 2 (in 1991) to 6 (in 2003), and eventually reached 14 (in 2007). Among the 14 species/subspecies listed on the Red List of 2007, it is noteworthy that only four of them were targeted by the lake fisheries and the rest were nontarget fishes (see a list of fish in the Appendix). Therefore, the decline of the ichthyofauna of the lake poses a serious problem not only in terms of fisheries, but also in terms of conservation of the fish biodiversity in general, and ultimately the entire lake ecosystem.

Why Have the Indigenous Fishes of the Lake Declined?

The following factors are considered responsible for the decline of the indigenous fishes of Lake Biwa (Rossiter 2000): (1) devastation of spawning and nursery grounds for fishes, (2) increase in non-indigenous fish species, (3) overharvesting, and (4) others as noted below.

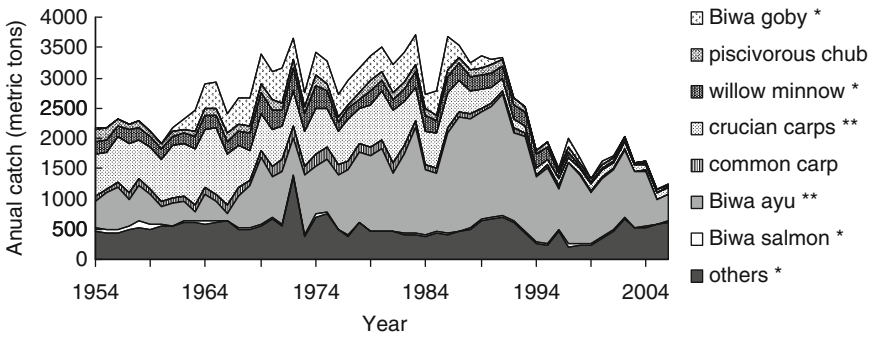

Fig. 1
Changes in the total catch of indigenous fishes from Lake Biwa (data from Shiga Prefecture fisheries statistics issued annually). *Endemic; **including endemic (s).

Devastation of Nursery Grounds

Many articles have claimed that devastation of spawning and nursery grounds is responsible for the decline of the lacustrine fishes (e.g., Kawanabe 1999; Nakai 1999; Rossiter 2000; Maehata 2004). The devastation resulted from various human activities during the periods of rapid industrialization and modernization in Japan after World War II, particularly the elimination of many reed beds in and around the lake and the general loss of paddy fields available for fishes to enter and spawn. There were more than 260 ha of reed beds in and around the lakeshore in 1953, reduced to less than 130 ha at present due to land reclamation projects involving the draining of attached lakes during/after World War II and extensive lakeshore development more recently including a 25-year project to construct roads and embankments around lake, the Lake Biwa Comprehensive Development Program. Attached lakes comprised more than 3,000 ha of water and wetlands before World War II, currently reduced to about 500 ha mainly due to reclamation for rice production. Paddy fields adjacent to Lake Biwa served as breeding grounds for some lacustrine fishes, especially crucian carps, common carp, and catfish, but at present there are nearly no paddy fields that fishes can enter because of the significant vertical drop introduced between paddy fields and their draining waterways as a result of land reconstruction for enhancing agricultural productivity.

Increase in Non-indigenous Fish Species

Many exotic fish species from both outside and inside Japan have been continually introduced since *Oncorhynchus keta* was introduced in 1883 (Furukawa and Awano 1969; Nakai 1999). Among these species, bluegill sunfish (*Lepomis macrochirus*) and largemouth bass (*Micropterus salmoides*), which were introduced from the USA, are particularly considered to have caused serious damage to the indigenous fish communities and the ecosystem of Lake Biwa. These two species now dominate the littoral fish community, and their increase coincided with a decline in the indigenous fish populations (Nakai 1999; Rossiter 2000).

Bluegills were first introduced to Japan as a souvenir from the USA in 1960 and were brought to Shiga Prefecture in 1963 and 1964. Escaped fish were first observed in Lake Nishino-ko, the largest attached lake of Lake Biwa, in 1965. Nowadays, it is found throughout Lake Biwa including all the attached lakes. Largemouth bass were introduced into Japan in 1925 and were first found in the northern basin of Lake Biwa in 1974. This fish, which is considered to have been released unlawfully by anglers, is also distributed throughout the lake now (regarding the detailed process of introduction and distribution of these two species, see Nakai (1999) and Rossiter (2000)). The former is basically an omnivore, but more carnivorous, while the latter is mainly piscivorous (e.g., Yoshizawa 1992). These fish species are most abundant in the littoral zone. Considering their habitats and food sources, these two seem to have exerted a great top-down impact on the native lake ecosystem (Nakai 1999).

In parallel with the two exotics mentioned above, two domestic, non-indigenous species are considered to have been affecting the native ecosystem of the lake due to their large number and wide distribution, namely Japanese short-spined trident goby ("Numa-chichibu" in Japanese, *Tridentiger brevispinis*) and Japanese smelt ("Wakasagi," *Hypomesus transpacificus nipponensis*). The former is an omnivore living around the lakeshore, which was first captured in the northern basin of Lake Biwa in 1989. Thereafter, it rapidly attained a lake-wide distribution, including inlets/outlets and the attached lakes within several years, and it mainly inhabits rocky and gravel shores at present.

The smelt, which is a pelagic dweller and zooplankton feeder, was repeatedly introduced into the lake as a fishery target fish since the 1910s, but all the release trials failed. However, it suddenly appeared in large quantities around the beginning of the 1990s, and it is becoming one of the more important objects of the lake fisheries (Nakai 1999). These two non-indigenous species are considered to have altered the lake ecosystem through competitions with and predation on indigenous fishes and other organisms in the lake, similar to those two fish species from the USA (Nakai 1999; Maehata 2003).

Overharvesting

The total annual catch of indigenous fishes in Lake Biwa was ca. 2,000 tons in the 1950s, but then it gradually increased to reach more than 3,300 tons in 1969 (*Fig. 1*). Since then, it was maintained at more than 3,000 t, with some exceptions, until 1991. Since 1992, however, catch numbers of suddenly turned downward, and plunged to only 1,100–1,200 tons in 2007 (*Fig. 1*). Except for Biwa ayu and Biwa salmon, the catch of all the main target fish species significantly declined.

Considering the initial rapid decrease in total fish catch and technical improvements in fishing implements/methods, it appears indisputable that overfishing is one of the causes for the decline in lacustrine fishes. Fishery regulations at the lake have been strengthened year after year to prevent overfishing, and larvae/fingerings of the main target fishes, such as round crucian carp, common carp, and willow minnow, have been released into the lake every year. These efforts, however, appear powerless to stop the decline in lacustrine fish resources.

Other Factors

Water pollution, especially eutrophication due to the entry of excessive nitrogen and phosphorus, is often blamed as a cause of the decline in lacustrine fishes. In Lake Biwa, algal "red tides" of especially *Uroglena americana* and *Anabaena* spp. were first recorded in 1977, and "green tides" of especially *Anabaena* spp. and *Microcystis* spp. were recorded starting in 1983. These still occur today, though their scale has become smaller in recent years. There is, however, no clear evidence that the recent drastic decline in lacustrine fishes was caused by such phenomena.

In the winter of 2007, a number of dead Biwa gobies ("Isaza," *Gymnogobius isaza*) and shrimps considered to be lake prawns ("Suji-ebi," *Palaemon paucidens*) were found at the bottom of the northern basin of Lake Biwa (Yomiuri Shinbun 2007). This was possibly caused by hypoxic conditions near the bottom due to insufficient mixing of waters between the surface and the bottom, which might have resulted from the usual, warm winters of recent years. The global warming trend of today might become a great threat in the very near future not only to the lacustrine fishes, but also to all other organisms living in the lake.

Conclusions

The fishes of Lake Biwa are today facing the largest threat ever experienced by them. The ongoing decline in lacustrine fishes will negatively affect not only the biodiversity of the lake, but also the traditional, unique culture, including the lacustrine fisheries, which has been fostered over a long period of time around the lake.

As in Lake Biwa, various factors have also been threatening the fishes in other lakes in the world, such as Lake Victoria in Africa (Witte et al. 1999). Combination of independent causes seems to exert negative influences on the fishes and ultimately the lake ecosystem, as has been pointed out by some researchers (e.g., Nakai 1999; Rossiter 2000). While remediation of all the responsible factors related to the decline of these fishes does not seem to be immediately possible, efforts must be made as soon as possible in order to improve circumstances. Various trials have actually been carried out over the last decade or more to restore the unique biota of the Lake Biwa area, via the restoration of reed beds, revival of attached lakes, extermination of exotic species, and other measures undertaken by the Shiga Prefectural Government in cooperation with citizen groups.

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2.6 Amphibians and Reptiles in and around Lake Biwa

Masafumi Matsui

Abstract Few native amphibians and reptiles utilize Lake Biwa as their main habitats. They occur very limitedly in shallow areas of the shore and areas with dense reed beds. Their migrations between the lake and adjacent paddies and/or grasslands tend to be interrupted by concrete-made shore protections and roads. The only amphibians and reptiles mainly inhabiting Lake Biwa are the American bullfrog and the red-eared slider. The former frog was introduced nearly 90 years ago and now seems to be an important member of the lake's ecosystem. The latter turtle is expanding its distribution in and around the lake and is thought to be expelling native turtle species. A variety of amphibians and reptiles are released into the lake by pet enthusiasts who have lost interest in keeping animals. This is a big problem that needs immediate countermeasures.

Keywords Amphibians • Reptiles • Diversity • Distribution • Alien species

Species Diversity of Amphibians and Reptiles in and Around Lake Biwa

With the inclusion of alien species, a total of 62 species (and five subspecies) of amphibians (24 for urodeles [salamanders and newts] and 38 for anurans [frogs and toads]) are currently known from Japan (Herpetological Society of Japan 2010). For reptiles, the total known number is 88, consisting of 12 chelonians (turtles), 35 lacertilians (lizards), and 41 serpentes (snakes). About half of them, however, occur on the Southwestern Islands, and many marine species are also included. Thus, only 30 amphibian and 16 reptilian species are recorded from the main Japanese island, Honshu, excluding marginal islands.

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From Shiga Prefecture, which includes Lake Biwa, 19 amphibian and 15 reptilian species have been recorded (Fukada 1979; Matsui 1979, unpublished data), and regions around the lake contain all of these species, with the exception of three amphibians: the smaller spotted salamander (*Hynobius yatsui*), the eastern-Japanese common toad (*Bufo japonicus japonicus*), and the stream brown frog (*Rana sakuraii*). None of them are endemic to Lake Biwa or river systems connected to the lake.

Among the prefectures of the Kinki region, Shiga Prefecture is the eastern-most situated, and is adjacent to the Chubu region of Honshu. Thus, amphibians and reptiles around Lake Biwa contain faunal elements that are intermediate between eastern and western Honshu. However, the Japanese giant salamander (*Andrias japonicus*) from Shiga is genetically grouped with western populations (Matsui et al. 2008), and the clouded salamander (*Hynobius nebulosus*) is also a western element among Japanese hynobiid salamanders (Matsui et al. 2006).

Relationships of Lake Environments and Amphibians and Reptiles

There are few amphibians and reptiles that are endemic to large lakes like Lake Biwa. Probably, three species of Mexican ambystomatiid salamanders, typified by the famous axolotl (*Ambystoma mexicanum*) endemic to Lake Xochimilco and Lake Chalco, and the Titicaca water frog (*Telmatobius culeus*) and its relatives from Lake Titicaca and surrounding regions, located on the Bolivian-Peruvian border, are the most famous lake inhabitants among world amphibians. Axolotls are neotenic (i.e., the adults retain juvenile features) and permanently live in the water, while water frogs are highly adapted for aquatic life in deep water with the modification of highly folded skin that enables them effective cutaneous respiration (i.e., respiration through the skin). Many reptiles, including turtles, monitor lizards (*Varanus*), and crocodiles, are often found in large lakes but few are famous lake inhabitants.

Amphibians and reptiles restricted to large lakes and marshes are generally rare in temperate and boreal regions. In Japan, several amphibian species, such as the Japanese black salamander (*Hynobius nigrescens*) and the Kajika frog (*Buergeria buergeria*), have been known to breed in some lakes and marshes, but they utilize the environments only for a short period of their life and never stay there permanently. Exceptionally, a population of the Ezo salamander (*Hynobius retardatus*) has been reported to live permanently in Lake Kuttara in Hokkaido as a neotenic form, like the Mexican axolotl (Sasaki 1924). This unique population, however, has not been found again since its initial report.

Although amphibians spend their earlier life stages as eggs and larvae (tadpoles) in the water, environments they can utilize are actually limited. Not all aquatic environments are suitable for them and most species select shallower places for breeding. Because eggs are normally laid at the bottom of the water, they will fail to develop in deep waters with low temperatures and insufficient oxygen supply. Therefore, species that can live directly in a large water body like Lake Biwa are very limited. In reptiles, turtles are closely related with the water, but they cannot spend all of their life in lakes and marshes because all of them are terrestrial breeders.

Relationship of Amphibians and Reptiles with Lake Biwa and Adjacent Regions

There are no strict quantitative data, but amphibian and reptilian species found in and around Lake Biwa and adjacent regions could be classified into three groups: (1) those closely related to Lake Biwa, (2) those occurring in lowlands surrounding Lake Biwa and having some relationships with the lake, and (3) those mainly inhabiting mountainous regions surrounding the lake and having little relationship with it.

Amphibian species with close relationships with Lake Biwa include the clouded salamander (*Hynobius nebulosus*, *Fig. 1*), the Japanese tree frog (*Hyla japonica*), the Japanese brown frog (*Rana japonica*, *Fig. 2*), the black-spotted pond frog (*Rana nigromaculata*), the Daruma pond frog (*Rana porosa brevipoda*, *Fig. 2*), and the American bullfrog (*Rana catesbeiana*, *Fig. 3*), and reptiles include the Japanese pond turtle (*Mauremys japonica*), the Asian brown pond turtle (*Mauremys mutica mutica*), Reeve's pond turtle (*Chinemys reevesii*), the red-eared slider (*Trachemys scripta elegans*, *Fig. 4*), the Chinese softshell turtle (*Pelodiscus sinensis*), the Japanese grass lizard (*Takydromus tachydromoides*), the Japanese rat snake (*Elaphe climacophora*), and the Japanese four-lined snake (*Elaphe quadrivirgata*).

Among these, species with the closest relationship with Lake Biwa are the introduced American bullfrog (*Rana catesbeiana*) and red-eared slider (*Trachemys scripta elegans*; see below), and the native Chinese softshell turtle (*Pelodiscus sinensis*) would be next. Within Lake Biwa, amphibians other than American bullfrog can only directly utilize marshy places near river mouths, shallow places a considerable distance from the shore and without strong waves, and reedy banks. In a part of the Kohoku area north side of the lake, clouded salamander (*Hynobius nebulosus* and Daruma pond frog (*Rana porosa brevipoda*) have been found in shallower areas of the shore, and *Rana japonica* was found breeding in reed beds in the Kosei area

Fig. 1
A hynobiid, the clouded salamander, *Hynobius nebulosus*, is found in the vicinity of Lake Biwa.

Fig. 2
Two native ranids, Daruma pond frog, *Rana porosa brevipoda* (*left*) and Japanese brown frog, *Rana japonica* (*right*), are now seldom found in Lake Biwa.

Fig. 3
The alien American bullfrog, *Rana catesbeiana*, was introduced into Lake Biwa nearly 90 years ago and is now the major amphibian there.

Fig. 4
The alien red-ear slider, *Trachemys scripta elegans*, is rapidly increasing its numbers in and around Lake Biwa, and requires immediate extermination measures. Photography by Shintaro Seki.

west side of the lake, but such habitats are rapidly decreasing. Among dense reed beds, species with high migration abilities, such as Japanese tree frog (*Hyla japonica*), black-spotted pond frog (*Rana nigromaculata*), and Japanese grass lizard (*Takydromus tachydromoides*), are frequently seen, and extraordinarily enormous Japanese four-lined snake (*Elaphe quadrivirgata*) are also inhabiting these environments, probably to feed on nesting great reed warblers (*Acrocephalus arundinaceus*).

On Chikubushima Island, one of the few islands in the lake, the American bullfrog (*Rana catesbeiana*), the Japanese gecko (*Gekko japonicus*), and the Japanese five-lined skink (*Plestiodon japonicus*) have been recorded, but the number of snakes seems not very large. If there were many bird-eating snakes like Japanese four-lined snake (*Elaphe quadrivirgata*) and/or Japanese rat snake (*Elaphe climacophora*) on the island, they would play a useful role in controlling the number of great cormorants (*Phalacronocorax carbo*), which pose a big problem by drastically damaging the natural environment of the island with their feces. In the past, a population of Asian brown pond turtle (*Mauremys mutica mutica*) was known only from the Katata Hills to the west of the lake, but individuals are now confirmed from Kusatsu, to the east of the lake. Whether or not these latter individuals have migrated by swimming across the lake is unknown.

Habitats more important than Lake Biwa proper for amphibians and reptiles occur in the countryside, which is also the catchment area of the lake. Mainly lowland amphibian species with some relationships with the lake include the Japanese giant salamander (*Andrias japonicus*), the Japanese fire-bellied newt (*Cynops pyrrhogaster*), the montane brown frog (*Rana ornativentris*), the wrinkled frog (*Rana rugosa*), the Indian rice frog (*Fejervarya limnocharis*), Schlegel's green tree frog (*Rhacophorus schlegelii*), and the forest green tree frog (*Rhacophorus arboreus*), and reptiles include Japanese gecko (*Gekko japonicus*), Japanese five-lined skink (*Plestiodon japonicus*), the burrowing rat snake (*Euprepiophis conspicillatus*), the Oriental odd-tooth snake (*Dinodon orientale*), the Japanese keelback (*Amphiesma vibakari vibakari*), the tiger keelback (*Rhabdophis tigrinus tigrinus*), and the Japanese mamushi (*Gloydius blomhoffii*). Of these, Japanese gecko and Japanese five-lined skink are found on Chikubushima Island as noted above.

The Japanese giant salamander (*Andrias japonicus*) is a stream-breeder and never lives in Lake Biwa itself. The species, probably recently artificially introduced, is breeding in the Takatoki River, which flows into the lake. Individuals were once captured from the lake and are thought to have been washed in from nearby rivers by floods. The species is sometimes found in reservoirs behind big dams, and could survive in deep water at least in the adult stage, although breeding in such environments would be impossible. In all other species of amphibians and reptiles, migration to and from the lake is now extremely difficult in many places because artificial structures act as barriers. Aquatic turtles, in particular, seem to be restricted in their distribution by the presence of concrete-made shore protection and roads surrounding the lake that hinder their migration to land for breeding.

Factors more severely affecting the distribution of these animals than the disjunction of Lake Biwa and adjacent countryside are the past changes in land use. Especially since the beginning of the 1960s, agricultural area dramatically decreased and the pattern of cultivation was also greatly changed by agricultural infrastructure improvement projects and land readjustments, all of which have made the life of amphibians and reptiles very difficult. For example, the Indian rice frog, *Fejervarya limnocharis*, although very common in the paddies in regions surrounding Shiga Prefecture, is seen in the prefecture only at hills far west of Lake Biwa and small areas of paddies south of the lake. The species, however, seems to have occurred widely in Shiga Prefecture along the western shore of Lake Biwa in the past. According to Akiyama (1935), Indian rice frog was abundant in the paddies along the western shore of Lake Biwa from Mano to Katata around 1934. The author also gave records from Imazu and Zeze, where the species is never found now. This simple example suggests the effects of land-use change on the distribution of frogs.

Amphibians and reptiles mainly inhabiting mountainous regions surrounding Lake Biwa and having little relationship with it are the Hida salamander (*Hynobius kimurae*), the Japanese clawed salamander (*Onychodactylus japonicus*), the eastern-Japanese common toad (*Bufo japonicus formosus*), the Japanese stream toad (*Bufo torrenticola*), Tago's brown frog (*Rana tagoi tagoi*), the Kajika frog (*Buergeria buergeri*), and the Japanese odd-scaled snake (*Achalinus spinalis*). These species may be accidentally washed into the lake by floods, but would have little chance of survival there.

Alien Amphibian and Reptilian Species Found in Lake Biwa

There is one amphibian and one reptilian species whose main habitat is Lake Biwa: the American bullfrog (*Rana catesbeiana*) and the red-eared slider (*Trachemys scripta*

elegans), both of which are not native to Japan. The American bullfrog is native to the eastern part of the USA but is now widespread throughout Japan, and there are probably no Japanese people who do not know its name. Actually, Shiga Prefecture, with Biwa Lake, is deeply related to the dispersal of this alien species within Japan.

It is recorded that the late Prof. Shozaburo Watase, then Professor of Tokyo Imperial University, imported ten males and four females of the American bullfrog from New Orleans. They arrived in Japan in the spring of 1918 and were reared in Tokyo for breeding (Matsui 2009). They laid eggs in the summer of the same year, and the offspring metamorphosed and became sexually mature 2 years later in 1920. Of these captive bred individuals, two males and three females were sent to Ibaraki (with Kasumigaura Lake), and two individuals of each sex were sent to Shiga (with Lake Biwa), where fisheries experimental stations tried to breed them. They began breeding in 1922, and eggs and/or tadpoles obtained there were sent out to other prefectures, where people began to enthusiastically breed the species. Around this period, the red swamp crayfish (*Procambarus clarkii*) was also introduced from the USA as a food of the bullfrog, and soon dispersed in Japan to become a very common aquatic animal.

Prof. Watase introduced the bullfrog as a food resource, but few Japanese took to the frog meat and frog breeding soon went out of fashion. In the Kansai area, including Shiga, people continued breeding the frog, and at the same time bullfrogs escaped and established feral populations, enlarging the distribution in Japan. In 1932, frozen legs of bullfrogs began to be exported to the USA for food, and breeding in captivity and collection in the field was revived. Exports were inevitably interrupted during World War II and bullfrogs in the field must have expanded their distribution during this time. However, frog exports soon resumed after the war, and contributed much to the economic recovery of Japan until 1969. In that year, the pesticide benzene hexachloride (BHC) was detected by the USA in frozen meat of Japanese bullfrogs, and the US government immediately put it under an embargo. This drove bullfrog breeding and field capture enterprises out of business in Japan, and frogs were left untouched, escaped, and further enlarged their distribution. In this way, bullfrogs are now widespread in ponds, canals, and rivers surrounding Lake Biwa in Shiga Prefecture.

The American bullfrog is thriving because of two main reasons. One is its voracious appetite to eat almost any moving object, including mice, snakes, fledglings, and even fishes in the water (Maeda and Matsui 1999). The other is its mode of reproduction, and this allows it to monopolize the habitat in Lake Biwa. The American bullfrog has an extensive breeding season from April to September, and loud calls by males that occur during this long period often cause "noise pollution." As noted above, eggs of native Japanese frog species laid in the bottom of deep water would soon die because of the shortage of dissolved oxygen. By contrast, the American bullfrog lays its eggs on the surface of the water, instead of at the bottom. A female oviposits more than 10,000 eggs at a time, and a mass of eggs laid soon becomes a thin, but very wide sheet on the surface of the water. On the surface, eggs receive direct sunshine, but the wind sweeping across the surface keeps them cool. Thus, the species can breed irrespective of water depth. Larvae hatch in a short period, have a good swimming ability, and can utilize a wide range of water conditions in Lake Biwa.

The problem of the American bullfrog disturbing ecosystems has long been pointed out, and at the end of 2005 it was listed as an Invasive Alien species (IAS) by the Ministry of Environment of Japan. From 1 February 2006, rearing, keeping, transportation, and importation of this species became regulated, and it was targeted for eradication, which on the face of it seems a reasonable decision.

In many regions of Japan, including Lake Biwa, however, few native frog species exist around the habitats of the American bullfrog. In localities where only American bullfrogs are now seen, native frogs probably would have been expelled long ago. Generally, paddy fields, where many native Japanese frogs occur, are rarely inhabited by American bullfrogs. This is because the American bullfrog prefers deep water, and as far as currently observed in the field, the species seems to generally segregate its habitat with native species such as black-spotted pond frog (*Rana nigromaculata*).

Although bullfrogs might have driven out native species in the past, it may currently be playing an important role in the ecosystem of its habitat, taking over the role of the native frogs after its introduction to Japan over 90 years ago. Actively driving out bullfrogs in regions newly invaded should be promoted, but rapidly getting rid of stable populations of bullfrogs, such as in Lake Biwa, possibly disturbs ecosystems. Functions of the American bullfrog within the ecosystem of Lake Biwa should be assessed by future investigations.

The red-eared slider (*Trachemys scripta elegans*) is native to an area from the southern USA to northeastern Mexico. This species began to be imported into Japan in the latter half of the 1950s as a pet. At first, the species was not so popular, but in the 1960s its smaller juveniles, named "green turtles," became very popular. Juveniles

seem pretty, with a green shell about 3 cm in the length and with red markings along the sides of the neck. They are still one of the biggest sellers in pet shops, and nearly one million individuals are still imported each year (Matsui 2009).

This alien turtle species is becoming a big problem because it is quickly enlarging its distribution in Japan. The species is thought to disturb natural ecosystems just like the American bullfrog, but unlike the latter, pet keepers are the sources of its range expansion. The pretty "green turtles" quickly grow to the adult size of 20 cm in males and 30 cm in females. In addition to rapid growth, it lives a very long time, about 20 years (maximum record of 30 years and 6 months in captivity). These features often discourage pet owners to continue rearing them, and instead they release the turtles into the environment. The released adult turtles are usually larger than native Japanese turtle species and eat not only animals, but also plant material. Moreover, they can endure somewhat polluted waters. Because of these high abilities of adaptation, red-eared sliders can live in various fresh water environments in Japan, from large lakes, like Lake Biwa, and large rivers to artificial ponds in parks, and ditches in towns.

Wherever this resilient red-eared slider invades, ecosystems are likely to be disturbed. Such effects by red-eared sliders have been of great concern in many countries of the world, and imports of this species have already been prohibited in some countries such as Korea and South Africa. However, the species is still imported in large numbers into Japan; it has never been listed as an IAS.

Lake Biwa is probably viewed as a good place to release various pet animals, and even sea snakes were once found in the lake (Fukada 1979). Recently, illegally released snapping turtles (*Chelydra serpentina*) have frequently been found there by fishermen, and most recently, a dead pitted-shelled turtle, *Carettochelys insculpta*, was found in Lake Biwa. However, release of all reptile species, including the red-eared slider, is prohibited by the Animal Welfare Law. It is necessary to get these facts across to all pet keepers, and at the same time measures to expel these "relatively new" invaders should be seriously discussed and brought into practice.

Acknowledgments

I wish to thank Shingo Tanabe, Yasuchika Misawa, Shintaro Seki, Shingo Mori, Keisuke Kobayashi, Masayoshi Maehata, and Kanto Nishikawa for gathering herpetofaunal diversity data in and around Lake Biwa.

2.7 Characteristics and Long-term Trends of the Avifauna of Lake Biwa

Hiroshi Hashimoto · Hisashi Sugawa · Kayoko Kameda

Abstract Lake Biwa is a large water body with a 220-km-long shoreline and a rich diversity of avifauna, especially waterbirds. Large numbers of waterfowl overwinter on the coast, and many birds breed in reedbeds along the shore. In this section, the current status of avifauna at Lake Biwa, especially wintering waterfowl, birds that breed in the reedbeds, birds found on islands in the lake, raptors, and threatened birds, is briefly introduced. Recent trends in the number of waterbirds wintering at Lake Biwa and the drivers of their presence are also discussed. We further report the results of statistical analyses of the relationship between the reedbed condition and breeding avifauna. Finally, we point out the importance of the coastal area, including the reedbeds, for the preservation of the rich avifauna at Lake Biwa.

Keywords Coast • Reedbed • Waterbirds • Wintering

Introduction

Lake Biwa is a large water body with a 220-km-long shoreline (Lake Biwa Research Institute 1991). There are various ecotones of vegetation types and avifauna, especially waterbirds, abound the lake. Large numbers of waterfowl winter on the coast, and many waterbirds and some warblers breed in reedbeds along the shores of Lake Biwa. However, over the past few decades, the environment of Lake Biwa has changed drastically. For example, reedbeds along the shoreline have been fragmented by the road constructed according to the Lake Biwa Comprehensive Development Plan, and submerged aquatic vegetation and populations of alien fish have increased in the water. These changes have affected the species richness and the number of birds present in the area. In this section, we report on the current status of avifauna at Lake Biwa, recent trends relating to wintering waterbirds, and the relationship between the reedbed condition and breeding avifauna.

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Avifauna of Lake Biwa

There have been several studies on the avifauna of Lake Biwa. The earliest recorded study was that of Kawamura (1934) who described 117 bird species. The comprehensive list of plant and animal species living at Lake Biwa produced by Mori and Miura (1990) mentioned 55 waterbird species. Timoshkin et al. (2006) counted the number of bird species at Lake Biwa and reported 140 avian species.

Compared with other aquatic organisms, it is often difficult to list the exact number of bird species present in aquatic areas because many waterbirds not only live in the water body, but also use the terrestrial areas along the water body as breeding, foraging, or resting sites. Coastal areas are also important sites for part of the life history of terrestrial birds. Thus, the land-water boundaries or ecotones are very important for many birds. In addition, visiting birds are often observed and recorded. The birds of Lake Biwa are defined in this section as follows:

1. Species observed at Lake Biwa and along its coasts as well as at the mouths of rivers and attached lakes connected to Lake Biwa and their coasts.
2. Species that use the above areas as breeding, foraging, roosting, or resting sites for at least part of the year.
3. Species observed within the past 40 years or so.

Using this definition, we listed 177 species at Lake Biwa (see Appendix 2) and reviewed the recent literature and records of bird species in Shiga Prefecture (Ezaki and Wada 2002; Shigaken Ikimono Chosa I'inkai 2006;

Hashimoto and Sugawa 2008; Nihon Yacho no Kai Shigashibu 2010).

As the largest lake in Japan, Lake Biwa is an important wintering site for waterfowl. Annual counts of waterbirds at Lake Biwa in Shiga Prefecture were 144,991 and 134,461 in January 2009 and 2010, respectively.

The most abundant species present at the lake were the common coot *Fulica atra*, the tufted duck *Aythya fuligula*, the European widgeon *Anas penelope*, and the European pochard *Aythya ferina*, which are winter visitors to Japan. The most abundant wintering bird species at Lake Biwa is the coot. The coots and ducks often form large flocks and float on the water in the lake. Several birds also inhabit the reedbeds along the lake shore, including the little grebe *Tachybaptus ruficollis*, which is the prefectural bird of Shiga, the moorhen *Gallinula chloropus*, and the oriental great reed warbler *Acrocephalus arundinaceus*. These birds breed in the reedbeds around Lake Biwa and its attached lakes. The barn swallow *Hirundo rustica*, the tree sparrow *Passer montanus*, and the gray starling *Sturnus cineraceus* also use the reedbeds as roosting sites after breeding. Many other migrating and wintering birds also use the reedbeds. Thus, the reedbeds at Lake Biwa are a very important habitat for several bird species.

The four islands in Lake Biwa are important habitats for birds. Chikubu Island, the northernmost island, has one of the largest colonies of the great cormorant *Phalacrocorax carbo* in Japan. The number of cormorants present at Lake Biwa was ca. 34,000 and 37,000 in May 2007 and 2008 and 67.7% and 80.0% of these were found on Chikubu Island, respectively (Shiga Prefectural Government 2010). The cormorant is regarded as a pest species as it causes great damage to fisheries and forests, and the population is currently regulated by culling (see Sect. 7.2.4). Chikubu Island also has colonies of herons and egrets. The gray heron *Ardea cinerea*, the black-crowned night heron *Nycticorax nycticorax*, the great egret *Egretta alba*, the intermediate egret *E. intermedia*, and the little egret *E. garzetta* form a mixed colony on the island. The gray heron once colonized Okishima Island, another island in the southeast of the northern basin of the lake. Takeshima Island is a smaller island located between Chikubu Island and Okishima Island, and the spot-billed duck *Anas poecilorhyncha* breeds on this island. The last island is Okino Shiraishi, which consists of a series of rocks rising above the lake surface. Several cormorants once bred there (Kawamura 1934). The peregrine falcon *Falco peregrinus* also breeds on one of the islands. The islands of Lake Biwa should be safe places for birds to breed because people and predators cannot easily approach the islands.

Other than the falcon, there are several Falconiformes species that inhabit Lake Biwa. Species of three large fish-eating eagles—the osprey *Pandion haliaetus*, white-tailed sea eagle *Haliaeetus albicilla*, and steller's sea eagle *H. pelagicus*—are mostly observed in the northern part of the lake. The osprey is resident, and the other two eagle species are winter visitors. Other typical species of the freshwater areas are the Asian marsh harrier *Circus spilonotus* and the hen harrier *Circus cyaneus*. These live around the reedbeds, and breeding behavior of the Asian marsh harrier has been observed in the large reedbed in the southern basin of Lake Biwa. The black kite *Milvus migrans* is abundant around the lake as well as at other coastal areas in Japan. The presence of such a variety of predatory birds means that fish, birds, and other animals are abundant at Lake Biwa.

Although Lake Biwa still has a rich biodiversity and avifauna, some species are threatened by degradation of the habitat (Shigaken Ikimono Chosa I'inkai 2006). *Table 1* shows the Red List of birds of Lake Biwa. A total of 150 species and 10 bird communities were listed in Shiga Prefecture in 2005, of which 83 species and three communities were from Lake Biwa. For example, the number of Little Grebe, the prefectural bird that is used to symbolize Lake Biwa, has declined dramatically over the past few decades. The factors affecting the decrease are thought to be habitat degradation and food shortages caused by anthropogenic changes to the environment, disturbance of breeding or foraging activities due to human leisure activities, or chemical hazards (Shigaken Ikimono Chosa I'inkai 2006). In particular, changes to the coastal environment, such as decreased reedbed area or aquatic plant vegetation, would affect the habitats of many birds. In order to conserve bird species, the entire area of Lake Biwa was designated a wildlife protection area in 1971. The lake was also designated a Ramsar Site in 1993, and Nishinoko, a marshy attached lake of Lake Biwa, was added to the designated area in 2008 (see Topic 23).

Trends in the Number of Waterbirds Wintering at Lake Biwa

As mentioned previously, Lake Biwa is the largest lake in Japan, and large numbers of waterbirds, such as waterfowl, grebes, coots, cormorants, and gulls, winter at this lake. The number of waterbirds present has been recorded three times by boat counts around the 220-km shoreline

Table 1

Red list of the birds living in Lake Biwa in Shiga Prefecture

Categories	Species or populations				
Critically endangered	*Botaurus stellaris*				
Vulnerable	*Ixobrychus sinensis*	*Gorsachius goisagi*	*Anser albifrons*	*Anser fabalis*	*Pandion haliaetus*
	Haliaeetus albicilla	*Haliaeetus pelagicus*	*Accipiter gentilis*	*Circus spilonotus*	*Falco peregrinus*
	Rallus aquaticus	*Porzana fusca*	*Asio flammeus*		
Near threatened	*Tachybaptus ruficollis*	*Podiceps cristatus*	*Butorides striatus*	*Egretta intermedia*	*Cygnus cygnus*
	Cygnus columbianus	*Tadorna tadorna*	*Aix galericulata*	*Anas formosa*	*Anas falcata*
	Anas americana	*Anas querquedula*	*Bucephala clangula*	*Mergus albellus*	*Mergus serrator*
	Mergus squamatus	*Mergus merganser*	*Accipiter nisus*	*Buteo buteo*	*Circus cyaneus*
	Falco columbarius	*Falco tinnunculus*	*Gallinula chloropus*	*Rostratula benghalensis*	*Charadrius placidus*
	Charadrius alexandrinus	*Charadrius mongolus*	*Pluvialis squatarola*	*Vanellus vanellus*	*Calidris ruficollis*
	Calidris subminuta	*Calidris temminckii*	*Calidris acuminata*	*Calidris ferruginea*	*Calidris canutus*
	Calidris tenuirostris	*Eurynorhynchus pygmeus*	*Philomachus pugnax*	*Tringa erythropus*	*Tringa stagnatilis*
	Tringa nebularia	*Tringa ochropus*	*Tringa glareola*	*Heteroscelus brevipes*	*Actitis hypoleucos*
	Xenus cinereus	*Limosa limosa*	*Limosa lapponica*	*Numenius arquata*	*Numenius madagascariensis*
	Numenius phaeopus	*Gallinago gallinago*	*Gallinago megala*	*Gallinago hardwickii*	*Himantopus himantopus*
	Glareola maldivarum	*Sterna albifrons*	*Alcedo atthis*	*Cuculus canorus*	*Anthus spinoletta*
	Locustella ochotensis	*Acrocephalus bistrigiceps*	*Acrocephalus arundinaceus*	*Cisticola juncidis*	*Remiz pendulinus*
	Emberiza fucata	*Emberiza schoeniclus*	*Sturnus philippensis*		
Data deficient	*Corvus dauuricus*				
Other important	*Hirundo daurica*				
Threatened local population	Bird community of Kohoku Waterbird Park	Bird community of the reedbed of Nishinoko Lake and the attached lakes around it	Bird community of Matshunokinaiko Lake		

Data from Shigaken Ikimono Chosa I'inkai (2006)

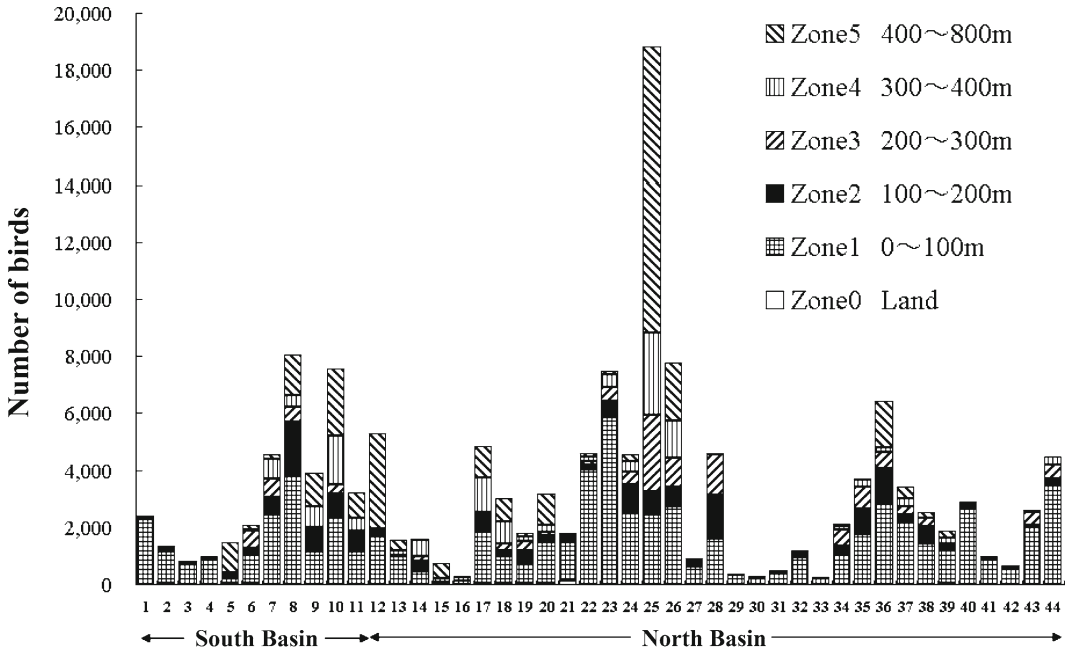

Fig. 1
Spatial distribution of waterbirds in the winter of 2007–2008.

(0–800 m zone) of Lake Biwa during the winter in 1989–1990, 1994–1995, and 2007–2008 (Sugawa 1991; Sugawa 1996; Hashimoto and Sugawa 2008). The number of dominant species present during winter 2007–2008 is shown in Topic 23.

Fig. 1 shows the spatial distribution of waterbirds present during winter 2007–2008. The 220-km shoreline was divided into 445-km blocks (0–11: South Lake, 12–44: North Lake), and the 800-m offshore water surface was divided into six zones (0: land, 1: 0–100 m, 2: 100–200 m, 3: 200–300 m, 4: 300–400 m, 5: 400–800 m). Although flocks of the black-necked grebe *Podiceps nigricollis* often swim on the offshore deep open waters, most of the waterbirds winter near the coast, especially in zone 1 (0–100 m from the coast), which is characterized by shallow waters and reedbeds along the lake shore. Among the 5-km block nos. 25, 36, 10, 12, and 17, large numbers of waterbirds were observed in zones 4 and 5. These areas were located in bays or near the large river mouths such as the Ane, the Ado, the Echi, and the Yasu, where the shallow waters extend offshore.

Shallow water areas in the lake are important feeding sites for dabbling (up-end feeding) ducks (falcated ducks *Anas falcata*, wigeons, and gadwalls *A. strepera*) that forage for submerged aquatic vegetation by up-ending or fresh water weeds by grazing, and also for diving ducks (tufted ducks, pochards, and scoups *Aythya marila*) that forage plant or animal matter from the bottom of the lake by diving (Kear 2005). Coots also forage for submerged aquatic vegetation by diving. Furthermore, pursuit divers (grebes, sawbills, loons, and cormorants) prefer shallow water because fish cannot escape into the deep water at the bottom of the lake. Little grebes dive up to 1 m (rarely 2 m) depth (Cramp 1978).

Reedbeds are important resting places for dabbling ducks, such as mallards *Anas platyrhynchos*, spot-billed ducks, and Eurasian teals *A. crecca*, which mainly rest in the daytime along the lake shores and forage in agricultural lands at night. Some large reedbeds are present in bays along the northeastern shoreline of Lake Biwa.

Fig. 2 shows the trend for the number of waterbirds present at Lake Biwa over the past 20 years. Numbers have increased dramatically from 63,060 in winter 1989–1990 to 80,035 in winter 1994–1995 and 143,096 in winter 2007–2008.

The number of coots in particular has shown a near 20-fold increase from 1,272 in 1989–1990 to 26,444 in 2007–2008. The number of diving ducks has increased almost threefold from 23,057 to 66,079 and that of dabbling (up-end feeding) ducks has doubled from 15,107 to 30,143. These dramatic increases are thought to be the result of an increase in the amount of submerged aquatic

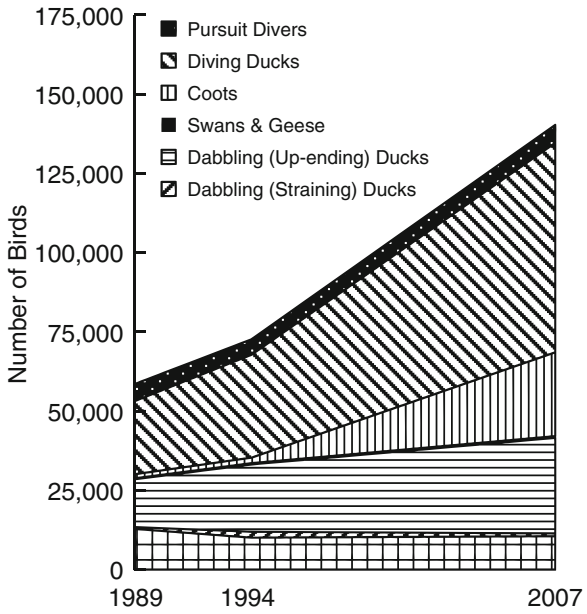

Fig. 2
Trend in the number of waterbirds present over the past 20 years at Lake Biwa.

vegetation (which is a good food for these groups), especially in South Lake, from the mid-1990s (see Sects. 2.3 and 3.1.3). Pochards, which numbered 36,385 in winter 2007–2008, are mainly herbivorous, feeding on tubers of submerged vegetation by diving (Kear 2005). Coots also forage on submerged vegetation by diving. Another diving duck, the tufted duck (population 28,528 in winter 2007–2008), often specializes on freshwater molluscs (Kear 2005), and its population has also increased over the past 13 years. Although we do not have information on the diets of ducks wintering at Lake Biwa, it appears that Lake Biwa still has abundant benthic animals supporting the large population of tufted ducks (see Sect. 2.4).

On the other hand, the numbers of field-feeding ducks, such as mallards and Eurasian teals, which mainly rest in the daytime on the lake shore, have decreased, and more ducks are now observed to be floating offshore, although the number of spot-billed ducks has increased slightly. The decline in the number of ducks present and the shift in resting place may be the result of increased human disturbances such as encroachment into coastal waters by anglers and fishing boats. Navigation of pleasure boats with two-cycle engines is prohibited by Shiga Prefecture regulations in some parts of the coast at Lake Biwa in order to prevent noise reaching residents near the coast and for waterbird preservation. However, the locations of the regulated area are restricted, and fishing boats without engines are not regulated.

The total number of pursuit divers has remained almost stable over the past 20 years, but numbers of most species with the exception of the black-necked grebe are declining. One of the reasons for the observed decline in this group at Lake Biwa is thought to be the decrease in the number of small fish present in the lake due to the alien fishes such as the largemouth bass *Micropterus salmoides* and bluegill *Lepomis macrochirus* (see Sect. 2.5. Most sawbills prefer small fish of 10–15 cm (Marquiss et al. 1998), and small fish (mostly 5–7 cm long) form a considerable proportion (40–50%) of the little grebe's diet in winter (Bandorf 1970). As mentioned above, the breeding population of great cormorants at Lake Biwa is greater than 30,000, but the wintering population is small (1,000–1,500) because fishes move to the deeper lake bottom where cormorants cannot feed easily in winter (see Sect. 7.2.5).

The number of swans (mostly the tundra swan *Cygnus columbianus*) and geese (mostly the bean goose *Anser fabalis*) has increased slightly, but their numbers change annually because of the weather and water level control. Murakami et al. (2000) reported that a nationwide cold winter with extensive snow cover induces the southward migration of bean goose and increases their numbers in Shiga Prefecture. In addition, due to poor feeding conditions, the geese move to neighboring inland areas when the water level of Lake Biwa increases.

The numbers of dabbling (straining) duck species, such as northern shovelers *Anas clypeata* and northern pintails *A. acuta*, have remained low.

Reedbed Condition and Breeding Avifauna at Lake Biwa

The condition of the reedbeds used by breeding birds at Lake Biwa was analyzed using TWINSPAN and Classification and Regression Tree model (Hashimoto and Sugawa 2006). The breeding bird density was surveyed at the largest reedbed every 5 km along the lake shoreline from 1993 to 1995 (Sugawa 1996).

The reedbeds were classified into five types by TWINSPAN. Type A reedbeds had spot-billed ducks, great reed warblers (>9 pairs), little grebes (>4 pairs), coots, and an area of more than 2.5 ha. Type B reedbeds had great reed warblers (>4 pairs), coots, and little grebes, mud sedimentation, reeds greater than 155 cm high, and an area

greater than 0.26 ha. Type C reedbeds had great reed warblers and reeds more than 155 cm high. Type D reedbeds had little grebes, no great reed warblers, and willows. Type E reedbeds had no breeding birds and a small area.

According to multiple regression analysis, the area of the reedbed and the existence of reedbeds inside the bank had positive effects on the number of species present in each reedbed. Great reed warblers appeared in reedbeds that had reeds that were more than 90 cm high and an area of more than 0.073 ha. Little grebes appeared in reedbeds that had an area of more than 0.088 ha. Spot-billed ducks appeared in reedbeds that were more than 300 m in length and 45 cm in depth. Coots appeared in reedbeds that were wider than 17 m.

Conclusion

The coastal area of Lake Biwa, including the reedbeds, is an important wintering and breeding habitat for many waterbirds in Japan and also East Asia (see Topic 23). Conservation of large reedbeds with tall reeds and mitigation of human disturbance at coastal areas are critical for the preservation of the rich avifauna at Lake Biwa.

Topic 3 Endemic Diatoms of Lake Biwa

Taisuke Ohtsuka

Diatoms are unicellular microalgae with siliceous cell wall. More than 500 diatom species have been reported in and around Lake Biwa, although the total number of species is unknown. Among them, three endemic species have been reported in and around Lake Biwa. All of them had previously been considered semi-endemic species (non-endemic, but have a restricted distribution) common to some North American lakes, but they have come to be recognized as new endemic species in the present century.

One of these three endemic species is *Aulacoseira nipponica* (Skvortsov) Tuji (*Fig. 1*), which had been identified as *Melosira solida* Eulenstein for a long time (Tuji 2002). In Lake Koga, an earlier stage of Lake Biwa, *A. nipponica* replaced a widely distributed fossil diatom, *Aulacoseira praeislandica* (Jousé) Simonsen, around 2.7 million years ago (Negoro 1981). Negoro (1956) reported that this species was very abundant in the water column between November and April in the north basin, and it was usually dominant among the phytoplankton in November, December, and April, while it usually rested on the lake bottom during the summer (Negoro 1954). Its dominance, however, has not been observed since 1986 (Ichise et al. 2007). The other two species belong to *Stephanodiscus*, and they are very similar to each other. The larger one is *Stephanodiscus suzukii* Tuji & Kociolek (*Figs. 2, 3*), and the smaller one is *Stephanodiscus pseudosuzukii* Tuji & Kociolek (*Figs. 4, 5*). They were formerly identified as *Stephanodiscus carconensis* var. *carconensis* Grunow and *Stephanodiscus carconensis* var. *pusilla* Grunow, respectively. However, their classification as independent species is still in controversy. Kato et al. (2003) synonymized them because of the shape of the rimoportula (a tubular process, which opens to the inside of the valve by a labiate slit), which Tuji and Kociolek (2000) used to distinguish the two species, cannot in fact be used for identification; it changes continuously with the size of the valve. Nevertheless, they can be distinguished from each other by using scanning electron microscopy (SEM): *S. pseudosuzukii* has a ring of spines near the valve edge, whereas *S. suzukii* lacks this feature. Both species are also found in Lake Yogo, just north of Lake Biwa, and at least in the past, in the Mikatagoko Lakes to the north west of Lake Biwa. Although very similar diatoms have been found in the strata of 390,000 years ago (Kuwae et al. 2007), their confirmed fossil records are only available from around 170,000 years ago. Three similar taxa have also been found in the older Kobiwako-group, but their relationships to the recent forms are unclear (Negoro 1981). According to Negoro (1956), in the recent past the three endemic species were usually the dominant phytoplankton in the north basin between January and March, but recently it varies from year to year (Ichise et al. 2007). *S. pseudosuzukii* sometimes also becomes abundant in the south basin (Anonymous 1991). They usually rest on the lake bottom during summer, just like *A. nipponica* (Negoro 1954).

All three of the endemic diatoms have heavily silicified frustules, which are advantageous for resting on the lake bottom, but causes faster settling velocities. The water of Lake Biwa's north basin is thermally stratified in summer and circulated in winter. Since the winter vertical circulation reduces the disadvantage of a fast settling velocity, their thick frustules grow in winter and are dormant in summer, so that they are adapted for the seasonal life cycle. The vertical circulation, however, tends to diminish due to rises in the water temperatures (Nakamuro et al. 2008, Kitazawa and Kumagai 2008), and this may threaten the endemic diatoms of Lake Biwa.

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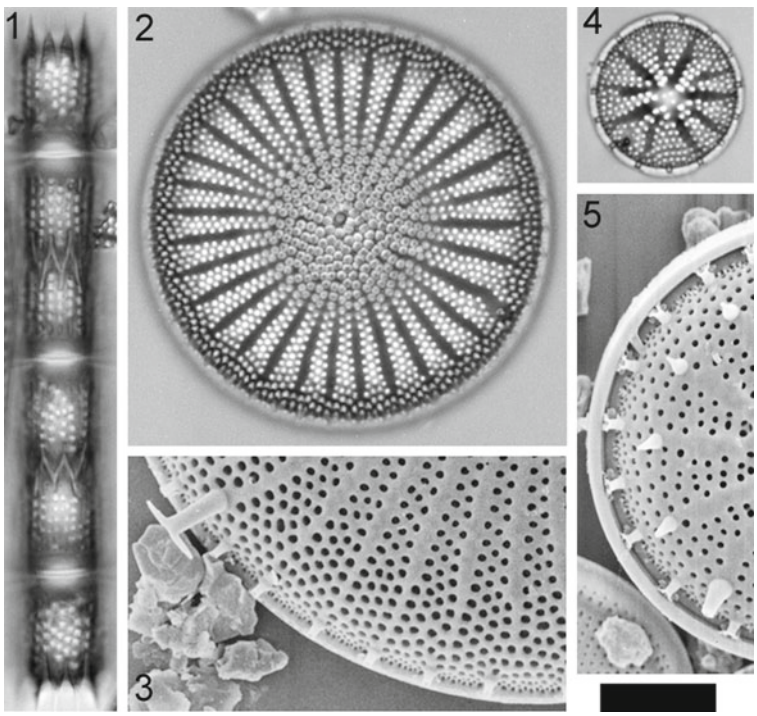

Fig. 1

***Aulacoseira nipponica*, LM (light microscopy). Fig. 2, 3 *Staphanodiscus suzukii*. Fig. 2: LM. Fig. 3. SEM (scanning electron microscopy) showing absence of spines. Fig. 4, 5 *Staphanodiscus pseudosuzukii*. Fig. 4: LM. Fig. 5: SEM showing presence of spines. Scale bar = 10 µm for Figs 1, 2, and 4, and = 5 µm for Figs 3 and 5.**

Topic 4 Biology of the Common Reed (*Phragmites australis*) surrounding Lake Biwa

Yuko Kaneko

Related Taxa Surrounding Lake Biwa

The three species of the genus *Phragmites* that are distributed around Lake Biwa are *Phragmites australis* (Cav.) Trin. ex Steudel (common reed), *Phragmites japonica* Steud., and *Phragmites karka* (Retz.) Trin. ex Steud. *P. japonica* and *P. karka* are tetraploid with a chromosome number of $2n = 48$ (Index to Plant Chromosome Numbers). The abundance of *P. karka*, a tropical evergreen herb, has increased over the past 20 years (Kaneko et al. 2010).

Geographic and Ecological Distribution

P. australis is a representative deciduous polycarpic perennial herb in the family Poaceae that is distributed widely in Japan from Hokkaido to Honshu, Shikoku, Kyushu, and the Ryukyu Islands. This species naturally forms a large mono-dominant thick-stemmed community in the freshwater and brackish marshes surrounding lakes or ponds or along the coast. It is also found in wet sites along rivers.

Chromosome Number and Karyology

P. australis includes a polyploid series of $2x$ ($2n = 24$), $3x$ ($2n = 36$), $4x$ ($2n = 48$), $5x$ ($2n = 60$), $6x$ ($2n = 72$), $7x$ ($2n = 84$), $8x$ ($2n = 96$), and $10x$ ($2n = 120$) with $x = 12$ (Pazourkova 1973; Index to Plant Chromosome Numbers). The dominant karyotypes surrounding Lake Biwa are decaploid, octoploid, and nonaploid ($9x$), and dodecaploid ($12x$) karyotypes, as determined by flow cytometry, also occur (Nakagawa et al. in press; Kaneko and Nakagawa, unpublished data). The determination of ploidy level is important for understanding genetic structure and reproductive biology and for better managing the genetic diversity of this species.

Phenology and the Growth

New annual cane-like aerial shoots appear aboveground from late April to early May. According to Tachibana (1983), the stem density, diameter, height, and estimated biomass of *P. australis* populations ranged from 24.5 to 101.0 stems/m^2 (mean = 49.2 stems/m^2), 4.4–8.8 mm (mean = 6.4 mm), 1.13–2.53 m (mean = 1.94 m), and 422–1,314 g/m^2 (mean = 731 g/m^2), respectively, in 13 populations surrounding Lake Biwa. Flowering occurs from late August until October. The seeds mature from late October to early December before winter dieback. The seeds serve as food for birds and animals during the winter.

Reproductive Biology

P. australis reproduces sexually, and each panicle (branching cluster of flowers) consists of hundreds of spikelets, with more than two florets per spikelet. The nearest floret from the base is a male flower, and the others are hermaphrodite with one ovule. The flower is lacking appreciable temporal separation of anther and stigma presentation and wind pollinated. The seeds have a pappus (a tuft of fibers) and are dispersed widely by wind or water (Boedeltje et al. 2004). The seed set rate of *P. australis* is highly variable among populations, ranging from 0% to 60% in the USA (Kettenring et al. 2010), from 0% to 45.9% in Lake Biwa (Tachibana 1984), and from 0.1% to 9.7% in

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Lake Biwa (Ishii and Kadono 2002). *P. australis* also propagates clonally by growing linear stolons that extend from the parent to a new offspring ramet and possibly by spreading via rhizome fragments drifting in water (Fer and Hroudova 2009).

Regeneration Patterns

P. australis has the potential to spread by seeds and rhizomes. In Lake Biwa, *P. australis* is considered a pioneer species, and its seeds recruit rapidly into new-formed bare sunny and sandy shallows after flooding (Tachibana 1980; Kira 1992). After *P. australis* establishes a new community, clonal spread prevails. The seeds of *P. australis* germinate best on bare or almost bare ground. Seed reproduction within established populations is limited by several ecological and genetic factors (Szczepanska 1971; Kettenring et al. 2010). Regeneration of this species depends on natural disturbances such as flooding.

Genetic Variation and Structure

Clonal diversity within a population detected using DNA microsatellite polymorphisms and amplified fragment length polymorphisms (AFLPs) varied widely among approximately 40 major sampled populations surrounding Lake Biwa or attached lagoons (Nishino et al 2008). The number of clones within a population ranged from 2 to 15 for 11–42 samples in our studies. No significant association was found between the population size and the amount of genetic or genotypic diversity within the investigated populations (Nishino et al. 2008).

The molecular variance was rather small among populations, with greater variability within populations. Such factors as self-incompatibility, wind pollination, and seed dispersal by wind and water should promote gene flow and decrease genetic differences among populations. Furthermore, genetic distances among populations were not significantly correlated with geographical distances in Lake Biwa (Kaneko et al., unpublished data).

Topic 5 Leeches of Lake Biwa

Tetsuya Itoh

Introduction

Leeches (Hirudinea) are found in aquatic and terrestrial habitats all over the world. Over 50 species (2 orders, 9 families, and 32 genera) have been found in Japan (Oka 1935; Soos 1965–1969b; Sawyer 1986), with 18 species from Lake Biwa, representing 2 orders, 6 families, and 13 genera.

The first taxonomic study of Lake Biwa leeches was done by Asajiro Oka (Oka 1917a, b). He compiled a list of 14 species belonging to 2 orders, 6 families, and 11 genera, all collected from Lake Biwa. In his compiled leech list, *Ancyrobdella biwae* (Oka 1917a), a glosshiphonid species with a unique morphology of its proboscis, was described in particular detail. Unfortunately, there were no taxonomic publications on Lake Biwa leeches for a long time after Oka's study. In 1993 and 1995, four leech species were newly added to the list of species collected from Lake Biwa and its outflow (Nishino 1993; Nesemann 1995, 1997). The present existing information on the leeches of Lake Biwa is mainly based on these publications.

Leeches are commonly known as blood-sucking parasitic animals that prey on mammals, amphibians, reptiles, and fish. Most Lake Biwa leeches, however, are free-living and only prey on aquatic insect larvae, snails, and oligochaetes (worms). Although several hosts and carrier animals for some leeches of Lake Biwa are known, few leeches are capable of sucking the blood of vertebrates (including humans). Oka (1917a, b) reported that diatom shells, fragments of vegetable tissue, etc. were found in the stomach of *Ancyrobdella biwae*, with no trace of blood. Herbivorous feeding habits of this species, however, are unlikely, as Oka also commented, because the slender tube-like proboscis is apparently better adapted for sucking than for swallowing solid particles (Oka 1917a, b). Considering the prey of other species belonging to the genus *Ancyrobdella* (*A. smaragdina*) and some other glossiphonid leeches, *A. biwae* is likely to be a predator of aquatic invertebrates, as many glossiphonid leeches are.

Habitats of Lake Biwa leeches range from the deep (80 m) to the shoreline of the lake, as well as in some of its inflowing and outflowing rivers, and in irrigation channels of rice paddies around the lake (Oka 1917a, b; Nishino 1993; Nesemann 1995, 1997). Leeches usually favor stagnant water environments, and they cling to hard surfaces, such as shells of freshwater bivalves or stones, but some leech species of Lake Biwa are known to inhabit mud. However, the caudal sucker of these mud-dwelling leeches is functional enough for them to effectively hold their bodies to hard surfaces, and they do not resemble some species (genus *Orobdella*) with a degenerated caudal sucker, which are known to live in shaded, moist ground (Richardson 1975).

Taxonomic Story of *Ancyrobdella* Species in and Around Lake Biwa

The Genus *Ancyrobdella* was established by Oka in 1917, with an original description of the type species *Ancyrobdella biwae* (Oka 1917a). The species is unusual not only because it was collected from the bottom of Lake Biwa (80 m), but also for its taxonomic characteristics, which are as follows: slender body shape, no eye spots, and three hook-like prominences at the tip of the long proboscis. Because *Ancyrobdella biwae* has not been collected since Oka's original description, and the location of the type depository in which the specimens were kept was not mentioned in the original description, *Ancyrobdella biwae* was regarded as gen. et sp. inquir. (genus and species unclear) (Sawyer 1986). However, Nesemann (1997)

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reported that the Japanese species *Glossiphonia smaragdina* (Oka 1910) collected in and around Lake Biwa possesses a characteristic of the genus *Ancyrobdella* (three hook-like prominences at the tip of the proboscis), and thus he concluded that the Japanese *smaragdina* species belongs not to the genus *Glossiphonia*, but to the genus *Ancyrobdella*. This discovery confirms the taxonomic stability of the genus *Ancyrobdella*.

In recent surveys, *Ancyrobdella smaragdina* has been frequently collected in Lake Biwa and its connecting water systems (Nishino, M. written communication). As a result, ecological information about the genus *Ancyrobdella* is gradually increasing. Nevertheless, there is still taxonomic confusion on a species level.

The taxonomic confusion of the genus *Ancyrobdella* is due not only to the lack of clarity regarding the taxonomy of the *biwae* species but also the taxonomic instability of the *smaragdina* species.

The *smaragdin*a species has been reported from China as belonging to the genus *Glossiphonia* (Moore 1924). This species of *smaragdina* has long been regarded as synonymous with *Glossiphonia paludosa* because the external morphology and distribution of the two species are virtually indistinguishable (Moore 1924; Autrum 1936; Yang 1996). To resolve the taxonomic confusion, it will be necessary to compare the Japanese *A. smaragdina* with the Chinese *smaragdina* species in future study. If it is determined that the Chinese *smaragdina* species indeed belongs to the genus *Ancyrobdella* (and not to the genus *Glossiphonia*), the Chinese species will thus be identified as *A. smaragdina* or *Ancyrobdella* sp., and the two species (*smaragdina* and *paludosa*) will no longer be considered synonymous. On the other hand, if it is determined that the Chinese *smaragdina* species does not belong to the genus *Ancyrobdella*, the Chinese species will hence be considered completely different from the Japanese *smaragdina* species (in which case the endemism of the genus *Ancyrobdella* in Japan will be strongly supported).

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Topic 6 Extinction of the Japanese Otter *Lutra nippon*

Motokazu Ando

Extinction of the Japanese Otter

Looking at the current highly industrialized status of Japan, one may think that the country must have lost much of its native wildlife. This is not the case for terrestrial mammals. Since the Meiji Restoration in 1867, when Japan opened its doors to the world, only two species of mammal have disappeared: the Japanese wolf and the Japanese otter. Before that, for more than 2,000 years, it seems that Japan did not lose any major mammal species from its mainland. During this long period, people received benefits from wildlife in the form of furs, medicines, and meats. Wild animals also appeared in folk tales, which enriched people's culture. On the other hand, people continuously fought against wildlife-caused damage to crops. This sustainable relationship suddenly changed in the Meiji era when the government adopted a national policy of increasing wealth and military power. As Japan had to purchase machinery and weapons, pelts became one of its important exports. Combined with the depletion of fur-bearing animals in western countries, the export of furs became a get-rich-quick type of business that generated many instant trappers. These newcomers went into the mountains along river courses to avoid the territories of traditional local hunters. Unfortunately, these routes overlapped with the habitats of Japanese otters, the fur of which was highly valued. In consequence, the number of Japanese otters decreased dramatically. The number of pelt transactions illustrates this, peaking at almost 900 in 1906 while dropping down to 43 in 1912 (Ando 2008). Otters did not recover even after World War II, and they went extinct simultaneously from the islands of Honshu and Hokkaido around the mid-1950s. A possible cause of this extinction was agrochemicals introduced in the early 1950s. Even though Shikoku Island remained as a last viable habitat, Japanese otters disappeared from Ehime Prefecture around 1975, and lastly from Kochi Prefecture probably around 1990 (see initial color page 5). Deterioration of water quality, depletion of food fishes, and loss of habitat due to road construction and river works could have been the final blows. Currently, although many river banks and lakeshores are now artificial, the general environmental conditions of freshwater habitats in Japan have been improving. In Korea, which has a similar natural environment to that of Japan, the otter population seems to be recovering. If the Japanese otter had not the misfortune to suffer its hardest years during the period of high economic growth, it would likely be able to maintain itself in present-day Japan.

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Otters in the Lake Biwa/Yodo River System

Many of the natural banks and shores of the Yodo River and Lake Biwa have been replaced with man-made artificial structures as a result of flood-control measures implemented ever since the Meiji era. Before then, the entire water system nurtured large wetlands (Nishino 2009). Along the shores of Lake Biwa, there used to be many satellite lakes, in which the water was calm and fish and reeds were abundant. Near Kyoto at the confluence of the Uji, Kizu, and Katsura Rivers to form the Yodo River, a huge flood wetland called Ogura Pond existed until it finally disappeared just before World War II, the final result of continuous reclamation work over the centuries. The name "Yodo" means stagnant river, and the lower Yodo River runs through the once marshy Osaka Plain. The entire drainage basin evidently used to provide a suitable habitat for otters.

Some local literature in Shiga Prefecture records the presence of Japanese otters until around the Taisho era in the 1910s (Ando 2008). Some elders insist that otters persisted until the postwar period. A document published in

Fig. 1
An otter-related *haiku* poem by Matsuo Basho, one of the best-known Japanese poets, is carved on this monument near the outlet of Lake Biwa.

1815 in Hikone, a town on the shore of Lake Biwa, tells how to make an otter trap from a *sake* barrel by driving nails inwards through the bottom, and placing the trap in the water. Hikone also has a local folk tale in which an old otter became a specter of the lake. The otter further appears in a *kyogen* classical comic play called "Suzuki Bouchou," performed in the fifteenth century. In this story, a boy was asked by his uncle to go and get a carp, but he failed to do so. Instead, he made up an excuse saying, "I got the largest carp in the Yodo River and tied it to a bridge pillar. But an otter emerged and took half of it …." There is a roadside stone monument inscribed with a Haiku poem by Matsuo Basho, a famous poet of the seventeenth century (*Fig. 1*). It says, "Go to the most remote part of the Seta River [the outlet of Lake Biwa] and find the offering of the otter." He is probably describing leftovers of fish and crustaceans on a rock as though they were an offering made to the gods by the otter.

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3 Ecological Changes in Lake Biwa

Machiko Nishino

The ecosystem of Lake Biwa has been greatly affected by various kinds of human activities. The water level has been decreasing in the long run since a manmade weir was constructed at the sole outlet the Seta River in 1905 and the water level was artificially controlled. Reclamation of shallow attached lakes or *naiko*s was conducted during the mid 1940s–1971 and led to the decrease in the water level. Levees along the lake shore, dams and enclosing bands on the river flowing into the lake were constructed during the 1970s–1990s, affecting adversely the spawning of the indigenous fishes. Changes in the water level control since 1992 have also affected the fish spawning. Invasive alien fishes, large mouth bass *Micropterus sarmoides* and bluegills *Lepomis macrochirus*, invaded the lake in the mid 1960s and 1970s, respectively. Feeding on or competing with indigenous fishes and shrimps, the two fish species have propagated since the 1980s, and had adverse affects on the indigenous fish communities which in turn changed the food web structure of the lake. Various kinds of alien species, such as submerged macrophytes, emerged plants, floating leaved plants, invertebrates, fishes and tetrapods, have invaded and increased in the lake. Eutrophication occurred both in the littoral and off shore areas during the 1960s–1970s or 1980s, but it almost ceased and water quality recovered during 1990–2010. Recently, global warming does have an impact on the water regime and plankton community.

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3.1 Ecological Changes in the Littoral of Lake Biwa and its Adjacent Areas

Machiko Nishino · Yoshihiro Azuma · Masaru Tatsumi · Yuko Kaneko

Abstract A long-term decrease in the water level diminished the area of Lake Biwa and surrounding attached lakes, and respectively 19.4 and 29.9 km^2 was lost during the past 100 years. This resulted in the decrease of the spawning areas of the indigenous, including endemic, fishes. The Lake Biwa Comprehensive Development Project that had been implemented during 1972–1997 damaged the spawning migration of the indigenous fishes. In 1992, the operation rule of the lake water level was established, and water level was kept low during mid July to October. As this period coincides with the breeding periods of the indigenous and endemic fishes, the low water level inevitably decreased their spawning areas. Along with the low water level, extremely low rainfall in 1994 brought a great drought, and the improved light condition invoked a rapid increase in the submerged macrophytes, especially in the south basin. The increase of alien floating and emerged plants caused the stagnation of the shallow water bodies, and alien fishes changed the food web of the littoral areas.

Keywords Water level control • Naiko • Submerged macrophytes • Indigenous fishes • Invasive alien species

Long-Term Changes in Water Level

In Lake Biwa, there is only one natural outlet, the Seta River, located at the southmost end. This river flows into Osaka Bay via the Yodo River, flowing through the densely populated area. In 1987, the standard water level of the lake, called the Biwako Basic Surface Water Level (BSL) (84.371 m above the mean water level of Tokyo Bay), was determined and observation of the lake water level has been initiated.

At the end of the nineteenth century, Lake Biwa and its adjacent areas were repeatedly hit by severe floods, and many people died and a lot of assets were lost. Thereby, the lake water level rose to BSL +2.71 m in a great flood in 1885, +2.00 m in another flood in 1889, and finally +3.76 m in an unprecedented flood in 1896. To reduce the flood damage both around the lake and downstream along the lower reaches of the Yodo River, the Japanese government dredged the Seta River and constructed a man-made weir in 1905 (Sect. 6.2.2). Since then, the lake water level has been controlled artificially and declined in the long run, combined with increasing water demand created by the industrial and economic growth in the downstream, that is, Osaka, Kyoto, and Kobe megalopolis (*Fig. 1*).

Long-Term Changes in the Littoral and Wetland Areas

The decrease in the water level inevitably diminished the areas of the lake and its surrounding lagoons and attached lakes, called *naiko*, and also greatly changed the land use in these areas. For example, about 100 years ago, the areas of Lake Biwa and its surrounding *naikos* were estimated at 688.1 and 35.2 km^2, respectively, based on the geographic map in the Meiji Era (Topic 7). By the 1990s, a total area of 19.4 km^2 had been lost in the former, which corresponds to 2.8% of the area it had in the Meiji Era (Topic 7). Much larger area (29.9 km^2) was lost in the *naikos*, corresponding to 84% of the past area.

Naikos are small and very shallow water bodies, mostly less than 3 m deep, surrounded by dense vegetation of the emerged plants *Phragmites* spp., and also covered with abundant submerged macrophytes. Azuma (2004) estimated the reed *Phragmites* spp. areas in 1948 at 5.2 km^2 (both in *naikos* and in Lake Biwa), based on the aerial photos.

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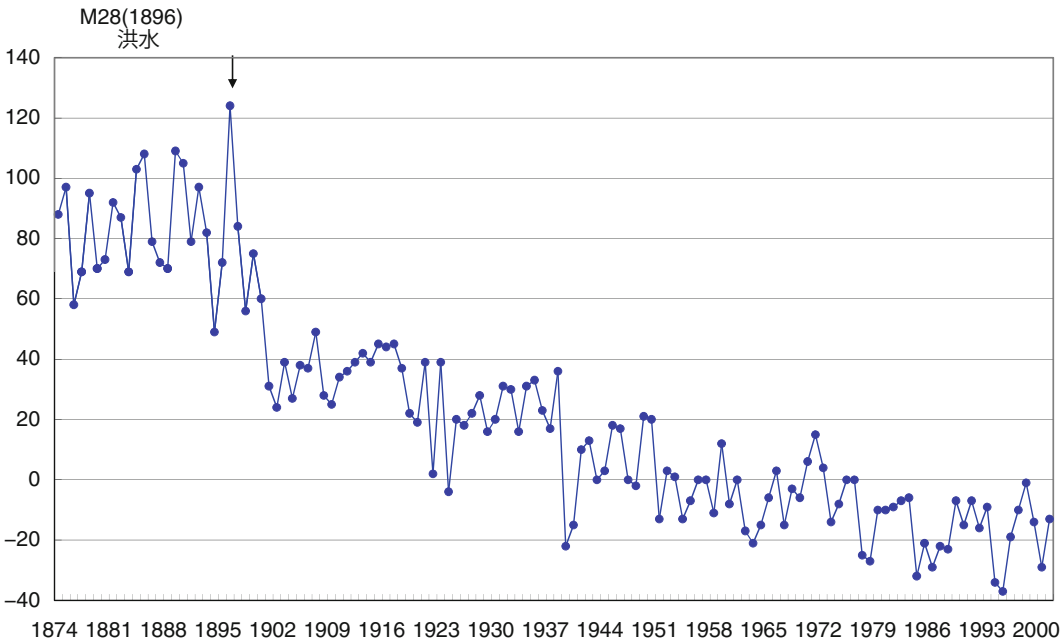

Fig. 1
Long-term changes in the annual mean water level of Lake Biwa.

However, it shrank to 3.2 km^2 in 2000 (Azuma 2004; Hamabata 2005b).

These areas provided spawning habitat for the indigenous and endemic cyprinid fishes (Biwako Seibutsu Shigen Chosa-dan 1966). However, with the decrease in the lake water level, most of the *naikos* became stagnant, resulting in diminished habitat and spawning areas of the indigenous fishes and causing the decrease in the fish catch there. From the mid-1940s to 1971, most *naikos* were reclaimed and changed into paddy fields, due to the demand for an increase in food production after the World War II. Since 1972, the total fish catch has begun to decrease, except Biwa-ayu fish (*Plecoglossus altivelis*), whose life is not dependent on *naikos* (Sect. 2.5).

During 1972–1997, the national project, Lake Biwa Comprehensive Development Project, was implemented in and around the lake. The primary purpose of this project is to promote economic development of the downstream areas by transforming Lake Biwa into a kind of artificially regulated reservoir for additional water supply through the Yodo River in preparation for extreme droughts (Sect. 6.4). In order to reduce adverse effects of droughts and floods, continuous levees were constructed around the lake, the irrigation system was improved for farmland around the lake, ports and harbors were renewed, and the *Setagawa* weir in the Seta River was reconstructed.

As a result, the artificial shore, most of which are levees, comprised 37% of the total shoreline length of the lake in 2007 (*Fig. 2*, Topic 7). Some 30% of the total farmland of Shiga Prefecture is supplied with pumped Lake Biwa water (Sect. 6.3.6). Eventually, levee construction prevented the spawning migration of the indigenous fishes from the lake to the remaining *naikos* and paddy fields around the lake. The pumping irrigation system, as well as the farmland consolidation (Sect. 6.3.6), also has adverse effects on the spawning migration of indigenous and endemic fishes (Sects. 2.5; 7.2, Topic 22), though these system greatly improved the agricultural efficiency and increased the productivity.

Effect of the Operation Rule of the Water Level Since 1992

In 1992, the operation rule of the *Setagawa* weir was established, and the lake water level was controlled to maintain the level at about 0.3–0.4 m lower than that in the previous years (*Fig. 3*). In 1994, both the low water level and the low rainfall in summer caused the lowest water level in the recorded history of the lake, that is, BSL –1.23 m in mid September. Thereafter, submerged macrophytes, whose density was low from the 1970s to early 1990s, perhaps because

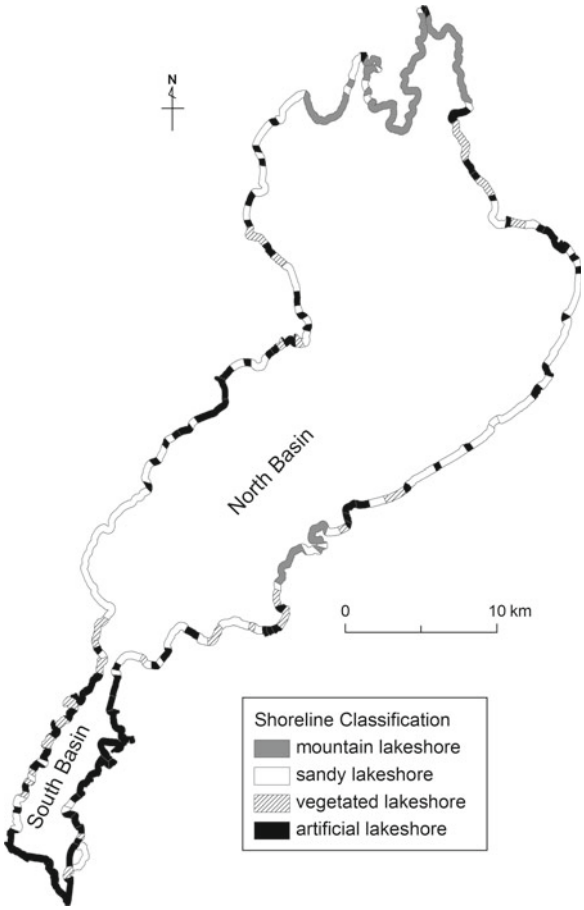

Fig. 2

Distribution of the mountain lakeshore (rocky beach), sandy lakeshore (sandy beach), vegetated lakeshore, and artificial lakeshore in 2007 (see Sects. 3.1.2 and Topic 7).

of eutrophication, began to increase especially in the south basin (Sect. 3.1.3). In 2000, the water level dropped again to BSL −0.97 m, and also to −0.99 m in 2002 (*Fig. 3*). In the south basin, the coverage area of the submerged plants was estimated at 6.2 km^2 in 1994, and rapidly increased up to 29.3 km^2 in 2000, then 43.0 and 43.3 km^2 in 2002 and 2007, respectively (Sect. 3.1.3). This means 85% of the south basin area was covered with the submerged macrophytes in 2007. Hamabata and Kobayashi (2002) considered that this was because of the improved light condition caused by the extremely low water level, although Haga and Ohtsuka (2008) doubted this theory. Most dominant macrophytes are the indigenous species such as *Potamogeton maackianus*, *Myriophyllum spicatum*, though exotic *Egeria densa* was also included in the dominant species (Sect. 3.1.3).

During the 1960s, the rich submerged macrophyte zone was used to provide good nursery areas for the indigenous cyprinid fishes. However, there is little evidence that the indigenous fishes spawn on such dense submerged plants in the south basin recently. On the other hand, about one-third of the area of the south basin was the area with a dissolved oxygen (DO) concentration of less than 50% in the water layer at 0.3 m above the bottom in summer (Haga et al. 2006b). As these areas are covered with dense submerged macrophytes, these plants might cause the stagnation of lake water.

The summer drought caused by the operation rule also affects the spawning of the indigenous fishes, as this period coincide with the breeding period of most of the indigenous and endemic fishes. Yamamoto et al. (2006) indicated that more than 70% of the spawning area of cyprinid fishes was lost when the water level was artificially lowered by 0.3 m from June to October. Moreover, Sato and Nishino (2010) found that the fish spawning did not occur unless the water level exceeded BSL +0.1 or +0.2 m, based on the monitoring data collected by the Biwako River Office during 2004–2008.

Effect of Alien Species

Invasion and expansion of the alien plants and animals, some of which are designated by the Invasive Alien Species Act, also had adverse effects on the littoral ecosystems. Alien floating plants, like *Azolla cristata*, the water lettuce *Pistia stratiotes*, and water hyacinth *Eichhornia crassipes*, and emerged plants, like the knotgrass *Paspalum distichum* and alligator weed *Alternanthera philoxeroides*, have invaded into the shallow areas and spread rapidly (Sects. 3.1.2 and 3.1.4). Along with the increase of submerged plants, these alien plants would also accelerate the stagnation of the shallow water bodies of both basins. The large black bass *Micropterus sarmoides* and bluegills *Lepomis macrochirus* also had adverse effects on the indigenous fish communities, resulting in the changes in the food web structure of the lake (Sects. 2.5 and 3.2.4).

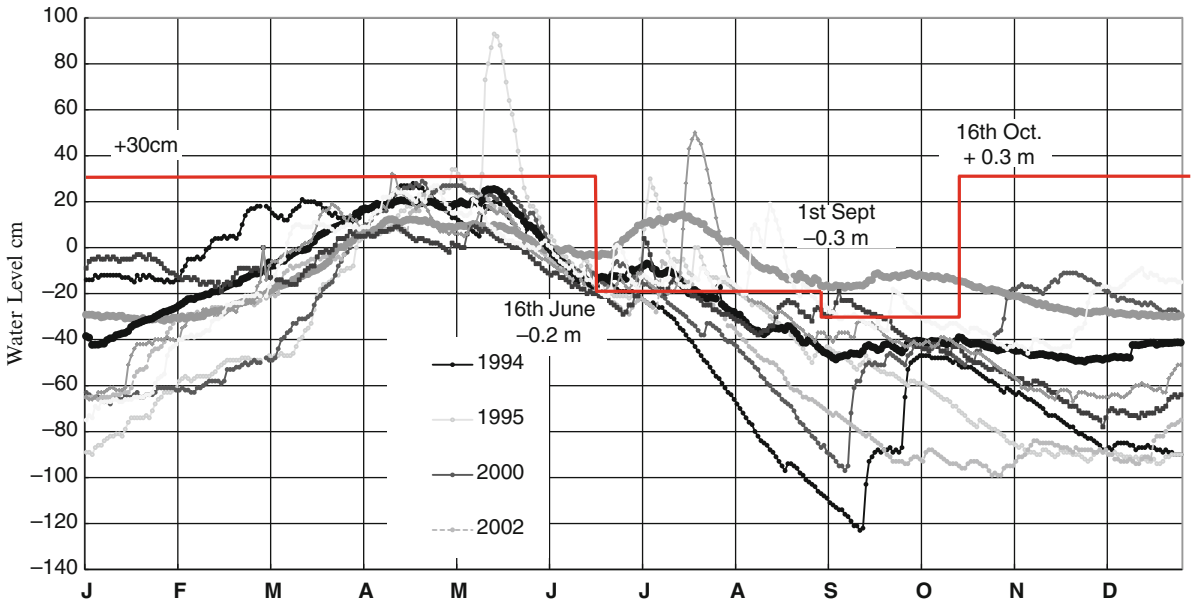

Fig. 3

Mean daily water level of Lake Biwa during 1962–1991 (*gray wide line*) and 1992–2002 (*black wide line*), and daily lake water level in 1994 (*black line*), 1995 (*gray line*), 2000 (*blackish gray line*), and 2002 (*dotted gray line*).

3.1.1 The Changes in Lakeshore Landforms of Lake Biwa

Masaru Tatsumi

Abstract Since last 20–30 years ago, the Lake Biwa area was significantly changed by the Lake Biwa Comprehensive Development Project. The author surveyed the lakeshore landform in 2007. And, the survey was compared with the same survey done 20 years ago. It became clear that the number of artificial shores increased on the whole shoreline, especially on the east coast of the south basin where shallow lake basin was reclaimed and lakeside road as well as the front beach was newly constructed. These artificial shores changed the natural shoreline considerably. On the other hand, the west coast of the south basin had already changed before 20 years ago, and the changes made since then were not on a large scale, except the urban area of Otsu where the shore was reclaimed and some recreational parks and esplanades were constructed.

Keywords Lakeshore landform • Natural landform • Artificial landform • South basin

Introduction

Lakeshore landform is one of the important factors influencing on the lake's ecosystem. The changes in lakeshore greatly affect all habitats in direct or indirect manner. There were two periods of time when the landform of shoreline was changed considerably. The first was from 1942 to 1971 during the reclamation of the shallow attached lakes (i.e., *naikos*). As a result, shoreline changed simple and smooth. The second was during the Lake Biwa Comprehensive Development Project, which was established in 1972 and finished in 1997. By the Project, some landfills and dikes on the shore with road were constructed. Also, many new shorelines were built. In Japan, this was the high growth period of the Japanese economy.

The previous survey of the lakeshore landform of Lake Biwa was conducted by Lake Biwa Research Institute in 1989. In 2007, the author surveyed the whole area of the lakeshore landform and compared with the previous survey. The survey of 1989 showed the distribution of natural and artificial landforms roughly, but it did not provide the detailed classification. On the other hand, the survey of 2007 was conducted using a map of 1/5,000 in 20 years ago, revised maps of the same scale, and aerial photographs, and with fieldwork.

In this report, the lakeshore landform in the south basin is introduced with some photographs.

Classifications of the Landform of Lake Biwa

The lakeshore landform can be classified into natural and artificial. Natural landform is further classified into sand beach, gravel beach, and vegetated beach covered with reed grasses, *Phragmites australis* and *P. japonica*, and willow coppices, as pictured in *Fig. 1 a, b, c, e* respectively. Artificial landform is characterized as stone masonry or concrete beach (*Fig. 1d*). Sand beach is distributed in the delta region of Yasu River, Hino River, Echi River, and Ane River, along the east coast of the north basin. Gravel beach is located in the mouth of Inukami River of the east coast, and most reed beds are distributed in the north part of the mouth of Ane River. Rock beach is distributed in the mountain region of the north basin. On the other hand, artificial stone masonry beach is located in the east coast of the south basin, and most concrete beach in the urban area of Otsu and Otsu Harbor of the south basin.

Seen the lakeshore in detail, however, there are many places, which have two or more factors except the above classifications of landform. The survey of 2007 covered all the factors in detail and reported wherein (Tatsumi 2008a).

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Fig. 1

Typical lakeshore landform (2007) (a) sand beach, (b) gravel beach, (c) vegetated beach covered with *Phragmites australis*, (d) artificial concrete beach, (e) rock beach.

Changes in the Shoreline of the South Basin

To investigate changes of the shoreline of south basin, we drew up the figure to show both changes by using the aerial photographs taken by US Army in late 1940s and the results on the survey of 2007 (*Fig. 2*). At the same time, the figure shows the present artificial shore and the lakeshores of emergent plant zones in 1940s (Tatsumi and Azuma 2010). The change of each area is explained using drawings and photographs (Tatsumi 2008b).

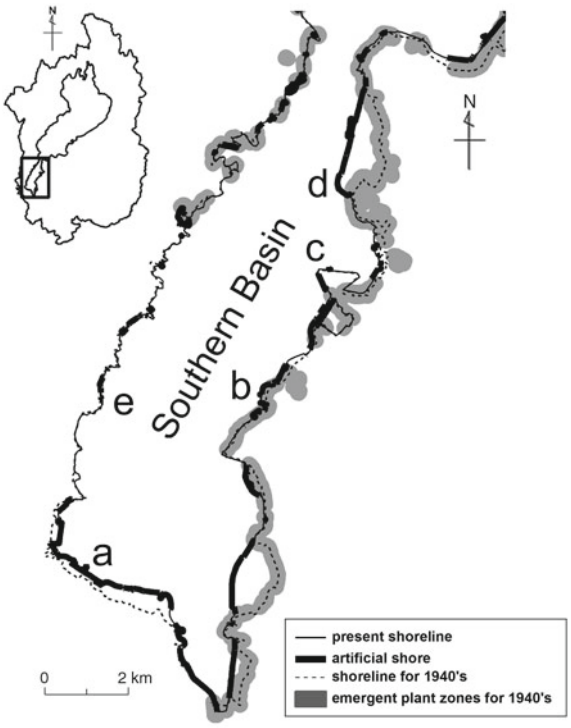

Fig. 2
Change in the shoreline of the south basin (Tatsumi and Azuma 2010) (*a*) Otsu Harbor, (*b*) Shina-cho, (*c*) Karasuma Peninsula, (*d*) Konohama-cho, (*e*) Karasaki.

(1) South coast of the south basin: urban area of Otsu from Otsu Harbor to Seta River
In this area, the shallow lake basin was reclaimed in the past 20 years, and the shoreline was moved frontward. Otsu Harbor was the area changed most, where the new harbor was constructed by reclamation, and the shoreline has moved more than 200 m forward. On the east of the harbor, many piers were built in front of the artificial lakeshore (*Fig. 3*). On the reclaimed land, many buildings were constructed (e.g., a museum, an auditorium, a hall, hotels, a water treatment facility, and a park with an esplanade, named as "Nagisa Park"). The esplanade, with more than 100 m in width, to the Omi Bridge and "Sun Shine Beach" made of sands with gravel in front of the park were built. Moreover, in the part of south end of Lake Biwa, a park with esplanade 20–50 m in width was built. It is called "Zeze Seiran no Michi," and it runs along the lakeside road to the railroad bridge of Japan Railway.

(2) East coast of the south basin
Among major changes made to the lakeside bank and the lakeside road, the road was built along the lakeshore, and front beach was completed from the mouth of the old Hayama River to Shina-cho (*Fig. 4*). Moreover, the road built into the lake appeared from Shina-cho to south point of Karasuma Peninsula (*Fig. 5*).

Fig. 3
Artificial reclaimed beach with stone masonry at the south of the south basin (Fig. 2a; October 2007).

Fig. 4
Aerial photograph of the lakeshore and Hayama River in Shina-cho, Kusatsu, east of the south basin. Artificial beach was constructed in the 1990s (Fig. 2a; August 2007).

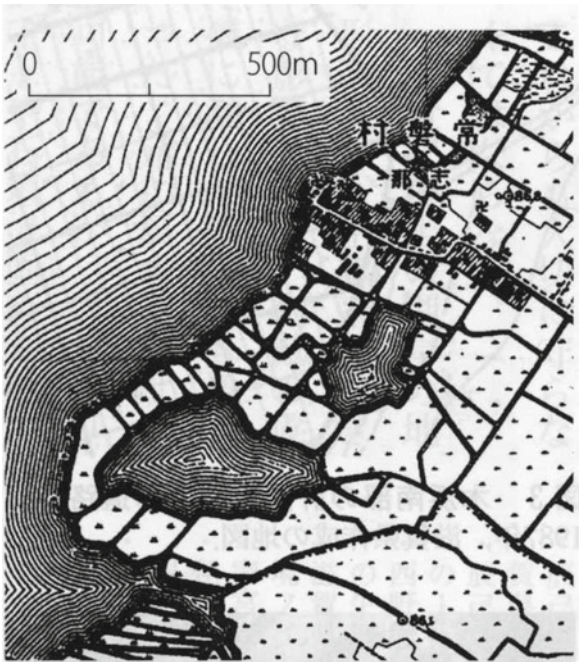

Fig. 5
Map of Shina-cho area at Meiji Era (1892 "KUSATSU," Geographical Survey Institute).

(3) From the Karasuma Peninsula in Kusatsu City to Konohama-cho, Moriyama City

In this area, some of the lakeside roads were built into the lake, and some harbors were newly built and repaired. The Karasuma Peninsula used to be a long sand spit. Trees were grown over, and people cultivated pearls inside the lake. Since 20 years ago, however, filled grounds have been expanded, and the lakeshores have been maintained. Now, there is Lake Biwa Museum (*Fig. 6*).

The landscape of this area has been changed since then. In the west side of the peninsula, there is a concrete harbor, and in the north, there are stone masonry beach and artificial white sand beach where reeds and lotus clump together. At north area from the root of the peninsula, a lakeside road was built in the lake around Akanoi Bay, and a new harbor was built. There is swampland between the lakeside road and original lakeshore. In 1961, paddy field and reed areas were connected with Lake Biwa via network of many creeks (*Fig. 7*, left). When Konohama filled ground was completed in 1966, the paddy fields around were separated from the lake. In the late 1980s, lakeside road, front beach with parks, and artificial lagoon were built in Akanoi-Konohama area (*Fig. 7*, right).

Fig. 6
Aerial photograph of the Karasuma Peninsula and Lake Biwa Museum, Kusatsu, east of the south basin (Fig. 2c, August 2007).

Fig. 7
Aerial photograph of the Akanoi-Konohama area, east of the south basin, in 1961 (*left*, Japan Map Center) and 2003 (*right*, Biwako Office, Kinki Regional Development Bureau), respectively (Fig. 2d).

Fig. 8
North side of the famous pine tree at Karasaki, west coast of the south basin, Otsu City (Fig. 2e, October 2007).

New lagoon is used as a fishing pond. All these changes are clear by comparing between the old map and the aerial photograph.

(4) West coast of the south basin
On the west coast of the south basin (i.e., from Katata to Otsu-Urban area), the lakeshore itself was not changed significantly, although some marinas were built. For example, *Fig. 8* shows the piers of 20 years ago that has been rebuilt and added. Similarly, some lands of the lakeshore of west side were used as resting places, condominiums, and residential areas.

The Changes of Lakeshores and Reed Areas

In 1993, Lake Biwa was inscribed as a registered wetland under the Ramsar Convention. The relationship was investigated between the reed areas with which the lakeshore had been covered and the changes of the lakeshore landforms. The study found as follows:

(1) On the east coast of the south basin, there used to be historically important reed areas. Many landforms of the area were greatly changed because of the Lake Biwa Comprehensive Development Project. Also, the form and structure of the lakeshore was changed considerably because of concrete and stone masonry beach. As a result, a number of reed areas decreased.

(2) The west coast of the south basin is a mountainous region largely occupied by hills, and there is a small plain, where residential or factory areas are located under private property on the lakeshore. This played an important role in restraining the large changes in both the landform and the lakeshore. It turned out that the reed fields were maintained in the area where reed vegetation was poor. Therefore, it was possible to protect the traditional ecosystem unless the landform was greatly changed. This was an example in which the scenery was maintained by the regulation of some laws (the Ordinance on the Reed Beds around Lake Biwa (1992), the Ordinance relating to the Appropriate Leisure Usage of Lake Biwa (2002), etc.).

Conclusions

Today, many people spend a holiday going to the lake to sail a yacht or boat, and enjoying a barbecue party and lure fishing on the lakeside. There are many cars with license plates of other prefectures. We have to protect the environment rich in water and nature hereafter.

Landform changes in the late twentieth century had a great influence on the ecosystem of the lake. Though it is impossible to restore the landform, today some people are working on an ecology movement to recover the environment by planting reeds in the lakeshore firmed concrete and stones. Also, scientists of every field are researching the present condition and discussing how to protect the ecosystem of the lakeshore. Moreover, most of elementary school and junior high school in Shiga Prefecture have adopted the environment education, and their students experience the field study at Lake Biwa.

The author would like many people to understand the changes from the past to the present, and hope them to search good ways for the environmental conservation of the lakeshore.

3.1.2 Characters and Changes of Shore Vegetation of Lake Biwa

Yasushi Sasaki · Yuhide Murakami · Yuko Kaneko

Abstract Lake Biwa is the biggest lake in Japan, and an ancient lake, which firstly formed about 4 million years ago. The shore area of Lake Biwa is composed of sand, gravels, and linked rocky mountain. The original vegetation of the shore area was poor, like *Phragmites japonica*, *Imperata cyrindrica* var. *koenigii*, and *Alnus japonica*, same willows. The change of shore vegetation was investigated during recent 20 years, and it was found about 566 plant species, including 141 alien and ornamental plants. Especially some alien species, that is, floating aquatic weeds (*Eichhornia crassipes* and *Azolla cristata*), emergent plants (*Alternanthera nodifera* and *Paspalum distichum*), submerged aquatics (*Elodea nuttallii*, *Myriophyllum brasiliense*, and *Egeria densa*), and terrestrial plants (many Graminae and Compositae from tropical area, Asia and America), spread widely. On the other hand, natives like *Sium suave* var. *nipponicum*, *Nymphoides peltata*, *N. indica*, *Persicaria foliosa* var. *nikaii*, and *P. Taquetii* were rare. Their patch population and ramet are also small now. In these conditions, concentration area "Hot Spot" of rare species is verified at some river mouth and attached lake area. Creates habitats for wetland, occurs such aliens, ecosystem of wetland and landscape are largely changing now.

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Keywords Alien • Hot spot • Natural vegetation • Potential natural vegetation • Swamp

Introduction

The shore area of Lake Biwa is mainly composed of granitic sand and basalt gravels that are transported from the surrounding Hira and Suzuka Mountain systems. Sometimes, people call Lake Biwa Awa-umi or O-umi; "umi" means sea. Earlier, the shore vegetation of Lake Biwa was very poor, like *Phragmites japonica*, *Imperata cyrindrica* var. *koenigii*, grass land and few trees of *Alnus japonica* and willows were there. Almost shore area of Biwa Lake was a sand beach. However, a few endemic species were living, except aquatics plants in the shore area (Sect. 2.3.2). Now, various types of vegetation such as grass communities, shrub, and forest develop on the beach; at the shoreline reed bed, meadow, and floating, emergent, and submerged aquatics are dominant. And to keep egg-laying site for the indigenous cyprinid fishes, local people, and some government offices tried to plant common reed for many years, and set up public parks or gardens with ornamental plants. As a result, many shore areas advanced succession to marsh, has alien plants, and changed landscape largely.

Characteristics of Vegetation on the Shore Area of Lake Biwa

Natural Vegetation

In the main part on the beach sand of the Lake Biwa, it can be found various coastal dune vegetations, such as *Imperata cyrindrica* var. *koenigii* – *Vitex rotundifolia* community, *Calystegia soldanella* – *Cynodon dactylon* community and some *Lathyrus japonicus* and *Tetragonia tetragonoides*. The sandy and rocky areas are covered with river vegetation, such as *Phragmites japonica*, *Salix gracilistyla*, and *Alnus*

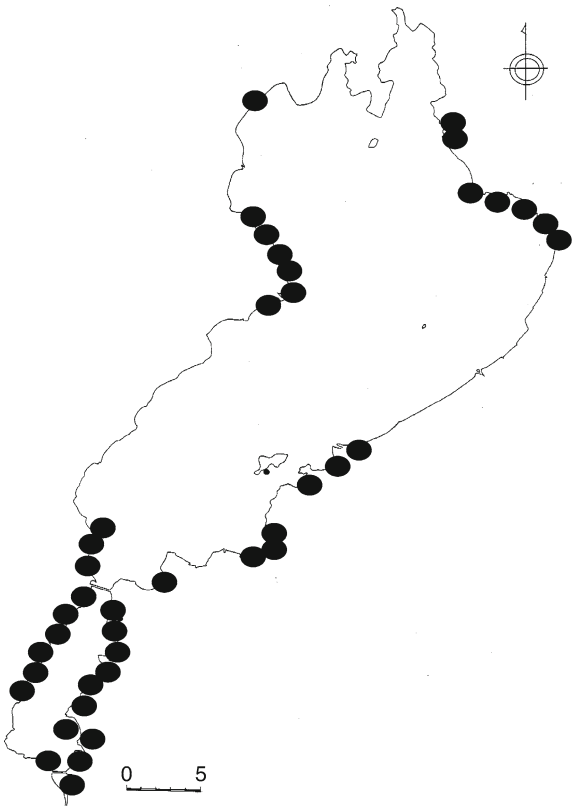

Fig. 1
Distribution of *Phragmites australis* (in 2010).

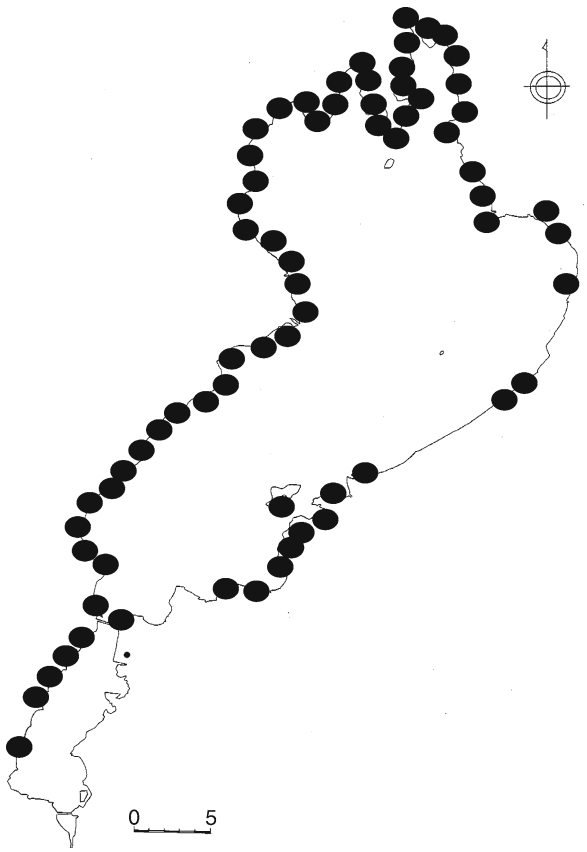

Fig. 2
Distribution of *Phragmites japonica* (including planted plant in 2010).

japonica communities. On the other hand, in the delta and river mouth areas, Ado and Echi Rivers distribute various swamp vegetations like *Phragmites australis*, *Miscanthus sacchariflorus*, *Scirpus yagara*, *Zizania latifolia*, especially in muddy area, occurs *Sparganium stoloniferum* and *Cicuta virosa* var. *nipponica*. In the wetland like attached lake around the lake Biwa, it was covered common reed *Phragmites australis* (Fig. 1), but in the shore area of Lake Biwa there is sandy area, it can be considered that *Phragmites japonica* covered almost (Fig. 2).

Chikubu Island, located at the northern end of the northern basin, was covered with evergreen forest, *Percea thunbergii*, which was destroyed by the colonized Japanese cormorant now. As a result, survey around Lake Biwa, *Percea thunbergii* forest (river mouth of Inugami River) and deciduous forest *Ulmus parvifolia*, *Celtis sinensis* var. *japonica* could be observed. It will be considered whether those forests are the climax forest or potential natural vegetation at upland areas.

Secondary Vegetation

In the shore area of the lake, the break out of strong waves by the northwest wind can be seen during winter season (Hamabata 1991). Public office and people cut grass in early summer and winter every year, and consequently, the succession of vegetation is saved in sand dune areas. Annual plant communities like *Festuca myuros*, *Silene gallica* var. *quinquevulnera*, and *Briza maxima* expand finally. In northern part, taller annual communities like *Raphanus sativa* var. *hortensis* f. *raphanistroides* and *Brassica juncea* are dominant. In the present time, many types of forests such as pine and willow cover the shore area of the lake, but almost all forests are planted artificially except those that are in river mouth areas. The pine forest (*Pinus thunbergii*) on the lake beach was planted after the World War II, but pine forest in Imazu area is over 100 years old. Those natural and secondary vegetation types are also very common in Japan. Many other forests are planted and expanded by ornamental plant

Table 1
Occupation rate of classification area by composition of vegetation (Sasaki 1991,1995a)

Zone	Community type	Occupation rate
A:	Community type of *Sparganium stoloniferum – Cicuta virosa* var. *nipponica*	6%
B:	Community type of *Trapa japonica – Zizania latifolia*	25%
C:	Community type of *Phragmites australis – Salix* spp.	28%
D:	Community type of *Cynodon dactylon – Pinus thunbergii*	19%
E:	Community type of *Phragmites japonica – Alnus japonica*	17%
F:	Artificial area	5%

species like poplars cedar, cherry tree, bamboos, and some alien trees such as *Melia azedarach*, *Robinia pseudoacacia*, *Ailanthus altissima*, and *Sapium sebiferum*.

Classification of Area by Composition of Vegetation

The shore of Lake Biwa can be divided into the following six zones based on the composition of natural vegetation. These six zones are depended on the geo-morphological characters and sedimentation of organic matters by the aquatic plant communities (Sasaki 1991, 1995a, b).

Zone C: community type of *Phragmites australis – Salix* spp. is grown in river mouth area, *zone D*: community type of *Cynodon dactylon – Pinus thunbergii* distribute in sand dune area, *zone E*: community type of *Phragmites japonica – Alnus japonica* distribute in rocky area, and *zone B*: community type of *Trapa japonica – Zizania latifolia* develops in areas with organic sediment matters, and in most sediment area expand community type of *Sparganium stoloniferum – Cicuta virosa* var. *nipponica*. *Zone A* and *zone F* is artificial area (*Table 1* and *Fig. 3*).

Vegetation Change

The change of shore vegetation was investigated in Lake Biwa during past 20 years, and it was found that a total of 566 plant species including 141 alien, 9 ornamental, and 8 planted plants reported so far (Sasaki 2009).

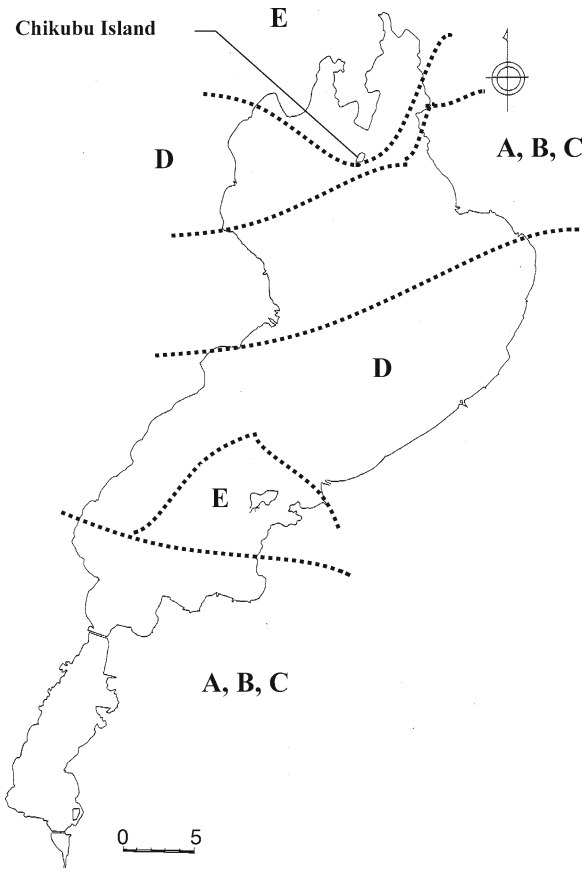

Fig. 3
Classification area by composition of vegetation (Sasaki 1991).

Alien Species

Especially there are some alien species; floating weeds such as *Eichhornia crassipes, Pitia stratiotes*, and *Azolla cristata*; emergent aquatics such as *Alternanthera nodifera* and *Paspalum distichum*; and submerged aquatics such as *Elodea nuttallii*, *Myriophyllum brasiliense*, and *Egeria densa*.

The alien species entered from the tropical areas, Asia and America, and are spreading widely now (*Figs. 4*, *5*, and *6*). Even the area around Lake Biwa is covered with snow in the winter, many aliens are passed the winter. In the last 20 years, it can be concerned the global warming effect of vegetation that species originate in tropical area expand widely.

For the terrestrial plants, many genera of Graminae plants, such as *Poa*, *Festuca*, *Bromus*, *Avena*, *Briza*, *Eragrostis*, *Paspalum*, *Sorghum*, *Vulpia*, *Lolium*, *Aira*, and *Andropogon*, and Compositae plants, such as *Bidens*,

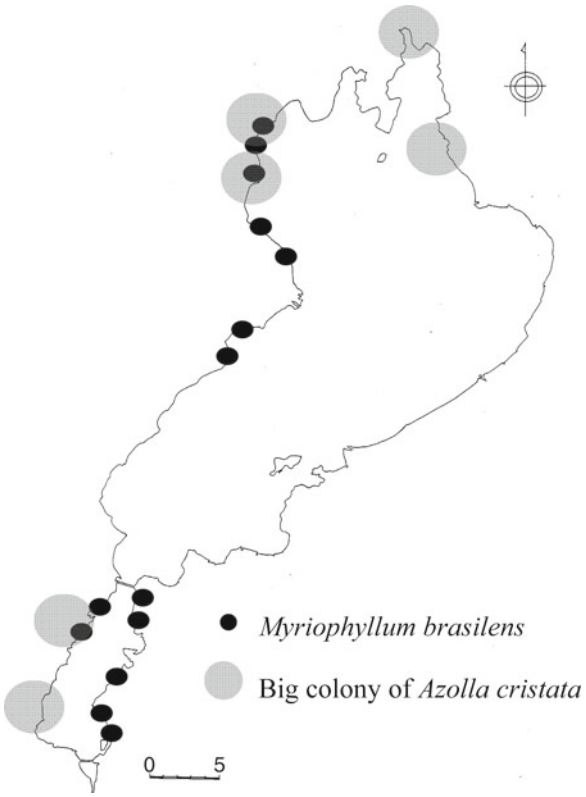

Fig. 4
Distribution of *Myriophyllum brasiliense*.

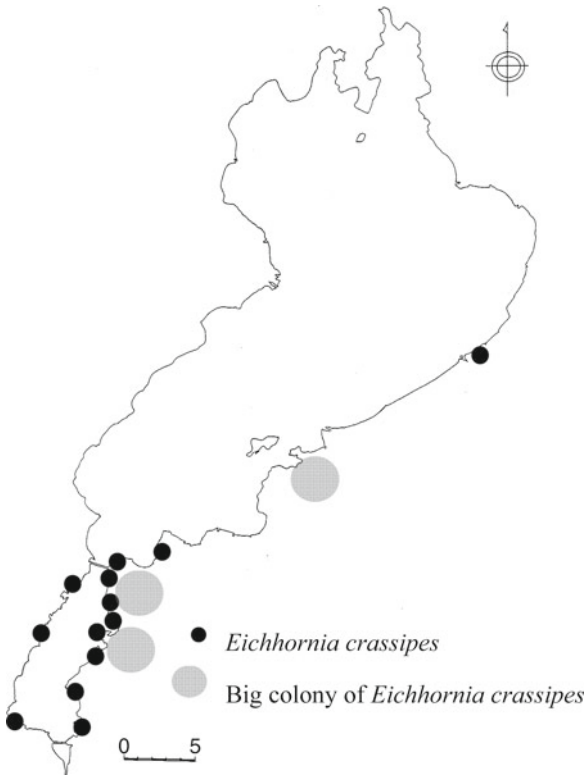

Fig. 5
Distribution of *Eichhornia crassipes* and *Azolla cristata*.

Eclipta, *Gnaphalium*, *Conyza*, *Sonchus*, *Helianthus*, *Erigeron*, *Solidago*, *Taraxacum*, *Lactuca*, *Senecio*, *Galinsogo*, *Stenactis*, *Aster*, and *Crossocephalum*, spread on whole area. Especially, *Phragmites karka* and *Arundo donax* that grow mainly in tropical areas were expanded (*Fig. 7*).

Before 20 years, *Paspalum distichum* occurred on every water edge, but now *Paspalum distichum* var. *indicum* is dominant as a substitute for its niche (*Fig. 8*).

On the other hand, natives like *Sium suave* var. *nipponicum*, *Nymphoides peltata*, *N. indica*, *Persicaria foliosa* var. *nikaii*, and *P. taqueii* are rare; their patch population and ramet are also small now. In these conditions, concentration area "Hot Spot" of rare species is verified at some river mouth and attached lakes.

Creates habitats for wetland, occurs such aliens, ecosystem of wetland and landscape in the shore area of the Lake Biwa are largely changing.

Flora of the Shore Area of Biwa Lake

Vascular flora of the shore area in the Lake Biwa has recorded a total of 566 species without submerged plants. They include species introduced as garden plants, planted artificially and aliens, and all of them accounted for 172 species, that is, 30.4% of total species (Sasaki 2009).

Human activities around the lake such as land reclamations, development of shore parks, parking areas, and intensive agriculture created eutrophication due to nutrient enrichment of water bodies. Phenomenon of eutrophication brings high biomass of plants, becomes vicious spiral of eutrophication, and causes high biomass production consequently. Actually, aliens spread rapidly in the river mouth and the gate of channel and waterway of irrigation.

Conclusions

Original shore vegetation in the Lake Biwa mainly comprises community type of *Cynodon dactylon – Pinus thunbergii and Phragmites japonica – Alnus japonica*, where many indicator plants of sandy and gravel conditions grow, such as *Calystegia soldanella, Lathyrus japonica*, *Vitex rotundifolia*, *Artemisia capillaries*, and *Arabis kawasakiana*. Except in the mouths of rivers, such as Ado River and Ane River, forest vegetation was very poor, and grow some *Salix chaenomeloides*, and *Salix subfragilis*.

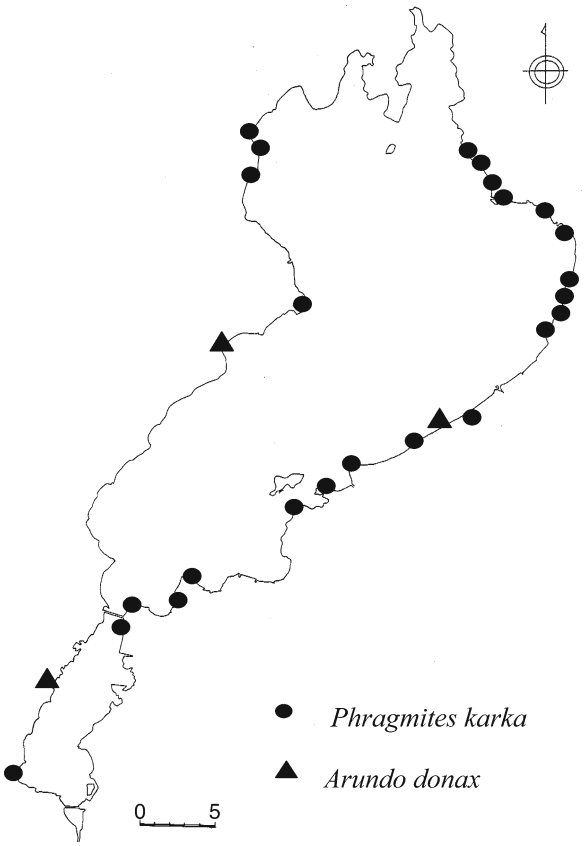

Fig. 6
Distribution of *Phragmites karka*.

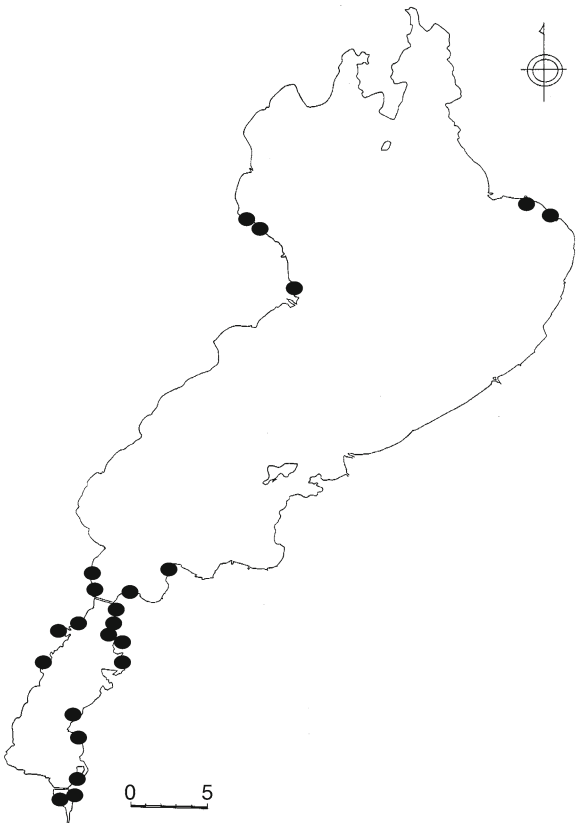

Fig. 7
Distribution of *Zizania latifolia* and *Arundo donax*.

Now, the landscape of the Lake Biwa shore is changed considerably. There are some indicator plants of muddy condition like *Cicuta virosa* var. *nipponica*, *Zizania latifolia*, *Phragmites australis*, and many alien species like *Eichhornia crassipes*. We can say that this is global warming effect, because many alien species are introduced from tropical countries. At the same time, human activities such as land reclamation, construction of any facilities, the expansion of intensive agriculture in and around area, and tree plantation and reed plantation of no agreeable condition on the pretext of nature restoration encourage the change of landscape and nature conditions of the Lake Biwa.

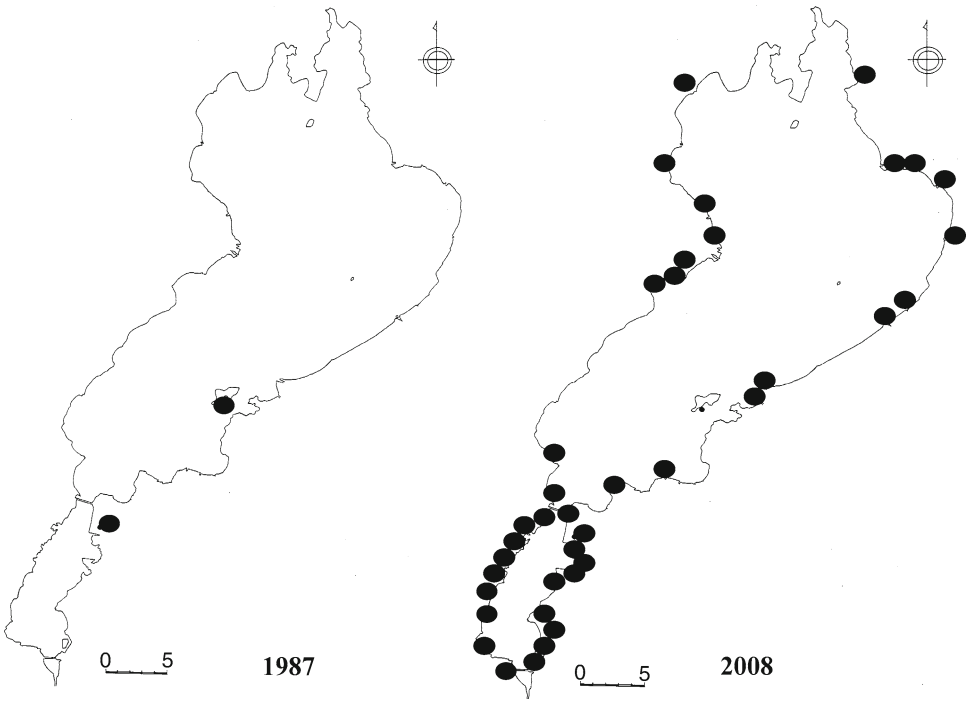

Fig. 8

Expansion of *Paspalum distichum* var. *indicum* from 1987 (*left*) to 2010 (*right*). *Paspalum distichum* var. *indicum* occurs as a substitute for *Paspalum distichum* niche.

3.1.3 Long-term Changes of Submerged Macrophytes in the South Basin of Lake Biwa

Hiroki Haga

Abstract Documented changes since 1936 in the areal extent and biomass of submerged macrophytes in the south basin of Lake Biwa are reviewed. Three periods can be recognized. During the first period (up to 1958), submerged macrophytes occupied nearly half of the surface area of the south basin. During the second period (1963–1994), they were in decline, while the third period (1995 to the present) has been a time of recovery. Particularly after 2000, submerged macrophytes have increased to a level far exceeding that of the first period. The record drawdown of water in 1994 has been considered to have triggered this increase, although this explanation has been questioned by some researchers. The current prolific growth of submerged macrophytes has begun to exert negative impacts on the lake's ecosystem and people's life.

Keywords Distribution range • Biomass • Decline • Recovery • Water level drawdown • Negative impacts

Introduction

The south basin of Lake Biwa (*Fig. 1*) has a surface area of 51.6 km^2 (Haga 2006) and a maximum depth of 7 m (Shiga Prefecture 2005). This basin accounts for about half of the suitable area for submerged macrophytic vegetation (i.e., areas of <10 m in depth) in the lake (Ikushima et al. 1962), and parts of the basin have been rapidly colonized by submerged macrophytes during the past decade (Haga et al. 2007). Although this increase in submerged macrophytes constitutes a "recovery" of the littoral community (Hamabata 2005a, b), massive development of submerged macrophytes also causes nuisances.

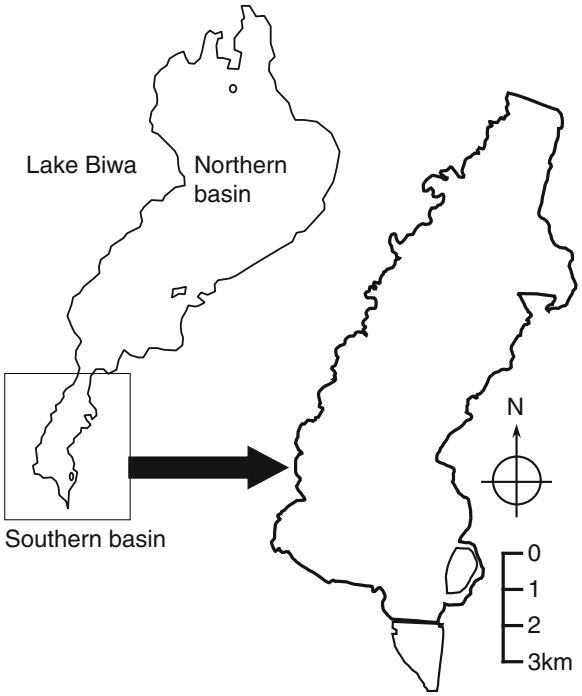

Fig. 1
South basin of Lake Biwa.

Long-Term Fluctuations in the Submerged Macrophytic Vegetation of the South Basin

Quantitative study of the areal extent and biomass of submerged macrophytes in the south basin began in 1936 (*Table 1*). Haga et al. (2006a) suggested that long-term fluctuations in these parameters can be divided into three periods.

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During the first period (up into the1950s), submerged macrophytes in the south basin were consistently distributed at the bottom shallower than 4 m deep (Yamaguchi 1938, 1943; Shiga Prefectural Fishery Experimental Station 1954; Ikushima et al. 1962). Based on this, Haga et al. (2006a) estimated the total areal extent of submerged macrophytes in the south basin during this period to have been 27 km^2, that is, nearly half the surface area of the basin. The areal extent was in fact 23 km^2 in 1958 (Shiga Prefectural Fishery Experimental Station 1954; Ikushima et al. 1962). The total biomass (dry weight) of submerged macrophytes in the south basin in 1936 was estimated to have been 3,940 tons by Haga et al. (2006a), based on Yamaguchi's (1938) data. Although the Shiga Prefectural Fishery Experimental Station (1954) reported a smaller total biomass of 553 tons in 1958, this value probably does not indicate that year's maximum biomass because the investigation was done in November. Ikushima (1966) suggested that submerged macrophyte growth (and thus standing biomass) reaches its maximum in late August or early September. Seven species (*Ceratophyllum demersum*, *Vallisneria asiatica* var. *biwaensis*, *Potamogeton maackianus*, *V. denseserrulata*, *Hydrilla verticillata*, *Najas marina*, *Myriophyllum spicatum*) accounted for 80% of the total biomass of submerged macrophytes in 1936 (Yamaguchi 1938). Every species had a comparable biomass, in the range of 307–838 t.

During the second period (1963–1994), submerged macrophytes in the south basin were on the decline. Their areal extent and biomass fell respectively to 0.6 km^2 and 11 tons in 1963 due to severe turbidity caused by reclamation work at Konohama in the northeastern part of the basin (Ikushima 1966). The submerged macrophytes showed a slight revitalization in 1969, their areal extent and total biomass reaching 7.1 km^2 and 802 t, respectively (Shiga Prefectural Fishery Experimental Station 1973), but through 1974, these values never exceeded 9.5 km^2 and 1,350 tons (*Table 1*). Two alien species, *Elodea nuttallii* and *Egeria densa*, appeared and expanded their ranges extensively during the second period. These two species accounted for >96% of the total biomass of submerged macrophytes in the south basin in 1974–1977 (Tanimizu and Miura 1976; Water Resources Development Public Corporation 1977a, b).

Submerged macrophytes expanded explosively during the third period (1994–present). Both their areal extent and biomass increased almost linearly until 2002, to 43 km^2 and 10,735 t, respectively. Thereafter, the areal extent continued to increase gradually, reaching 47 km^2 in 2007 (Haga and Ohtsuka 2008). The biomass of submerged macrophytes in the south basin did not increase significantly from 2002 to 2007; it was 9,630 tons in 2007 (Haga et al., unpublished data). Haga et al. (2006a, b) suggested that four native species together (*P. maackianus*, *H. verticillata*, *C. demersum*, and *M. spicatum*) and the alien species *Egeria densa* respectively accounted for 88% and 10% of the total submerged macrophytes in the south basin in September 2002. The biomass of *P. maackianus* was exceptionally high among the four native species, being 4,827 tons and accounting for 45% of the total biomass. It should be noted that filamentous algae then had the sixth largest biomass (504 t) among the macrophytes and algae. Such massive growth of filamentous algae was not mentioned in any study conducted during the first or second period.

Why Did Submerged Macrophytes Start to Increase in 1994?

Hamabata (2005a, b) believed that the recent expansion of submerged macrophytes in the south basin of Lake Biwa was triggered by a severe draught, which, in September 1994, caused a record water drawdown to −1.29 m (relative to Biwa-ko Standard Water Level: BSL). He speculated that the breeding of submerged macrophytes might have been facilitated by an increase in light intensity at the lake bottom due to this drawdown. Scheffer et al. (2001) had earlier suggested that a drawdown may be influential in causing a catastrophic shift from a turbid water state dominated by phytoplankton to a clear water state dominated by submerged macrophytes, and the scenario proposed by Hamabata (2005a, b) was in accord with this model. Objections were brought by Haga and Ohtsuka (2008). They found that light conditions at the bottom did not improve during the most severe drawdown period (late September) in 1994 compared to previous months; in fact, a decrease in Secchi disk transparency was noted. In addition, using the Secchi disk transparency data and the monthly water level data recorded by Shiga Prefecture and the Ministry of Land, Infrastructure, Transport, and Tourism from 1979 through 1994, they calculated that the actual areal extent of submerged macrophytes only reached 9–48% of the expected range. Haga and Ohtsuka (2008) thus concluded that light conditions defined by turbidity and water level were not the sole (or the most effective) factor limiting the growth of submerged macrophytes in the south basin of Lake Biwa between 1979 and 1994. However, no other prime factor has been identified.

Table 1

Long-term fluctuations of submerged macrophytes in the south basin of Lake Biwa

		1st period		2nd period									3rd period						
Year		1936	1953	1964	1969	1973	1974	1976	1977	1981	1984	1994	1995	1997	2000	2001	2002	2003	2007
Biomass (dry weight) (ton)	*P. maackianus*	521			<1		22	3	8				962				4,827		
	C. demersum	838			110			40	95				75				1,424		
	H. verticillata	442			313				7				156				2,417		
	M. spicatum	307			2								3				820		
	P. malaianus.	93			17				4				7						
	V. asiatica var. biwaensis	788			200			0	8				36				12		
	V. denseserrulata	505			5				38				91				67		
	Najas marina	352			30				7				5						
	Egeria densa						577	1,279	811				83				1,088		
	Erodea nittalii				118		21		110				1,053				39		
	Others	94			6			15	7				29				41		
	Total	3,940	553	11	801		620	1,338	1,093	530			2,500			6,500	10,735		9,625
	Filamentous algae																508		
Area of distribution range (km^2)		27.0	23.4	0.6	7.1	2.7	3.3	5.7	9.4		3.9	6.2	9.5	24.0	29.3	29.0	43.0	43.0	43.3
References		1, 17	2	3	4	5	6	7	8	9	7	12	13	14	12	15,16	17	18	19

Ecological and Social Impacts of Prolific Growth of Submerged Macrophytes in the Third Period

Because submerged macrophytes had been on a decline during the second period, their resumed growth and range expansion during the third period has been recognized as a "restoration" of the littoral community (Hamabata 2005a, b; Haga et al. 2006a). However, after 2000, both the areal extent and the total biomass of the submerged macrophytes came to greatly exceed those that prevailed during the first period.

The average Secchi disk transparency in the south basin increased from 1.8 to 2.7 m from 1994 to 2009 (Shiga Prefectural Government 2010). Such an increase will ordinarily be caused by a decrease in phytoplankton. Haga et al. (2007) noted that the PVI (percent volume infestation: Maceina and Shireman 1980) in 2003 was close to 30%, at which level chlorophyll-*a* in the water column drastically decreases (Canfield et al. 1984).

Haga et al. (2006b) found depletion of oxygen (<50% saturation) just above the lake bottom at 36 of 84 investigated sites in the south basin in September 2002. Multiple regression analysis suggested that biomass of three species of submerged macrophyte (*E. densa*, *M. spicatum*, and *P. maackianus*) was a significant factor in reducing the oxygen concentration in the water. Oxygen depletion associated with dense macrophyte beds might adversely affect animals such as bivalves living on the lake bottom, but no detailed study of this has yet been conducted.

The current exuberant growth of submerged macrophytes has caused nuisances to the fishery and navigation, and it has also impaired the landscape value of the lake (Ohtsuka et al. 2004). Decaying driftweed on the shore causes unpleasant odors. Ichise et al. (2007) estimated that submerged macrophytes drifting ashore in the south basin each year might amount to as much as 1,000 tons (wet weight). The Shiga Prefectural Government and local authorities make a sizable effort and allocate substantial funds to harvest submerged macrophytes, in order to prevent such nuisances (Shiga Prefectural Government 2010).

3.1.4 Non-indigenous Species in and around Lake Biwa

Katsuki Nakai · Yuko Kaneko

Abstract In the ecosystem of Lake Biwa, quite a few nonindigenous species have become predominant, originating either outside (alien species) or within Japan (translocated species). The best-known examples concern the overgrowth of alien waterweeds in the submerged vegetation and the explosive increase of alien predatory fishes in the littoral fish community. Both have attracted much public attention because of the continuous efforts taken for their control. Including these examples, a total of 45 nonindigenous species may be regarded as having become established or naturalized in Lake Biwa. In addition, there is an immediate threat of further invasions, either by invasive species that have already become established in waters near Lake Biwa, or by any of a continuous stream of species likely to be introduced in the future.

Keywords Nonindigenous species • Invasive alien species

Definitions and Terminology

A variety of plant and animal species have been expanding their distribution ranges through anthropogenic processes. In this review, such human-introduced species are called *nonindigenous species*, irrespective of their geographical origins, domestic or exotic. Many terms for nonindigenous species are in use (e.g., nonnative, alien, exotic, introduced, and translocated). Here, considering geographical origins, the following terminology will be employed: *alien species*, those having foreign origins; and *translocated species*, those with domestic origins but now found outside their original, natural distribution ranges.

Serious negative impacts of nonindigenous species have been recorded repeatedly after their intrusion into new localities. This situation has promoted a realization of the need for legal frameworks to control nonindigenous species showing invasive tendencies. In Japan, the Invasive Alien Species Act came into force in June 2005. It designates as *Invasive Alien Species* or *"Tokutei-gairai-seibutsu"* (*IAS*, hereinafter), those having nonnegligible adverse effects on native ecosystems, primary industries, and human health and property. The Ministry of the Environment further designated a number of *Adventive Species* or *"Yô-chûi-gairai-seibutsu"* (*AS*, hereinafter) to be treated with vigilance because of their potential invasiveness. In 2007, the government of Shiga Prefecture, where Lake Biwa is located, issued an ordinance for coexistence with wildlife, in which additional, local regulations pertaining to alien species were included. This ordinance designates various plants and animals as *Local Invasive Species* or *"Shitei-gairai-shu"* (*LIS*, hereinafter), which were not designated as IAS but nonetheless were considered to be so invasive as to require proper regulation in the prefecture (see Sect. 7.2.4 herein).

After entering a new locality, some nonindigenous species succeed in establishing reproductive populations, while others do not, even though they may be (or are assumed to be) living there continuously under natural conditions for a long time owing to a long life span or frequent and repeated invasions/introductions. We refer these two categories as *established* and *naturalized* (but not yet established) species, respectively.

In general, there is only limited academic literature and other information on translocated species, in comparison with that on alien species. For aquatic animals contributing to inland fisheries, however, relatively many data on species translocations are available for the region in and around Lake Biwa. Most intentional introductions carried out in the context of the promotion of commercial fisheries have been recorded by the relevant agencies, and the aquatic macrofauna has been well surveyed and

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monitored in comparison with the terrestrial environment. Owing to the availability of such data, this review can deal with both alien species and translocated species.

As for geography, this review covers nonindigenous species established or naturalized in and around Lake Biwa, including its satellite lakes (so-called naiko) and other water bodies in the floodplain around the lake, namely the lower reaches of inflowing rivers and streams, artificial creeks, and irrigation canals. While the emphasis is on nonindigenous species having either aquatic or amphibious habits, some terrestrial species requiring special attention are also considered, if invasive impacts on aquatic or amphibious species are expected through predation or competition. Also covered are some invasive nonindigenous species whose establishment in and around Lake Biwa has not yet been confirmed, but which are already established in and around the lake's catchment area.

Recently, in particular, there have been many reports of species that are kept as pets or for ornamental purposes being found in natural settings such as shallow waters of Lake Biwa. Many such species are expected to fail in becoming established because of their tropical or subtropical origin. Such species are not treated in this review, but those expected to be capable of establishing populations for various reasons such as their temperate origins are mentioned as species requiring special vigilance.

Lists of Nonindigenous Species in Shiga Prefecture

Several publications are available that review either the purposeful introductions for the benefit of fisheries or records of observation or capture of nonindigenous species in Shiga Prefecture. Furukawa and Awano (1969) collected records of species introductions in Lake Biwa fisheries. The "Red Data Book of Shiga Prefecture 2000" categorized invasive nonindigenous animals and provided descriptions of them (Shiga Prefecture 2001). Matsuda and Seki (2002) provided the most comprehensive review of nonindigenous aquatic or amphibious animals such as fish, mollusks, crustaceans, amphibians, and reptiles in Shiga prefecture. Nakai (1996), Nakai and Hamabata (2002), and Nakai (2003) outlined the situation concerning nonindigenous species, with notes on historical events and the ecological impact of these species in Lake Biwa. The present review is based on these references with recent additional information.

Table 1 lists 45 nonindigenous aquatic or amphibious species established or naturalized in and around Lake Biwa. These include 1 bird, 3 reptiles, 1 amphibian, 12 fishes, 4 crustaceans, 7 mollusks, 2 other invertebrates, and 15 plants. Most are alien species, but four translocated species, all of them being fish, have also become established in Lake Biwa: a cyprinid, *Abbotina rivularis*; a subspecies of masu salmon, *Oncorhynchus masou ishikawae*; the Japanese smelt, *Hypomesus nipponensis*; and the trident goby, *Tridentiger brevispinis*.

Predominant and/or Invasive Species in Lake Biwa

Tetrapods

The red-eared slider *Trachemys scripta elegans* (AS) and American bullfrog *Rana catesbeiana* (IAS) are widely established along quiet shores of Lake Biwa as well as in satellite lakes, creeks, irrigation ponds, and the lower reaches of rivers and streams flowing into the lake.

Juveniles of red-eared slider, called "midori-game" (= green turtle), have been one of the most popular pets sold at affordable prices in Japan. This turtle became established in Shiga Prefecture in the 1980s and has been caught in Lake Biwa since 1985 (Matsuda and Seki 2002). It has become the commonest among the nonindigenous reptiles in Shiga Prefecture as well as in many other parts of Japan. According to interviews with fishermen, the number of these turtles captured in stationary nets on the lakeshore has markedly increased in recent years, which suggests that its population is increasing along the lakeshore.

American bullfrogs in the prefecture may have originated from introductions of juveniles to 49 places within the prefecture in 1922 and 1923 for aquaculture (Furukawa and Awano 1969). This frog has established a lake-wide distribution including remote islands such as Oki-shima and Chikubu-shima (Matsui et al. 2001). It is also common in paddy areas in the floodplain surrounding the lake and in satellite lakes. During its spawning season in late spring, many are killed by vehicles on the coastal roads, which provide an indication of frequent migration between the lakeshore and the adjacent floodplain (Nakai, personal observation).

Fishes

The cultured strain of common carp *Cyprinus carpio* have been stocked artificially on a nationwide scale, including in Shiga Prefecture (Matsuda and Seki 2002). Genetic studies

Table 1

Non-indigenous aquatic or amphibious species established or naturalized in and around Lake Biwa

Family		Species name	English [Japanese] name	Origins
Bird (1 species)				
Anatidae		*Anas platyrhynchos*	Domestic duck [Ahiru/Aigamo]	Industrial
Reptiles (3 species)				
Emydidae	○	*Trachemys scripta elegans*	Red-eared slider [Aka-mimi-game]	Alien (N. Am.)
Geoemydidae		*Chinemys reevesii*	Reeve's pond turtle [Kusa-game]	Alien (E. As.)
		Mauremys mutica mutica	Asian brown pond turtle [Shiro-ishi-game]	Alien (E. As.)
Amphibian (1 species)				
Ranidae	●	*Rana catesbeiana*	American bullfrog [Ushi-gaeru]	Alien (N. Am.)
Fishes (12 species)				
Cyprinidae		*Abbottina rivularis*	[Tsuchi-fuki]	Domestic
		Carassius auratus auratus	Golden fish [Kin-gyo]	Alien (E. As.)
		Cyprinus carpio	Common carp [Koi]	Alien (E. As.)?
	※	*Ctenopharyngodon idellus*	Grass carp [Sô-gyo]	Alien (E. As.)
		Hypophthalmichthys molitrix	Silver carp [Haku-ren]	Alien (E. As.)
	◉	*Rhodeus ocellatus ocellatus*	Continental rosy bittering [Tairiku-bara-tanago]	Alien (E. As.)
Salmonidae		*Oncorhynchus masou ishikawae*	Amago trout [Amago/Satsuki-masu]	Domestic
Osmeridae		*Hypomesus nipponensis*	Japanese smelt [Wakasagi]	Domestic
Gobiidae		*Tridentiger brevispinis*	Trident goby [Numa-chichibu]	Domestic
Centrarchidae	●	*Lepomis macrochirus*	Bluegill [Burû-giru]	Alien (N. Am.)
	●	*Micropterus salmoides*	Largemouth bass [Ookuchi-basu]	Alien (N. Am.)
Channidae	※	*Channa argus*	Northern snakehead [Kamuruchí]	Alien (N. Am.)
Crustaceans (4 species)				
Palaemonidae		*Neocaridina denticulata sinensis*	(Palaemonid shrimp) [Shina-numa-ebi]	Alien (E. As.)
Cambariidae	※	*Procambarus clarkii*	Red swamp crayfish [Amerika-zarigani]	Alien (N. Am.)
Crangonyctidae		*Crangonyx floridanus*	(Sideswimmer) [Furorida-mamizu-yoko-ebi]	Alien (N. Am.)
Daphniidae		*Daphnia plicaria*		Alien (N. Am.)
Mollusks (7 species)				
Ampullraiidae	○	*Pomacea canaliculata*	Golden apple snail [Sukumi-ringo-gai]	Alien (S. Am.)
Lymnaeidae		*Galba truncatula*	Dwarf pond snail [Koshi-taka-hime-monoara-gai]	Alien (Eu.)
		Pseudosuccinea columella	American ribbed fluke snail [Habutae-monoara-gai]	Alien (N.Am.)
Physidae		*Physa acuta*	Tadpole snail [Saka-maki-gai]	Alien (N. Am.)
Mytilidae	●	*Limnoperna fortunei*	Golden mussel [Kawa-hibari-gai]	Alien (E. As.)
Unionidae		*Hyriopsis cumingii*	(Chinese freshwater pearl mussel) [Hire-ike-chô-gai]	Alien (E. As.)
Corbiculidae	※	*Corbicula fluminea*	Asian clam [Taiwan-shijimi]	Alien (E. As.)

(continued)

Table 1
(continued)

Family		Species name	English [Japanese] name	Origins
Other invertebrates (2 species)				
Dugesiidae		*Girardia tigrina*	(Free-living flatworm) [Amerika-nami-uzu-mushi]	Alien (N. Am.)
Pectinatellidae		*Pectinatella magnifica*	Jelly ball moss animal [Oo-mari-koke-mushi]	Alien (N. Am.)
Plants (15 species)				
Salviniaceae	※	*Salvinia auriculata*	Eared watermoss [Oo-sanshô-mo]	Alien (S. Am.)
Azollaceae		*Azolla microphylla x filiculoides*	[Azora-zasshu]	Industrial
Amaranthaceae	●	*Alternanthera philoxeroides*	Alligator weed [Naga-e-tsuru-no-geitô]	Alien (S. Am.)
Cabombaceae	※	*Cabomba caroliniana*	Green cabomba [Hagoromo-mo]	Alien (N. Am.)
Brassicaceae	※	*Nasturtium officinale*	Watercress [Oranda-garashi]	Alien (Eu.)
Haloragaceae	●	*Myriophyllum aquaticum*	Parrot feather [Oo-fusa-mo]	Alien (N. Am.)
Scrophulariaceae	●	*Veronica anagallis-aquatica*	Water speedwell [Oo-kawa-jisha]	Alien (Eu.)
Asteraceae	●	*Gymnocoronis spilanthoides*	Senegal tea plant [Mizu-himawari]	Alien (S. Am.)
Hydrocharitaceae	※	*Egeria densa*	Brazilian elodea [Oo-kanada-mo]	Alien (S. Am.)
	※	*Elodea nuttallii*	Western waterweed [Ko-kanada-mo]	Alien (N. Am.)
Pontederiaceae	※	*Eichhornia crassipes*	Common water hyacinth [Hotei-aoi]	Alien (S. Am.)
Iridaceae	※	*Iris pseudacorus*	Yellow iris [Ki-shôbu]	Alien (Eu.)
Poaceae	※	*Paspalum distichum* var. *distichum*	Knotgrass [Kishû-suzume-no-hie]	Alien (N. Am.)
	※	*Paspalum distichum* var. *indutum*	Knotgrass [Chikugo-suzume-no-hie]	Alien (N. Am.)
Araceae	●	*Pisia stratiotes*	Water lettuce [Botan-uki-kusa]	Alien (Af.)

Abbreviations in origins are *Af.* Africa, *E. As.* East Asia, *Eu.* Europe, *N. Am.* North America, *Oc* Oceania, *S. Am.* South America. Symbols given at the species name indicates; ●: Invasive Alien Species (Invasive Alien Species Act), ○: Local Invasive Species (Shiga Ordinance), ※: Adventive species (Ministry of the Environment)

have revealed that this strain is similar to Chinese and German strains, but different from the so-called wild carp (Mabuchi et al. 2010). In 2004, koi herpesvirus (KHV)-infected stocks of carp were introduced into the lake, and a huge number of both cultured and wild carp died, but no mass mortality has been observed since then.

Largemouth bass *Micropterus salmoides* (IAS) and bluegill *Lepomis macrochirus* (IAS), both from North America, are the most invasive nonindigenous species of fish in the lake's littoral zone (see Sect. 7.2.4). Both established an almost nationwide distribution including northern Japan by the end of the twentieth century, causing serious negative impacts on indigenous species and local fisheries. Genetic analyses suggest that mass introduction of Florida largemouth bass *M. salmoides floridanus*, in addition to the already present northern largemouth bass *M. micropterus micropterus*, took place in the 1990s (Yokogawa et al. 2005).

Before the explosive invasions of these North American predatory fishes, two East Asian fishes had long been established, northern snakehead *Channa argus* (AS) and continental rosy bitterling *Rhodeus ocellatus ocellatus* (LIS).

The northern snakehead is a predatory fish that was introduced into Shiga Prefecture in 1933 and immediately expanded its range throughout the Lake Biwa watershed (Furukawa and Awano 1969). Although there has been some worry about its impact, this fish has not become invasive. In the most recent survey of the littoral fish communities, its abundance was still decreasing (Shiga Prefectural Fishery Experimental Station 2005).

Continental rosy bitterlings were first brought into the Kanto District near Tokyo around 1940 as contaminants in shipments of giant cyprinid fishes such as grass carp *Ctenopharyngodon idellus* and silver carp *Hypophthalmichthys molitrix* from China. These species are suspected to have entered into Lake Biwa in the form of eggs or larvae harbored within the gill cavities of Biwa pearl mussel *Hyriopsis schlegelii* shipped back from another lake, Kasumi-ga-ura, to stimulate freshwater pearl culture in Lake Biwa. Before the invasion of this bitterling, Lake

Biwa was inhabited by the Japanese endemic subspecies, Japanese rosy bitterling *R. ocellatus kurumeus*. This subspecies has gone locally extinct because of hybridization with the invading alien subspecies (Shiga Prefecture 2001), which is also suspected of being highly competitive with other native bitterlings over possession of unionid bivalves for spawning.

Among the translocated fishes, Japanese smelt were frequently introduced between 1910 and 1953, but these attempts to establish them were not successful (Furukawa and Awano 1969). However, natural spawning of the smelt started to be observed around 1993. According to fisheries statistics, its annual catch reached a peak 513 tons in 2004, and was highest among all fish categories in 2005. In spite of a decreasing tendency thereafter, the smelt has maintained a second-dominant position in the lake catch, behind only the indigenous ayu fish *Plecoglossus altivelis altivelis*.

Trident gobies were first found in Lake Biwa in 1989 and they established a lake-wide distribution within a few years. In spite of this quick range expansion and a larger body size in comparison with native gobies such as *Rhinogobius* spp. OR and BW, the trident goby has not become predominant in the littoral fish community in terms of either abundance or biomass (Shiga Prefectural Fisheries Experimental Station 2005).

Benthic Invertebrates

Red swamp crayfish *Procambarus clarkii* (AS) were translocated from the Kanto District in the early 1930s (Furukawa and Awano 1969). Shiga Prefecture's "Alien Watchers Project" (see Sect. 7.2.4) revealed that this crayfish was found in 61% of the surveyed meshes in the first year of the project, 2009, the highest proportion among all of the 10 targeted aquatic species. This crayfish often becomes abundant in the reed beds of Lake Biwa and in satellite lakes (Shiga Prefectural Fishery Experimental Station 2005).

The golden mussel *Limnoperna fortunei* (IAS) has a planktonic larval stage in its life history, and later, after metamorphosis to juvenile shells, firmly attaches to the hard substratum with its byssus, a fibrous secretion. These two ecological characteristics are not shared by any Japanese native freshwater mollusk. When this mussel was first found in Lake Biwa in 1992, serious impacts of zebra mussels *Dreissena polymorpha* (IAS), with ecological properties similar to those of golden mussels, had already become known in the Great Lakes of North America. There was initially fear of a similar disaster in Lake Biwa and areas to which its water is distributed, but no explosive increase in mussel density has been observed in the littoral zone of the lake itself. However, some facilities utilizing larva-infected water have often suffered negative impacts in their ordinary operations due to fouling by golden mussels (Nakai and Matsuda 2000).

During the past few decades, the quantity of corbiculid clams *Corbicula fluminea* (AS) imported into Japan has increased (Nakai and Matsuda 2000), and its distribution has expanded throughout Japan, including Shiga Prefecture (2001). At some localities in the southern basin of Lake Biwa and in the Seta River, this alien clam often becomes dominant in abundance in the molluscan community, overwhelming native clams and mussels.

A Chinese unionid mussel *Hyriopsis cummingii* was introduced for freshwater pearl culture, a procedure that was originally developed using the endemic Biwa pearl mussel *H. schlegelii*. Recent genetic analysis has shown the Chinese mussel to be so closely related as to be able to hybridize with the endemic mussel (Shirai et al. 2010).

As a resource suitable for aquaculture, the South American apple snail *Pomacea canaliculata* (AS, LIS) was introduced into Japan from Taiwan in the 1970s and 1980s. There were no successful commercial results, but cultured snails were discarded into the wild, including Shiga Prefecture. Having first been found in 1987 in Yasu city, apple snails largely remain confined to a few river systems, including the founder population, on the eastern side of the lake. In addition, a remote population was established in Hikone city by the mid-2000s, and a lakeshore population was found in Katata Fisheries Port on the west side of the lake in 2007 (Kanao et al. 2007). Apple snails have thus gradually been expanding their range along the lakeshore on both the western and the eastern sides (Matsuda and Nakai, unpublished).

Few benthic invertebrates have established introduced populations in Lake Biwa, but the cragonyctid amphipod *Crangonyx floridanus*, the atyid shrimp *Neocaridina denticulata sinensis*, and the dugesiid planarian flatworm *Girardia tigrina* have successfully done so (Nishino et al. 2002; Kaneda et al. 2007; Kawakatsu et al. 2007). Since these benthic invertebrates of small body size have recently spread in many localities in Japan and often become dominant, we cannot help foreseeing invasive impacts in Lake Biwa.

Plants

In Lake Biwa, two alien species of submerged plant, western waterweed *Elodea nuttallii* (AS) and Brazilian waterweed *Egeria densa* (AS), became alternately predominant in the 1960s (Nakai and Hamabata 2002) and remained so until 1994. However, since an exceptional low-water

episode in 1994, the proportion of alien waterweeds in the submerged vegetation has declined because of unprecedented overgrowth mostly dominated by indigenous species (see Sect. 3.1.3).

Another submerged plant, the parrot feather *Myriophyllum aquaticum* (IAS), whose leaves and stems often protrude above the water surface, has become common in the shallower shoreside zone of the lake, as well as in satellite lakes and creeks.

Among the floating-leaved plants, water hyacinth *Eichhornia crassipes* (AS) and water lettuce *Pistia stratiotes* (IAS), both widely sold as ornamental aquatic plants, had been ironically expected for their usefulness in water purification. They were able to reach Lake Biwa and its satellite lakes owing to their floating habit and flourished there, covering considerable expanses of the water surface. After having been designated as IAS, water lettuce was successfully eradicated from the prefecture (see Sect. 7.2.4).

Among the emergent plants, the knotgrasses *Paspalum distichum* vars. *distichum* and *indutum*, which were once recommended for use as spawning grounds for native fishes in restricted sites, have grown into large-scale patches in the shallow littoral zone of the lake and satellite lakes. Yellow iris *Iris pseudoconus* (AS) has been planted for ornamental purposes, and forms narrow beds here and there along the lakeshore. In 2007, invasions of alligator weed *Alternanthera philoxeroides* (IAS) and Senegal tea plant *Gymnocoronis spilantoides* (IAS), both designated as IAS, were noticed in several localities on the lakeshore, in some satellite lakes, and in the lower reaches of inflows. Both of these IAS species are considered to be in the earlier stages of establishment, and intensive cooperative efforts have been taken for their complete eradication (see Sect. 7.2.4).

Established Species Apparently Confined to Restricted Ranges, Inside and Outside the Lake

Species Preferring Warmer Water

Two African fishes, Zill's tilapia *Tilapia zillii* and Nile tilapia *Oreochromis niloticus*, have established populations in Moriyama and Hikone cities, respectively. Both species have been occasionally recorded from Lake Biwa proper, but it is apparent that their populations are supported by a constant supply of warm discharge water from a factory and a sewage plant, respectively (*Table 2*).

The mosquitofish *Gambusia affinis* (IAS) is also restricted to a small geographical region where the water temperature does not go down significantly in winter owing to a sufficient supply of ground water. It is not clear whether this IAS fish will remain confined to its present range (Uonokai).

The Malaysian trumpet snail *Melanoides tuberculatus*, with a wide geographical distribution in tropical and subtropical regions including the Ryukyu Islands in Japan, is in Shiga Prefecture restricted to the same warm-water discharge system as Zill's tilapia (Matsuda and Seki 2002).

Species Preferring Colder Water

Rainbow trout *Oncorhynchus mykiss* (AS) has been cultured in hatchery facilities, including the prefectural Samegai Salmon Hatchery (Furukawa and Awano 1969). This trout is naturalized in the cold water streams around them.

Stocks of red-spot masu salmon *Oncorhynchus masou ishikawae* have been translocated into many mountain streams in Shiga Prefecture. Stream-dwelling populations have thus been established, while "lake-run" smolts are often captured in the deeper zone of the lake together with the endemic Biwa salmon *O. masou* subsp. In spite of continuous introductions in many localities, large-scale hybridization between red-spot masu salmon and Biwa salmon has not been observed.

In 2009, it became apparent that the prefecture's best-known population of the landlocked three-spined stickleback *Gasterosteus microcephalus*, confined to spring-fed streams or rivers, has been almost completely hybridized with migratory three-spined stickleback *G. aculeatus*, assumed to have been artificially released there. Care should be taken that the migratory stickleback will not invade the remaining few three-spined stickleback populations through migration via lake.

The New Zealand mudsnail *Potamopyrgus antipodarum* (LIS) has established populations in irrigation canal systems in Moriyama, Hikone, and Takashima cities (Urabe 2007). This snail has recently expanded its range, partly because of utilization in new localities as bait for stream-dwelling larvae of the firefly *Luciola cruciata*. At all known localities in Shiga Prefecture, this snail seems to be confined to stretches of canals with low-temperature spring-water influence even in summer. However, considering its wider habitat and environmental preferences, as well as its extremely high population densities in other known cases, vigilance is needed to prevent any invasion by this snail into Lake Biwa.

In 1926, the signal crayfish *Pacifastacus leniusculus* (IAS) was firstly introduced into the mountain reservoir Tankai-ko, which is located in the upper reaches of the

Table 2

Non-indigenous species requiring special attention for the Lake Biwa ecosystem

Family	Species name	English [Japanese] name	Origins
1. Species established or naturalized in and around the catchment area of Lake Biwa			
Mammal			
Myocastoridae	● *Myocastor coypus*	Coypu [Nûtria]	Alien (S. Am.)
Fish			
Cobitididae	※ *Misgurnus mizolepis*	Chinese wetherfish [Kara-dojô]	Alien (E. As.)
Salmonidae	※ *Oncorhynchus mykiss*	Rainbow trout [Niji-masu]	Alien (N. Am.)
Poeciliidae	● *Gambusia affinis*	Mosquitofish [Ka-dayashi]	Alien (N. Am.)
Gasterosteidae	◉ *Gasterosteus aculeatus*	Threespine stickleback [Ito-yo]	Domestic
Percichthyidae	◉ *Coreoperca kawamebari*	Japanese perch [Oya-nirami]	Domestic
Centrarchidae	● *Micropterus dolomieu*	Smallmouth bass [Kokuchi-basu]	Alien (N. Am.)
Cichlidae	*Tilapia zillii*	Zill's tilapia [Jiru-tyrapia]	Alien (Af.)
	※ *Oreochromis niloticus*	Nile tilapia [Nairu-tyrapia]	Alien (Af.)
Crustaceans			
Astacidae	● *Pacifascatus trowbridgii leniusculus*	Signal crayfish [Tankai-zarigani]	Alien (N. Am.)
Mollusks			
Melanoidae	*Melanoides tuberculatus*	Malaysian trumpet snail [Nunome-kawa-nina]	Alien (E. As.)
Hydrobiidae	◉ *Potamopyrgus antipodarum*	New Zealand mud snail [Komochi-kawa-tsubo]	Alien (Oc.)
Plant			
Azollaceae	● *Azolla cristata*	(Water fern) [Azora-kurisutata]	Alien
2. Species possibly able to become established and occasionally recorded in and around Lake Biwa			
Reptiles			
Chelydridae	● *Chelydra serpentine*	Snapping turtle [Kamitsuki-game]	Alien (N. Am.)
	◉ *Macrochelys temmincki*	Alligator snapping turtle [Wani-game]	Alien (N. Am.)
Emydidae	*Pseudemys concinna*	River cooter [Ribâ Kûtâ]	Alien (N. Am.)
Trionychidae	*Apalone* sp.	American softshelled turtle [Amerika suppon]	Alien (N. Am.)
Fish			
Lepisosteidae	◉ *Atractosteus spatula*	Alligator gar [Arigêtâ-gâ]	Alien (N. Am.)
	◉ *Lepisosteus oculatus*	Spotted gar [Supotteddo-gâ]	Alien (N. Am.)
	◉ *Lepisosteus osseus*	Longnose gar [Rongu-nôzu-gâ]	Alien (N. Am.)
	◉ *Lepisosteus platostomus*	Shortnose gar [Shôto-nôzu-gâ]	Alien (N. Am.)
Cyprinidae	● *Mylopharyngodon piceus*	Black carp [Ao-uo]	Alien (E. As.)
	Scardinius erythrophthalamus	Rudd [Raddo]	Alien (Eu.)
	Tinca tinca	Tench [Tenchi]	Alien (Eu.)
Ictaluridae	● *Ictalurus punctatus*	Channel catfish [Chaneru-kyatto-fisshu]	Alien (N. Am.)
3. Terrestrial species invasive to aquatic or amphibious species in and around Lake Biwa			
Mammals			
Procyonidae	● *Procyon lotor*	Racoon [Arai-guma]	Alien (N. Am.)
Plants			
Fabaceae	※ *Robinia pseudoacacia*	Black locust [Hari-enju]	Alien (N. Am.)
Cucurbitaceae	● *Sicyos angulatus*	Oneseed bur cucumber [Arechi-uri]	Alien (N. Am.)

Ishida River, an inflow into Lake Biwa, and since then this crayfish has been confined to that pond. Although this may be attributed to its preference for cold water, precautions need to be taken, considering the lower water temperature of the deeper zone of Lake Biwa and its finding in the lowland floodplain in Chiba Prefecture east of Tokyo in 2009.

Species Unable to Reproduce But Long-Lived

Three species of giant cyprinid, the grass carp *Ctenopharyngodon idellus* (AS), black carp *Mylopharyngodon piceus*, and silver carp *Hypophthalmichthys molitrix*, have been captured occasionally in the Lake Biwa fisheries (Matsuda and Seki 2002; Shiga Prefectural Fishery Experimental Station 2005). All of them are believed to require large-scale riverine conditions for successful reproduction, and there has been no evidence for their reproduction within the Lake Biwa system. Nevertheless, ecological impacts of these carps may continue because of their long life span and giant body size. In addition, due to the expectation that grass carp might effectively control aquatic weeds, its introduction into the watershed has continued.

Species of High Risk for Future Invasion

Species Already Established in Proximity

After its first record there in 2002, there has been fragmentary evidence of coypu *Myocastor coypus* (IAS), a large, semi-aquatic aquatic rodent, inhabiting Shiga prefecture. Populations have certainly been established along the lower reaches of the Kiso River in southwestern Gifu Prefecture and along the middle reaches of the Yodo River (locally called the Uji River) in southern Kyoto Prefecture. Considering the geographical proximity of both populations to Shiga Prefecture, with no significant barriers to migration, its eventual invasion of Lake Biwa seems inevitable (*Table 2*).

Recently, Chinese weatherfish *Misgurnus mizolepis* has been used for a substitute for Japanese weatherfish *M. anguillicaudatus*. Both fishes are widely distributed alive as human food, and naturalization of the Chinese species has taken place in many parts of Japan, including Shiga Prefecture. In addition, there is a risk for hybridization between the two species, as has already been observed in some localities (Sugiyama, personal communication).

Since 1995, smallmouth bass *Micropterus dolomieu* (IAS) has been sporadically collected in Lake Biwa. Recently, established populations have been found in three mountain dams, the Inukami (2008), Ichino (2009), and Yasugawa (2010) Reservoirs. Downstream range expansion from these reservoirs has been detected already, which may presage its invasion into and establishment in Lake Biwa in the wake of the invasive largemouth bass and bluegill.

Besides sporadic captures of single individuals, a capture of plural individuals of channel catfish *Ictalurus punctatus* occurred in the Seta River in 2009. This suggests intentional introduction of this IAS species, and more specimens than those captured are likely to remain in this river downstream from the lake.

Japanese perch *Coreoperca kawamebari* (LIS) is a Japanese red-list species having its natural distribution range in western Japan. Shiga Prefecture is outside of this range, so this perch, despite having established two populations in the prefecture, is regarded as being nonindigenous (Matsuda and Seki 2002). Such nonindigenous populations of this species outside its original range have been found in many other parts of Japan. In spite of being a riverine fish, the introduced perch has successfully established a population in an irrigation pond in Nara Prefecture (Takada, personal communication). In addition, some of the endemic fishes in Lake Biwa might not have shared a history of coexistence. So, we should be precautious for its invasive impacts in Lake Biwa.

Species Prone to Be Introduced

Snapping turtles *Chelydra serpentine* (IAS) and alligator snapping turtles *Macrochelys temmincki* (AS, LIS) have been found in Shiga Prefecture, including Lake Biwa, several times. The former species has already established populations in eastern Japan around Tokyo, while the latter was reported to lay eggs in a park pond in Tokyo in 2006. Considering their great longevity, special vigilance is needed to assure that both species do not establish reproductive populations in the prefecture.

In Japan, a variety of ornamental aquarium fishes have been collected in the wild, probably thrown away when their keepers face one or another difficulty. Some such fishes are of temperate-zone origin and relatively large; such characteristics raise anxieties concerning successful establishment and invasive effects. Lepidosteid gars are the most typical examples captured in Lake Biwa, because they were neither designated as IAS nor listed as AS, in

spite of their evident ecological risk and frequent capture in the wild; therefore, Shiga Prefecture designated them as LIS (see Sect. 7.2.4).

Conclusion

Lake Biwa has already suffered serious ecological impacts following the introduction of invasive nonindigenous species, typically exemplified by alien waterweeds and predatory fishes. Furthermore, an additional immediate threat is posed by invasive species that have already become established close to the lake or its watershed, or that may be introduced one after the other in the future. We should not forget most of the problems caused by nonindigenous species are human-induced issues, which may be prevented, if we are wise, by a variety of as yet untaken measures.

Acknowledgements

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3.2 Ecological Changes in the Offshore of Lake Biwa

Machiko Nishino

Long-term monitoring data obtained by the Shiga Prefectural Fisheries Experiment Station showed that decreased transparency and increased plankton biomass were observed at offshore sites of the north basin during the 1950s to mid-1980s (see Sect. 7.1.1). This indicates that the north basin had suffered from eutrophication since the 1950s. In fact, unusual algal blooms of *Anabaena* spp. had occurred since 1965, *Uroglena americana* since 1977, *Microcystis aeruginosa* since 1983, and foul-smelling tap water since 1969 (Lake Biwa Research Institute & ILEC 1988; see Appendix 3). Nevertheless, transparency has gradually increased since the 1990s, and both total phosphorus and chlorophyll-*a* concentration have decreased at most sites of the north and the south basins (see Sects. 3.2.1 and 7.1.1). This is perhaps due to the various measures taken to reduce the input loading, such as construction of sewage system on its catchment areas (see Sect. 7.1.1).

Along with the decrease of nutrients, both plankton biomass and species composition have also changed greatly. Tsugeki et al. (2010) showed that phytoplankton biomass had increased during the 1960s–1970s and indicated that the north basin had eutrophicated, based on the analysis on the core sample collected at the offshore site (75 m deep). Since the 1980s, however, all fossil pigments and algal remains have decreased or stabilized, suggesting that changes in the water regime may have been caused by the decrease of wind velocity, perhaps as a result of global warming (Tsugeki et al. 2010). Ichise (2008) also showed that phytoplankton biomass (estimated by volume) in the 2000s was almost half of that in the 1980s. These facts suggest that eutrophication had already ceased in the lake, and that instead global warming would affect the water movement and plankton community of the offshore lake.

Another change is observed in the pelagic and littoral food web (see Sect. 3.2.4). Fish trophic levels rose in the 1970s, when north basin had eutrophicated. But they decreased between the 1980s and 1990s. During this period, two alien fishes *Micropterus salmoides* and *Lepomis macrochirus* propagated and littoral spawning habitats of the indigenous and endemic fishes were extremely modified with the progress of the Lake Biwa Comprehensive Development Project (see Sects. 3.1 and 3.1.4).

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3.2.1 Lake Biwa's Offshore Ecosystem and its Biogeochemical Processes

Kazuhide Hayakawa · Shigeo Tsujimura

Abstract The north basin of Lake Biwa is characterized by a specific ecosystem and biogeochemical processes appropriate to a deep lake averaging 44 m in depth. In this section, we introduce the biological and chemical characteristics of the offshore zone of the north basin. Vertical profiles of chemical and biological aspects reveal its nutrient and organic matter cycles. Long-term monitoring data of the lake confirm eutrophication in the 1960s–1970s and the subsequent recovery of the lake in the 1990s.

Keywords Nutrients • Dissolved oxygen • Vertical profiles • Biogeochemical processes • Primary production • Long-term monitoring

Introduction

Lake Biwa contains two basins: a deep and large basin in the north, and a shallow and smaller one in the south. The differences in the physical structure and nutrient status between the two basins have given rise to a valuable diversity of biological and chemical ecosystems in the lake. In the north basin, with depths averaging 44 m, thermal stratification occurs from spring to autumn, creating a specific ecosystem and biogeochemical processes. In this section, we introduce biological and chemical characteristics of the offshore zone of the north basin.

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Biological and Chemical Properties in the Offshore Zone

The sunlight radiation needed for photosynthesis of phytoplankton attenuates under the lake water with increasing depth, due to absorption and scattering by water molecules and suspended particles. The attenuated sunlight can reach the lake bottom in the shallow inshore zone, but not in the deep offshore zone. The offshore zone of Lake Biwa roughly coincides with the area of the lake deeper than 20 m, where sunlight cannot reach the lake bottom. This zone comprises 72% of the total lake area. Lake Biwa is a monomictic lake in which thermal stratification occurs from April to January (stratified period) and vertical mixing from February to March (mixing period). The lake epilimnion during the stratified period corresponds to a euphotic layer, which is roughly 10–20 m in depth.

Phytoplankton live in the epilimnion of the lake, and their abundance and species composition vary throughout the year. Green algae are the dominant species in the epilimnion during the stratified period (Ichise et al. 2001). Vertical profiles of chlorophyll-*a* concentrations in summer show that most phytoplankton are present in the epilimnion (*Fig. 1*). Relatively high concentrations of chlorophyll-*a* above the thermocline are due to the stagnation of sinking phytoplankton at the thermocline, with phytoplankton growth consuming abundant nutrients that have migrated from below the thermocline (Nakanishi et al. 1999), and to the photo-inhibition of photosynthesis near the surface water (Tanaka 1999). In the hypolimnion, the phytoplankton biomass is considerably reduced because of the lack of sunlight in this layer. Mortal phytoplankton, seston, and fecal particles drift down from the epilimnion and decompose in the hypolimnion.

Vertical profiles of dissolved oxygen (DO) and nutrient concentrations reveal the biogeochemical processes within the hypolimnion (*Fig. 2*). The DO concentrations below the thermocline are low, since the sinking phytoplankton

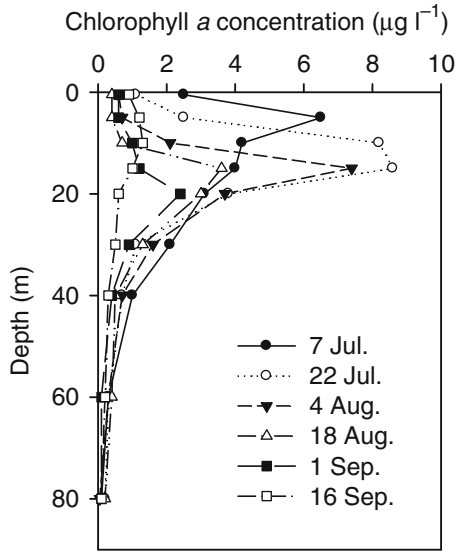

Fig. 1

Vertical profiles of chlorophyll-*a* concentrations at station 17B in the north basin from July to September 2008. Data are from the Environmental White Paper of Shiga Prefecture (Shiga Prefecture 1979–2008).

and seston stagnate and consume the DO at this layer. DO concentrations near the lake bottom are also low, since the DO in that layer is consumed by the decomposition of organic matter in the water and sediment. Relatively high concentrations of phosphate near the lake bottom indicate the regeneration of organic matter in the sediment or turbid water in that zone (*Fig. 2*).

A grazing food chain originating from phytoplankton via zooplankton to fish comprises the main ecosystem in the offshore zone. The major zooplankton in the north basin are a copepod *Eodiaptomus japonicus* and a cladocean *Daphnia galeata* (Yoshida et al. 2002). The main zooplankton predator in the offshore is Biwa ayu *Plecoglossus altivelis* subsp, while the major fish predators in the offshore are the cyprinid fish "piscivorous" chub *Opsariichthys uncirostris uncirostris* (*Hasu* in Japanese), Biwa catfish *Silurus biwaensis* and Biwa salmon *Oncorhynchus masou* subsp. Alien fishes from the United States (i.e., largemouth bass *Micropterus salmoides* and bluegill *Lepomis macrochirus*) are not found in the food web of the offshore zone, since they live in the littoral zone. In a study of the food chain using stable carbon and nitrogen isotopes, the main food chain in the offshore zone of Lake Biwa is formed from small phytoplankton via the copepod *E. japonicus*, via Biwa ayu, to Biwa salmon or Biwa catfish (Yamada et al. 1998).

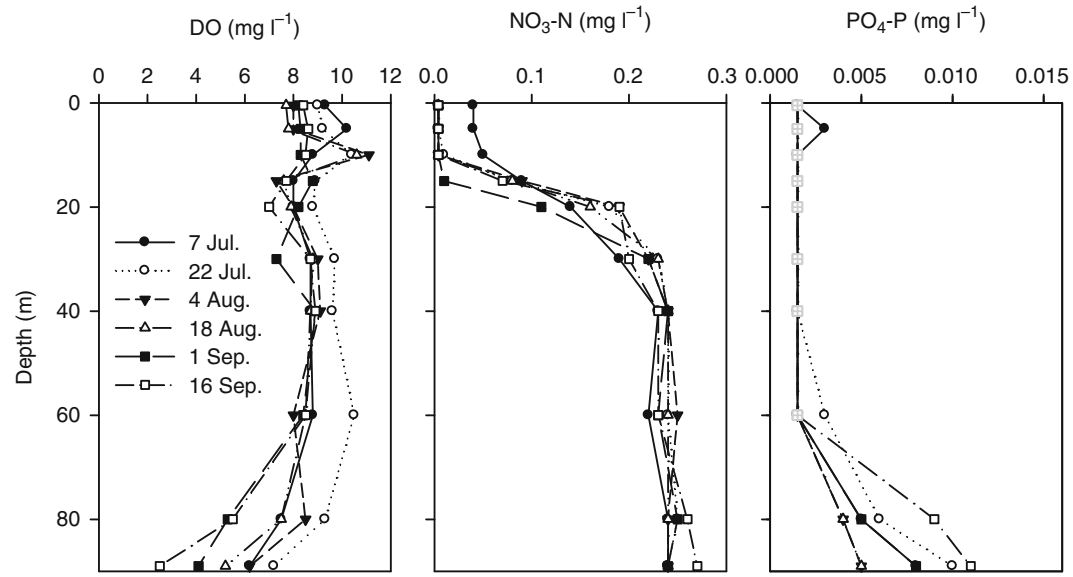

Fig. 2

Vertical profiles of dissolved oxygen (DO), nitrate (NO_3-N), and phosphate (PO_4-P) concentrations at station 17B in the north basin from July to September 2008. The phosphates at 0–60 m depths include under the detection limit. Data are from the Environmental White paper of Shiga Prefecture (Shiga Prefecture 1979–2008).

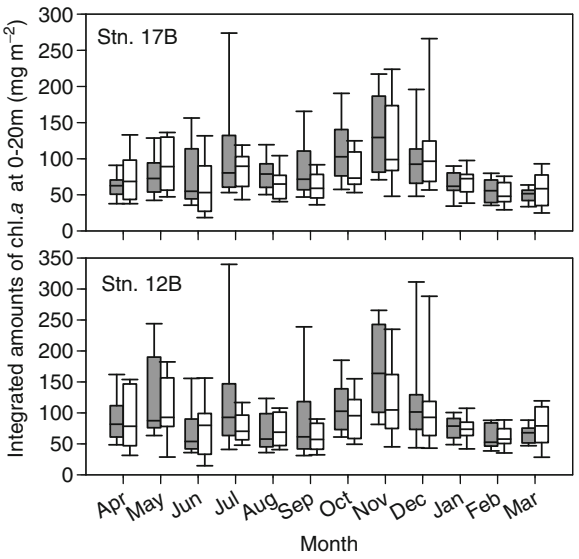

Fig. 3

Box plots of seasonal chlorophyll-*a* concentrations at stations 17B and 12B in the north basin from 1986 to 2005. *White* and *gray boxes* are data from 1986 to 1995 and 1996–2005, respectively. *Horizontal lines* of the box show first quartile, median, and third quartile from below. *Error bars* denote 10 and 90 percentiles. Data are from the Environmental White paper of Shiga Prefecture (Shiga Prefecture 1979–2008).

Primary Production and Nutrient Cycles in the Epilimnion

Relatively high concentrations of chlorophyll-*a* in the epilimnion appear in spring and autumn (*Fig. 3*). Phytoplankton growth depends on water temperature, light, and nutrient availability. Water temperature was found to be a key factor in increasing primary productivity in the north basin (Takahashi et al. 1995). In early spring, the water temperature in the epilimnion is too low for phytoplankton growth in spite of the nutrient-rich water. The water warming up from spring to summer produces increasing primary productivity in two ways: due to the active growth of phytoplankton and stabilizing the epilimnion by thermal stratification. Major phytoplankton species in spring over the past decade were the chrysophyte *Uroglena americana*, the diatom *Fragilaria crotonensis*, and the desmids *Closterium aciculare* and *Staurastrum dorsidentiferum* var. *ornatum* (Ichise et al. 2007). While red tide blooms of *U. americana* in the north basin have occurred annually in May and June over the past decades, they have vastly decreased since 2000 (Ichise et al. 2007). Although photosynthetic activity in the epilimnion reaches a maximum in summer, the phytoplankton biomass in this layer is relatively lower than those in spring and autumn. Grazing zooplankton also become so highly active in summer that they control the phytoplankton biomass in the epilimnion. The picoplankton *Synechococcus* spp., which is less than 2 μm in size, has often increased its abundance in June and July (Maeda et al. 1992). In autumn, some large phytoplankton in the epilimnion increase due to an abundant nutrient supply from below the thermocline, which move deeper as the water cools. Major phytoplankton species in autumn over the past decade included the green algae *Planktosphaeria* sp., *S. dorsidentiferum* var. *ornatum*, and *Coelastrum cambricum* (Ichise et al. 2007). The body sizes of these phytoplankton are too large to be grazed by zooplankton, so that high chlorophyll-*a* concentrations in the epilimnion appear in autumn. In winter, chlorophyll-*a* concentrations in the epilimnion are low, since the lake water mixes vertically.

Nutrient availability in the lake also influences phytoplankton growth. Phosphorus is the most critical element for primary production in Lake Biwa. Phosphate concentrations are quite low in the epilimnion, thus limiting phytoplankton growth. The 90% of phosphorus fixed by phytoplankton in the lake water is regenerated into phytoplankton uptake. The elimination rate of phosphorus in the epilimnion is only 10% (Takahashi 2005). The phosphorus concentrations needed for maintaining organisms in the epilimnion can be supplied from the watershed of the lake (Yoshimizu et al. 2002).

Nitrogen is also an important element for primary production. For nitrogen uptake, phytoplankton favor ammonia, urea, and nitrate forms in that order. The nitrogen is fixed by phytoplankton, and thereafter released into the water as ammonium by several passes, such as exudation by phytoplankton, digestion and excretion by zooplankton, bacterial uptake and release, and so on. Eighty percent of nitrogen fixed by phytoplankton in the epilimnion is regenerated into phytoplankton uptake (Mitamura and Saijo 1986; Takahashi et al. 1995), while the remaining 20% is eliminated from the epilimnion by phytoplankton sinking and by other transport processes. Nitrate concentrations in the epilimnion reach their lowest levels each summer due to nitrate uptake by phytoplankton, indicating that nitrate is the stock resource of nitrogen in the epilimnion. Nitrate concentrations are occasionally inadequate for phytoplankton growth during late summer.

Small phytoplankton (picoplankton with a body size of <2 μm) contribute 16% of the total phytoplankton biomass and 25% of primary production in the lake (Mitamura et al. 1999). The picoplankton allows for easy consumption

by heterotrophic flagellates, while some studies have proposed that the grazing food chain from flagellates to large zooplankton is largely inefficient (Nagata et al. 1996). However, a taxonomic examination of protozoa such as flagellates, ciliates, and rotifers is insufficient. The behavior and function of protozoa for the lake ecosystem, including the microbial loop, remain unknown, and further studies are needed. Mid-sized phytoplankton (i.e., nanoplankton with a body size of 2–20 μm) contribute roughly 30% of primary production in the lake. Although the nanoplankton generate high photosynthetic activity, their numbers are kept in check by substantial consumption by zooplankton. Consequently, the biomass of nanoplankton in the epilimnion is relatively stable from spring to autumn. Large phytoplankton (macroplankton with a body size over 20 μm) roughly account for 45% of primary production of the lake (Yoshimizu et al. 2001). The macroplankton biomass fluctuates year by year. When their biomass is abundant, they maintain their high contribution to primary production in the lake. Since the macroplankton are difficult to be grazed by large zooplankton, their contribution to the grazing food chain is limited. The macroplankton generally sink to the hypolimnion through the thermocline, while some studies have suggested that they are lysed by fungal infection in the epilimnion (Kagami et al. 2006).

Sinking and Decomposition of Algal and Sestonic Organic Matter in the Hypolimnion

Sinking fluxes of organic matter in the water have been measured by sediment trap experiments. The export fluxes from the epilimnion to the hypolimnion accounted for 10–20% of primary production in the epilimnion (Takahashi et al. 1995; Yoshimizu et al. 2001), and are equivalent to DO amounts subtracted the respiratory loss from the primary production in the epilimnion (Takahashi et al. 1995). The positive correlation between the sinking fluxes and zooplankton biomass in the water suggests that zooplankton fecal matter is a major component of sinking organic matter in the lake (Yoshimizu et al. 2001). Large phytoplankton, such as *S. dorsidentiferum* var. *ornatum*, are the exception, settling on their own to the lake bottom without zooplankton grazing. The decomposition rate of sinking organic matter is comparable to the consumption rate of DO in the hypolimnion. One study of stable carbon isotopes confirmed that DO consumption correlates with increasing rates of total carbon dioxide in the hypolimnion (Miyajima et al. 1997). However, sediment trap collecting near the lake bottom of the north basin has often caught larger fluxes of organic matter than organic carbon production in the epilimnion above. This indicates that the transport of organic matter to the hypolimnion is not only due to vertical sinking, but also to horizontal convection or sediment suspension (Maeda et al. 1986). Inorganic reducers in the sediment are one of the possible sources of DO consumption near the lake bottom (Miyajima 1992a, b).

Long-Term Changes of Biological and Chemical Properties in the Lake

There are some reports of long-term monitoring data in Lake Biwa. Their evaluations of water quality are generally given at a depth of 0.5 m. However, we extrapolated the vertical integrated values within the epilimnion (0–20 m depth) to counteract the heterogenous presence of biological and chemical factors within that zone using some references, and considered long-term changes of biological and chemical properties in the lake (*Figs. 4, 5, 6,* and *7*).

The long-term monitoring of settled volumes of plankton measured by the Shiga Prefectural Fishery Experiment Station shows that the level of microorganisms increased from the 1950s, and peaked in the mid-1970s. After 1990, it either remained high or slightly decreased (*Fig. 4*).

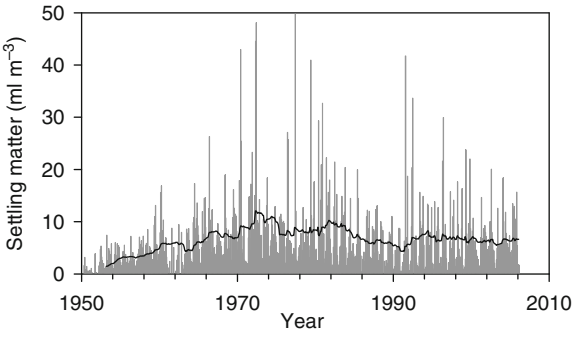

Fig. 4

Changes in the settled volumes of plankton at 0–20 m depths at stations III and IV (mean values) monitored by the Shiga Prefectural Fishery Experiment Station (Shiga Prefectural Fishery Experiment Station 1950–2010). *Black line* denotes running means of 3 years.

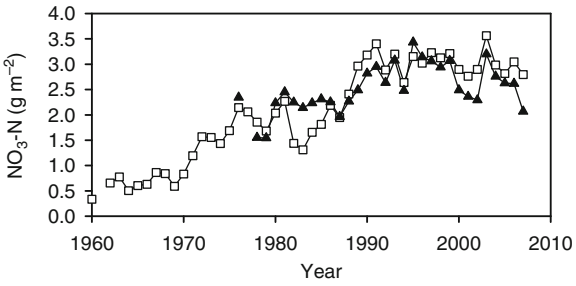

Fig. 5

Changes in annual averages of nitrates at 0–20 m depths at stations III and IV (mean values) monitored by the Shiga Prefectural Fishery Experiment Station (Shiga Prefectural Fishery Experiment Station 1950–2010).

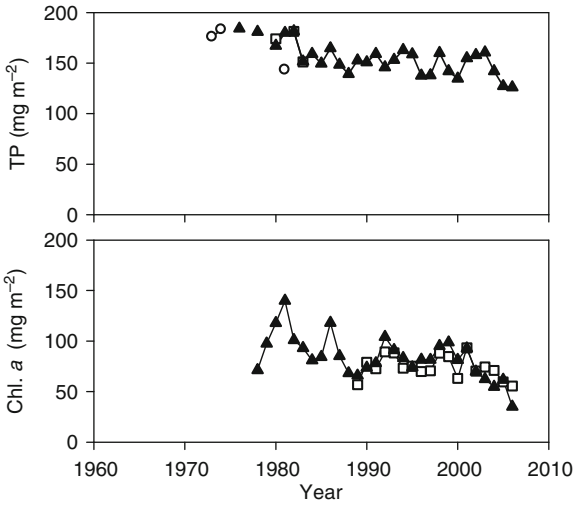

Fig. 6

Changes in the annual averages of total phosphorus (*TP*) and chlorophyll-*a* concentrations at 0–20 m depths at stations 17B and 12B in the north basin. Data are from the Environmental White paper of Shiga Prefecture (Shiga Prefecture 1979–2008).

Nitrate concentrations in the epilimnion measured by the Shiga Prefectural Fishery Experiment Station also showed increases in the 1960s and 1970s. Phosphate data were unreliable during the early monitoring in Lake Biwa, but some early reports showed increases of total phosphorus concentrations in the lake water in the 1960s and 1970s (e.g., Hori et al. 1992). Those monitoring data also indicated that eutrophication of the lake proceeded during those two decades. After 1979, Shiga Prefecture and the National Ministry of Construction started monthly

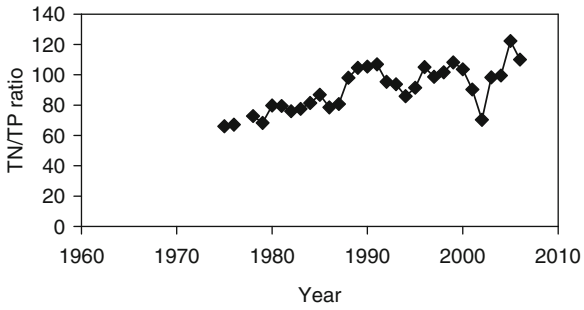

Fig. 7

Total nitrogen/total phosphorus (TN/TP) ratios at 0–20 m depths at stations 17B and 12B in the North basin. Data are from the Environmental White paper of Shiga Prefecture (Shiga Prefecture 1979–2008).

monitoring of the lake water quality. Their data showed that chlorophyll-*a* concentrations and total phosphorus in the north basin steadily declined from 1980 to the present (*Fig. 6*).

The decreases of both chlorophyll-*a* and phosphorus concentrations explain that the latter concentration in the lake water have limited phytoplankton growth (*Fig. 6*). Monthly variations of integrated chlorophyll-*a* amounts in the 0–20 m depth layer over the past two decades show that the phytoplankton biomass every October and November clearly decreased over those two decades (*Fig. 3*). The decrease of large phytoplankton appearing in autumn might have reduced primary production and DO consumption in the deep layer; however, we could not find the evidence in the monitoring data. Changes in the amounts of nitrogen in the 0–20 m depth layer continued to remain high from 1990 to the present (*Fig. 5*) in spite of the decrease in the integrated phosphorus amounts at a depth of 0–20 m (*Fig. 6*). Total nitrogen/total phosphorus (TN/TP) ratios are steadily increasing (*Fig. 7*).

The impact of the increase of TN/TP ratios on the lake ecosystem is unknown, and future studies should examine the response and adaptation of lacustrine organisms to the N/P increase. Previous ecological studies of other lakes suggest that N/P ratios can affect the species composition of phytoplankton and zooplankton (e.g., Elser and Hasset 1994; Jeppssen et al. 2005).

Ichise et al. (2001) showed that the species succession of phytoplankton in Lake Biwa has occurred over the past three decades. Future studies of the lacustrine ecosystem in Lake Biwa must clarify the impact of the change in nutrient supply, water warming, etc., on both phytoplankton and zooplankton.

3.2.2 Measurement of Primary Productivity in Lake Biwa

Toshiyuki Ishikawa

Abstract Measurement of primary production in Lake Biwa commenced with the Biological Research Group in Lake Biwa (BST) program in 1963. Due to strict regulation of radioactive isotopes, primary production is often measured with stable tracer ^{13}C. Lower sensitivity of ^{13}C compared to ^{14}C requires longer incubation, which may explain why primary production has not been routinely measured in Lake Biwa. Although reduction is found in phosphorus, a limiting nutrient of phytoplankton, no clear decrease tendency is shown in compiled data for primary production overall. For the pelagic zone of south basin and the littoral areas, monitoring has been highly limited despite primary production being fundamental ecosystem data.

Keywords Primary production • Methodology • Long-term data

Primary Production in the Pelagic Zone of North Basin

Primary production relates to the amount of organic matter produced by plants. In shallow areas of lakes, both planktonic and non-planktonic plants are primary producers. The latter includes both macrophytes and attached algae. In deeper areas, planktonic plants are primary producers, that is, the phytoplankton. Because plant productivity is a direct indicator of ecosystem productivity, it can be said that measurement of primary production is a direct assessment of the trophic status of lakes. However, primary production varies seasonally, due to phytoplankton biomass, light condition, temperature, and so on. Therefore, trophic status assessment requires repeated primary production measurement under varying conditions throughout the year.

In Lake Biwa, the first intensive measurement of primary production was conducted in 1963 as a part of the whole-lake biological observation program, "Biological Research Group in Lake Biwa (BST)" to assess impact of dam construction in the Lake. *Table 1* shows primary production as measured by several researchers at different times (*Table 1*).

Due to strict regulation of radio isotope use in the field in Japan, use of stable isotope ^{13}C has been frequently employed after establishment of the method by Hama et al. (1983). Due to a low sensitivity of the analytical method, use of ^{13}C requires longer incubation than use of ^{14}C, which seem to be a reason why primary production has not been monitored routinely.

Long-Term Trend in Pelagic Zone

Because nutrient limitation on phytoplankton growth in Lake Biwa is mainly due to phosphorus (Tezuka 1984), one may expect changes in primary production to be proportional to that of phosphorus. Monitoring data of phosphorus concentration in Lake Biwa has shown a slight decrease trend (see Sect. 3.2.1). In contrast, primary production measurements in pelagic zones of north basin (*Table 1*) do not show such a clear tendency. This discrepancy may relate to frequency of measurement, light, climate, temperature, food-web structure, and so on. Therefore, it is important for understanding long-term primary production to establish more simple measurement methods to analyze the condition status of primary producers.

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Table 1

Measurement of primary production in pelagic zone in North Basin of Lake Biwa

Year	Month	Cg m^{-2} day^{-1}	Method	Location	Reference
1963~1964	1~10	0.077~0.66	^{14}C	Off Hikone & Ohmi-Maiko	Saijo and Sakamoto (1970)
1971~1973	1~12	0.20~0.90	^{14}C	Shiozu bay	Nakanishi (1976)
1976	3~11	0.22~0.90	^{14}C	Pelagic	Nakanishi (1984)
1982~1984	1~12	0.16~1.50	^{13}C	Off Wani	Tsuda and Nakanishi (1992)
1985	5~10	0.45~0.79	^{14}C	Off Ohmi-Maiko	Mitamura(1990)
1985~1987	1~12	0.21~1.48	^{13}C	Off Chikubushima Island	Takahashi et al. (1995)
1989	5~9	0.48~1.95	DO &^{14}C	Off Wani	Nakanishi et al. (1992)
1992	6~11	0.28~1.29	^{13}C	Off Wani	Urabe et al. (1995)
1996~1997	7~11	0.25~2.20	^{13}C	Off Wani	Urabe et al. (2005)

Table 2

Measurement of primary production in plagic zone in South Basin of Lake Biwa

Year	Month	Cg m^{-2} day^{-1}	Method	Location	Reference
1963~1964	7~10	0.18~–0.50	^{14}C	Off Shina	Saijo and Sakamoto (1970)
1976~1977	1~12	0.03~0.70	DO	Off Ogoto	Nakanishi (1984)
1978~1979	1~12	0.07~2.17	^{14}C	Off Ogoto	Nakanishi (1988)
1983~1984	1~12	0.11~1.2	DO	Off Shina	Ichiki (1987)

Table 3

Measurement of primary production by macrophyte communities

Year	Month	Cg m^{-2} day^{-1}	Method	Location(dominant species)	Reference
1964	4,7	1.36	DO	Off Okishima Island *Elodea nuttalli*	Ikushima (1966)
1969	7,11	3.3	DO	Shiozu Bay *Elodea nuttalli*	Ikushima (1975)
1974~1975	1~12	–1.27~4.01	DO	South Basin *Egeria densa*	Tanimizu and Miura (1976)

Primary Production in South Basin

Measurement of primary production in south basin is restricted to four studies (*Table 2*), the latest measurement conducted over two decades ago in 1984. Yet, total phosphorus decrease appears clearer in south basin than in north basin suggesting more drastic primary production change there. Furthermore, there was a clear shift of primary producer in south basin from phytoplankton to macrophytes around the mid-1990s (see Sect. 3.1.3). Thus, it is highly probable that primary production has changed both qualitatively and quantitatively in parts of Lake Biwa.

Primary Production in Littoral Zone

Two major types of primary producers in addition to phytoplankton found in littoral zones are macrophytes and attached algae. In Lake Biwa, measurement of both has been limited (*Tables 3* and *4*). In order to discuss these producers, one must accept a large heterogeneity of their distribution and abundance when evaluating whole-lake productivity. Distribution of macrophytes is discussed in Sect. 3.1.3. As for attached algae, information has been quite limited (Nozaki 2001). Because the littoral structure of Lake Biwa has been altered substantially, both these primary producers might have been affected. In addition,

Table 4

Measurement of primary production by sessile alage

Year	Month	Cg m^{-2} day^{-1}	Method	Location	Reference
1963~1964	2,8	0.01~0.10	^{14}C	Hanno-Ura	Saijo and Sakamoto (1970)
1995~1996	1~12	−0.10~5.17	DO	Kita-Komatsu	Nozaki (2001)
1997~1998	2~12	0.02~1.60[a]	^{14}C	Kaizu-Ohsaki	Ishida et al. (2006)

[a] Estimated fom the data in the paper

changes in water transparency as measured by standard Secchi disk would affect all producers. As shown in Sect. 3.2.1, transparency of Lake Biwa decreased during 1950s to 1980s, and increased since 2000. Transparency alters light condition within the lake, therefore productivity and distribution of benthic primary producers might change according to transparency variation. Examination of such factors is one issue of primary production.

Conclusion

In this section, historical data on measurement of primary production was reviewed. Although there is a slight decreasing tendency of total phosphorus, a limiting factor of phytoplankton growth, the Lake Biwa reviewed data does not suggest clear decrease in primary production. In addition, there are very few data on primary production in south basin and in littoral areas of the lake. When considering the lake ecosystem, production ecology is a fundamental point. Scientists and government officials must not overlook this important issue when attempting to measure production of Lake Biwa organisms relating to primary production.

Acknowledgements

The information in this work is mostly attributed to Professor Nakanishi and Professor Urabe from their listed reference papers. Dr. Nozaki helped access obscure data. The author thanks members of Lake Biwa Research Institute for critical and helpful discussion on topics raised here.

3.2.3 Fish Predation on Pelagic Zooplankton

Keiichi Kawabata

Abstract Since the 1950s, Biwa ayu (*Plecoglossus altivelis* subsp.) has been the most commercially important zooplanktivorous fish in the offshore areas of the north basin. The annual fishery of the Biwa goby (*Gymnogobius isaza*) was also high from the 1960s to the 1980s, and similar amounts of pond smelt were harvested from the late 1990s. Biwa ayu selectively consumes large daphniids such as *Daphnia galeata*, thereby significantly diminishing the prey population. The dominant zooplankton, the copepod *Eodiaptomus japonicus*, however, sometimes relieves heavy predation on daphniids by acting as an alternative food source for the Biwa ayu. The complex relationship between *Daphnia galeata* and *E. japonicus* should be reevaluated in the whole context of the food web of Lake Biwa.

Keywords Biwa ayu • Predation • Mortality • Daphnia galeata • Eodiaptomus japonicus

Introduction

Planktologists have invoked fish predation to explain the mortality of zooplankters, without quantitative data. On the other hand, ichthyologists have treated zooplankton assemblages merely as the food of fishes, ignoring the diversity of these tiny invertebrates. In the population ecology of a planktonic species, all sources of death, including predation, should be quantitatively estimated and compared. Data needed for calculating predatory mortality are the spatial and temporal abundance of both predators and prey, in addition to the functional response of predation rates. In fact, actual predation impacts in the field are hard to estimate, especially in natural, large lakes, which are spatially heterogeneous. In Lake Biwa, only the predation by Biwa ayu has been quantitatively studied.

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Fauna of Zooplanktivorous Fishes

As shown in Sects. 2.5 and 5.1.2, offshore fishes in Lake Biwa are *Gnathopogon caerulescens* (willow minnow), *Carassius cuvieri* (Japanese crucian carp), *Silurus biwaensis* (Biwa catfish), *Chaenogobius isaza* (Biwa goby), *Oncorhynshus masou* subsp., (Biwa salmon), and *Plecoglossus altivelis* subsp. (Biwa ayu). In addition to the two native zooplanktivores, Biwa ayu and Biwa goby, an exotic zooplanktivore *Hypomesus transpacificus nipponensis* (Japanese smelt) increased abruptly from the mid-1990s.

Among the three zooplanktivorous fishes, Biwa ayu has been the most commercially important since the 1950s (*Fig. 1*). The annual fishery of isaza goby was also high from the 1960s to the 1980s, and similar amounts of pond smelt were harvested from the late 1990s.

Predation by Biwa Ayu

Biwa ayu is the most important zooplanktivore in June and July in the offshore areas of the north basin. Shirakihara et al. (2001) studied the daily vertical distribution of Biwa ayu, with a quantitative echosounder and an underwater video camera. They found that Biwa ayu were confined to the epilimnion (top layer of the water column) throughout the day, without any clear vertical migration. Thus, the vertical distribution of Biwa ayu overlaps with that of planktonic crustaceans that also show no daily vertical migrations (see Sect. 2.4.5).

The stomachs of Biwa ayu were empty at night and were filled within 2 h after sunrise (*Fig. 2*). The total prey mass then fluctuated until sunset, with a tendency toward reduction in the morning. Nishino and Kawabata (2003) showed that the stomach contents of Biwa ayu were ingested in less than 2 h before the moment of collection by observing gastric evacuation. Thus, Biwa ayu preys upon crustaceans during the daytime of 14.3 h and the daily turnover time of the stomach was about 7 h.

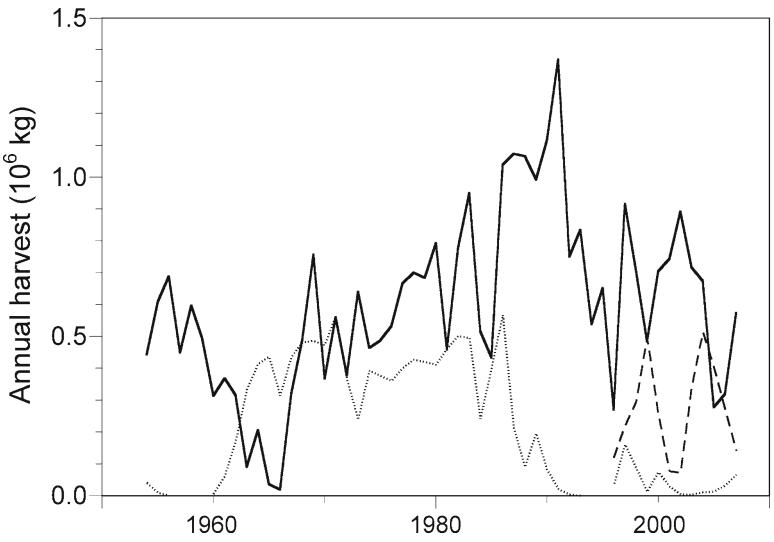

Fig. 1
Temporal changes in annual harvest of Biwa ayu (*solid*), Biwa goby (*dotted*), and Japanese smelt (*broken*) (Modified from Shiga Prefecture 2009).

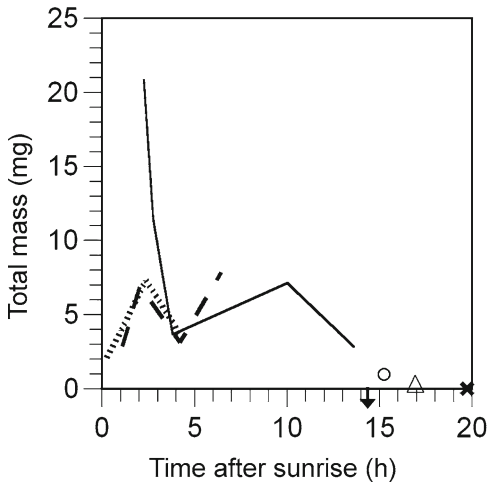

Fig. 2
Temporal changes in mean dry mass of stomach contents of Biwa ayu individuals in June and July 1996. Each *line* or each *symbol* shows a single sampling date, and an *arrow* indicates sunset (Modified from Kawabata et al. 2002).

Kawabata et al. (2002) identified 18 types of prey from the stomachs of Biwa ayu, and 15 of them were planktonic crustaceans. *Daphnia galeata* comprised a major fraction of the prey mass, followed by *Eodiaptomus japonicus* (*Fig. 3*). Whereas pelagic zooplankton was dominated by *E. japonicus*, Biwa ayu mainly consumed the less abundant *D. galeata* (*Fig. 4*). The size distribution of ingested daphniids consists of higher numbers of larger specimens compared with that of daphniids in the water column (*Fig. 5*). Thus, the predation by Biwa ayu was selective both for species and size; they preferred large daphniids. Consequently, mature daphniids suffer high mortality and the effect on population dynamics should be fatal.

The daily predation rate of individual Biwa ayu on daphniids (Y, 10^3 individuals/individual/d) can be calculated by the following equation: $Y = 4.76 + 1.03\,D - 0.14\,E$, where D and E are the densities (individuals/l) of *D. galeata* and *E. japonicus*, respectively (Kawabata et al. 2006; Nishino and Kawabata 2003). When $D = E = 10$, common values in Lake Biwa, $Y = 14$ is given. The density of Biwa ayu at the distribution centers was about 2 individuals/m^3 (Shirakihara et al. 2001). The Biwa ayu assemblage in the 1-m^3 lake water consumes in a day about 3×10^4 daphniids whose abundance is only 10^4. Although this figure is unrealistic, the predation pressure is really destroying. Furthermore, reproducing daphniids are the major victims.

The term "-0.14 E" in the above equation indicates that *E. japonicus* individuals are ten times as abundant as daphniids, and cancel selective predation on the latter. On the other hand, the two crustaceans differ in food preferences, and the selective feeding by *E. japonicus* may improve the food conditions of coexisting daphniids (Becker et al. 2004). Hence, the interaction between *E. japonicus* and *D. galeata* is not simply antagonistic. Their complex relationship should be reevaluated in the whole context of food web in Lake Biwa.

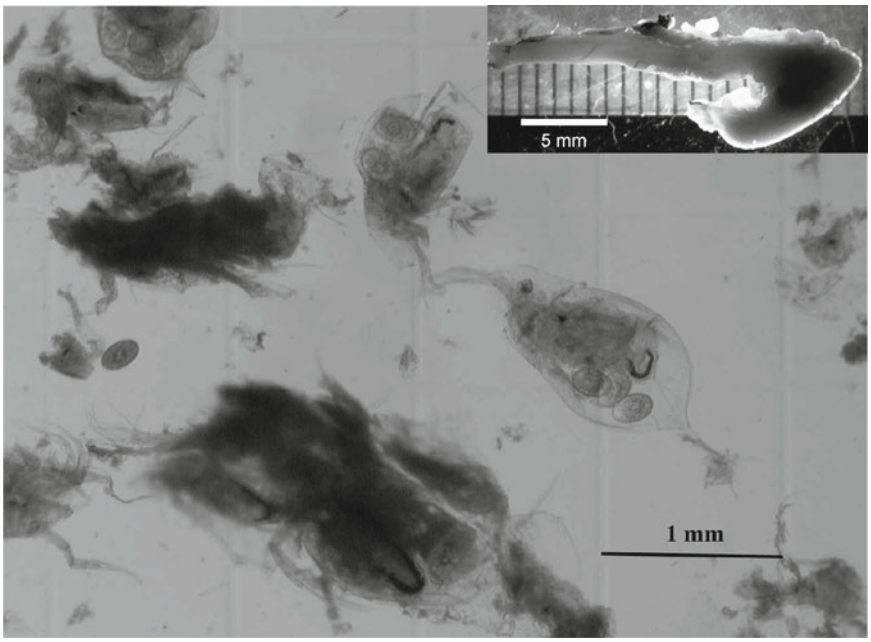

Fig. 3
Contents of a stomach (*insert*) of Biwa ayu.

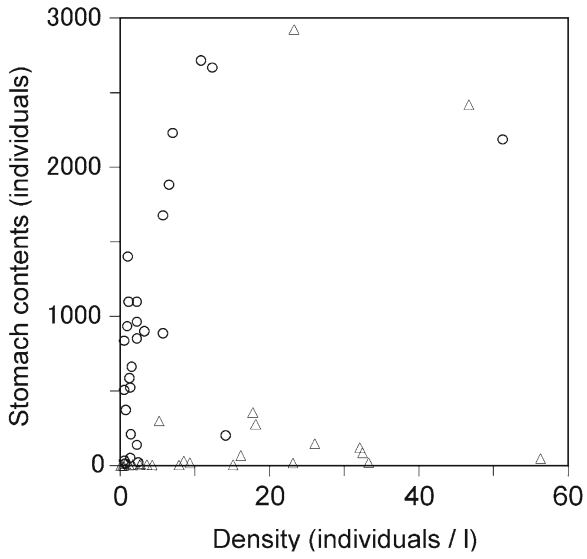

Fig. 4
Mean number of *Daphnia galeata* (*circle*) and *Eodiaptomus japonicus* (*triangle*) in the stomachs of Biwa ayu plotted against each density in the lake (*x*-axis) (Modified from Kawabata et al. 2006).

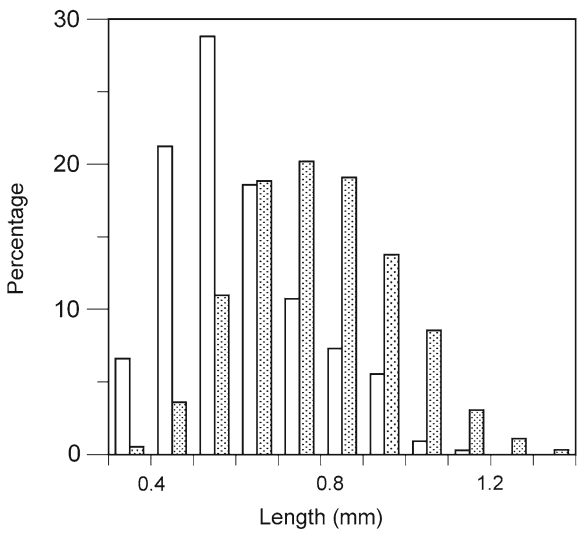

Fig. 5
Size distribution of *Daphnia galeata* in the lake (*clear*) and in the stomachs of Biwa ayu (*dotted*) (Modified from Kawabata et al. 2006).

Predation Ecologies of Other Zooplanktivores

Isaza goby and pond smelt are other zooplanktivorous fishes. Isaza goby stomachs contain planktonic crustaceans (Nagoshi 1966). From summer to autumn, isaza stayed on the lake bottom in the daytime, and swam up to the lower epilimnion in the dark (Takahashi 1981). Thus, the spatial overlap of isaza and epilimnetic crustaceans is restricted.

The main diet of pond smelt was daphniids and diaptomids in Lake Towada (Makino et al. 2001), and *Bosmina* and *Eodiaptomus* in Lake Suwa (Chang et al. 2005). However, the spatial and temporal changes in abundance of pond smelt in Lake Biwa are unknown.

Conclusion

Biwa ayu has been the most commercially important zooplanktivore for more than half a century. It selectively consumes large daphniids, thereby significantly diminishing the prey population. This exploitation has affected the zooplankton structure. At the end of the twentieth century, however, an exotic planktivore, pond smelt, increased abruptly. Therefore, further quantitative studies are necessary to understand the effects of predation by these fishes on the lake's food web.

3.2.4 A Food Web and its Long-term Dynamics in Lake Biwa: A Stable Isotope Approach

Noboru Okuda · Tomohiro Takeyama · Takefumi Komiya · Yoshikazu Kato
Yutaka Okuzaki · Jin'ichi Karube · Yoichiro Sakai · Michio Hori · Ichiro Tayasu
Toshi Nagata

Abstract We delineated the food web structure of the current ecosystem in Lake Biwa using stable isotope analysis (SIA) for a total of 1,163 specimens, including 29 fish species, 8 macrozoobenthos taxa and macrozooplankton (a mixture of copepods and cladocerans) with their basal foods. These animals occupied a variety of trophic positions and their trophic pathways were integrated by a top predator, the Biwa giant catfish (*Silurus biwaensis*), whose trophic level was estimated as 3.75. A food web of this lake highly relied on phytoplankton production, reflecting predominance of the pelagic habitat characteristic of deep lakes. We also measured the nitrogen isotope ratio for 1,177 archival specimens, including 45 aquatic species collected from the lake since 1914, to view the long-term trophic dynamics at the community level. As a whole, fish trophic levels rose in the 1970s when nutrient loadings began to occur, whereas they drastically decreased between the 1980s and 1990s, during which eutrophication progressed, exotic fishes propagated, and littoral habitats were extensively modified. We stress that our stable isotopic approach is useful in assessing human impacts on lake ecosystems.

Keywords Archival specimens • Ecosystem assessment • Endemism • Production reliance • Trophic level

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How to Assess Human Impacts on Food Webs?

All over the world, there are no longer lakes free from anthropogenic disturbances, including climatic changes. Especially local human activities, such as nutrient loadings, habitat destruction, overexploitation, and exotic species introduction, are considered strong drivers for ecosystem alteration of lakes. However, it is difficult, even for scientists, to answer exactly how and when they were altered, although it is easy to imagine. In order to manage lake ecosystems that provide public services, we have to quantitatively assess how each human activity can affect the properties of their ecosystems. Although traditional long-term studies on lake ecosystems are usually based on archival water chemistry data (Smith et al. 2006), such approaches only focus on a facet of the whole ecosystem. In contrast, archival biological specimens may provide us with a holistic view of long-term changes in their natal ecosystem because ecological and environmental information are recorded in their tissues in the form of stable isotope ratios.

SIA is a powerful tool to study food webs in lake ecosystems (Vander Zanden and Vadeboncoeur 2002; Vander Zanden and Fetzer 2007). The principle of this analysis is based on the general pattern that a consumer's carbon isotope ratio ($\delta^{13}C$) reflects its basal food source (DeNiro and Epstein 1978), while its nitrogen isotope ratio ($\delta^{15}N$) is

enriched by a given factor through trophic interactions (Minagawa and Wada 1984). It is also useful to perceive food web alterations under human disturbances (Vander Zanden et al. 1999; Layman et al. 2007; Anderson and Cabana 2009). A recent study has demonstrated that the technique is applicable to the $\delta^{15}N$ measurement for archival specimens preserved in organic solvents (Ogawa et al. 2001). Although it enables us to examine the long-term variation in the trophic level (hereafter *TL*) of a focal species (Nakazawa et al. 2010), the application to trophic dynamics at the community level remains limited and challenging (but see Vander Zanden et al. 2003).

In this section, we first delineate the food web structure of the current Lake Biwa ecosystem, which is characterized by the predominance of the pelagic habitat and endemism of pelagic species in association with its deep structure of lake morphology and long geological history (Sects. 1.2 and 2.5), using the SIA. Next, we examine the long-term food web alterations by measuring the $\delta^{15}N$ for archival specimens collected from this lake since 1914, and demonstrate that the lake food web was sensitive to a variety of human disturbances.

Current Food Web

To characterize the current food web based on the SIA, we collected a total of 1,159 specimens, including 29 fish species and 8 macrozoobenthos taxa (4 molluscs and 4 crustaceans) from Lake Biwa. We also collected four macrozooplankton samples (>300 μm), consisting of copepods and cladocerans, at a pelagic site Ie-1 (long-term monitoring site of CER: 35°12′58″N, 135°59′55″E). These animals were categorized by habitat type and functional feeding group (Appendix 1). As their basal foods, we regarded phytoplankton (particulate organic matter of 0.7–150 μm) in the pelagic habitat (Ie-1), periphyton (epilithic organic matter) in the littoral habitats, and terrestrial-derived organic matter from tributary rivers (riverine particulate organic matter; see Kohzu et al. 2009; Karube et al. 2010 for details).

After dry powder samples of their muscle tissues or whole body were immersed in a chloroform: methanol (2:1) solution for 24 h to remove lipids, following the methods of Focken and Becker (1998), we measured their $\delta^{13}C$ and $\delta^{15}N$ using a mass spectrometer (Finnigan MAT Delta-S, Germany). We plotted their stable isotopic signatures on a $\delta^{13}C$-$\delta^{15}N$ bi-plot (*Fig. 1*) and estimated their trophic position (*Box 1*). Almost all of these animals were located within the stable isotopic range between two food chains starting from phytoplankton and periphyton. Zooplankton (hereafter referred to by its taxa code in Appendix 1, i.e., 38) was typical of primary consumers embedded in the pelagic food chain, showing a *TL* of 1.93 with its exclusive reliance on phytoplankton. Zoobenthos inhabiting the littoral zone showed strong reliance on either the pelagic or the littoral food chain, depending on their feeding habits: for example, for grazing snails (30) and a littoral grazing gammarid (35), their production reliance on periphyton was 85.0% on average, while filter-feeding bivalves (31, 32, and 33) relied on phytoplankton production for on average 86.2% of their biomass.

Fishes occupied a wide variety of trophic positions within the food web (*Fig. 1*). In relation to adult fish, pelagic species showed higher reliance (on average 81.8%) on pelagic production, compared to littoral species whose production reliance varied from 24.6% to 100% (on average 70.9%). Three piscivores (3, 6, and 21) had high *TL*s, with the highest (3.75 *TL*) for the Biwa giant catfish *S. biwaensis* (21), which is considered a top predator in Lake Biwa. Though they are all pelagic, their production reliance was intermediate between pelagic and littoral food chains, suggesting that they fed on both littoral and pelagic preys. Such cross-chain omnivory (*sensu* Polis and Winemiller 1996), that is, mixed feeding on preys derived from different food chains, can couple pelagic and littoral trophic pathways, resulting in integrated energy flows within the food web.

Among fishes, there existed a few exceptional cases in which their trophic position was outside of a continuum of pelagic–littoral food chains. For instance, juvenile crucian carps (16¢) had more depleted $d^{15}N$ than that of phytoplankton and periphyton. In Lake Biwa, adult crucian carps usually migrate to littoral reeds, tributary attached lakes, paddy fields, and irrigation channels for spawning, while their hatchlings stay there, leaving for the main lake after growing (Sect. 7.2.1(2), (3)). In their natal habitats, terrestrial-derived organic matter, which shows relatively depleted stable isotope ratios, usually predominates as their potential food sources (Shibata et al. 2011). Therefore, the extraordinary isotopic signatures of the specimens studied suggest that these juveniles had recently migrated from their natal habitats to the main lake. In another case, *Odontobutis obscura* (24) was located on the pelagic food chain but its *TL* was estimated as 1.19, much lower than expected from its feeding habit as a benthic carnivore. Such discrepancy may be attributed to the fact that their main habitat is tributary rivers in which the primary food source is terrestrial-derived organic matter with depleted isotope ratios.

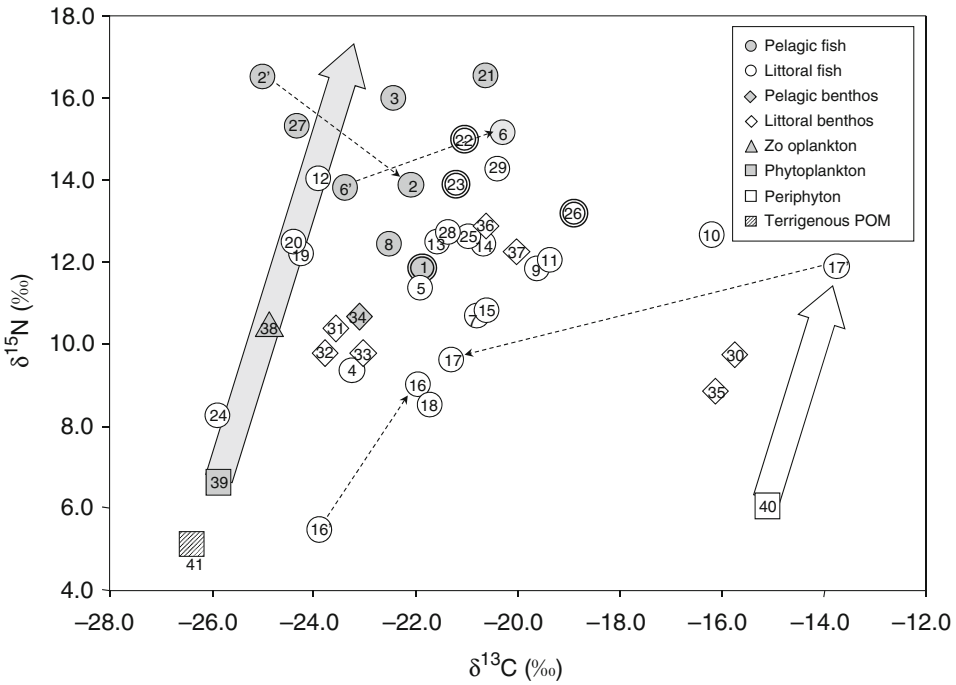

Fig. 1

The current food web of Lake Biwa in $\delta^{13}C$-$\delta^{15}N$ bi-plot space. *Thick arrows* represent the hypothetical trophic pathway starting from each primary producer (*shaded*: phytoplankton; *open*: periphyton) with exclusive reliance on it. *Dotted arrows* represent life historical changes in stable isotopic signatures from juvenile or young to adult stages. *Double circles* are for exotic species. Plot numbers correspond to taxa code in Appendix 1.

Box 1 How to Estimate Trophic Position?

We can estimate trophic position of aquatic consumers embedded within the food web, based on their $\delta^{13}C$ and $\delta^{15}N$ and those of their basal foods, as follows:

$$\begin{cases} f_1 + f_2 = 1 \\ f_1\delta^{13}C_1 + f_2\delta^{13}C_2 + \Delta\delta^{13}C_{ef} * (TL - 1) = \delta^{13}C_{cons} \\ f_1\delta^{15}N_1 + f_2\delta^{15}N_2 + \Delta\delta^{15}N_{ef} * (TL - 1) = \delta^{15}N_{cons} \end{cases}$$

where f1 and f2 represent the proportion of reliance on two primary producers, phytoplankton and periphyton (hereafter production reliance), respectively. δR_1, δR_2, δR_{cons} (R = ^{13}C or ^{15}N) are stable isotopic signatures of phytoplankton, periphyton, and each consumer, and TL trophic level. $\Delta\delta^{13}C_{ef}$ and $\Delta\delta^{15}N_{ef}$ are called trophic enrichment factors of $\delta^{13}C$ and $\delta^{15}N$, respectively, assuming that the consumer's $\delta^{15}N$ is enriched by 3.4‰ relative to its diets (Minagawa and Wada 1984) and its $\delta^{13}C$ by 0.8‰ (DeNiro and Epstein 1978). The two source mixing models mentioned above enable us to estimate the TL and the production reliance (f_n) for each consumer. If its production reliance on either of the two basal foods exceeds one only slightly, we regard it as exclusive reliance (i.e., 100%).

Except for such species relying on allochthonous (i.e., terrestrial-derived) resources, adult fish showed a high pelagic production reliance as a whole (72.6% ± 16.6SD, $n = 28$). Our finding is very interesting when compared to North American temperate lakes, in which fishes have been reported to strongly rely on benthic production (43–59%; Vander Zanden and Vadeboncoeur 2002). Vander Zanden and Vadeboncoeur (2002) pointed out that lake size is one of the important factors affecting their pelagic production reliance because perimeter-to-area ratios are lower for larger lakes, resulting in a higher contribution of pelagic habitats relative to benthic habitats. A deep structure, characteristic of tectonic lakes, will also diminish the relative contribution of benthic production because of substantial light attenuation at the lake bottom. In Lake Biwa, fishes, even littoral species, showed strong reliance on the pelagic production in spite of their benthivorous feeding habits, suggesting a direct trophic pathway via their feeding on plankton-derived detritus and/or an indirect pathway via their feeding on zoobenthos that rely on pelagic production. In this lake, in which the pelagic habitat is highly dominant, the food web structure seems to have a variety of trophic pathways linking with phytoplankton. Especially among endemic fishes, which have long evolved behavioral, morphological, and life historical traits adapted to pelagic environments (Sect. 2.5), their high pelagic production reliance was straightforward. In the tectonic Lake Biwa, the unique food web has been shaped by the lake's structure and longevity.

Long-Term Food Web Dynamics

Next, we examined the long-term dynamics of the past food web by measuring the $\delta^{15}N$ for archival specimens. We used a total of 1,177 preserved specimens, including 45 aquatic animal species (30 fishes, 8 molluscs, and 7 crustaceans) collected from Lake Biwa between 1914 and 2004. For the baseline adjustment to estimate their *TL*s, we used published data from Ogawa et al. (2001) who measured the $\delta^{15}N$ for chronological samples of a deep sediment core. Using the ^{210}Pb method, Ogawa et al. (2001) estimated that the measured sediment core samples were deposited from 1901 to 1995. We also measured the $\delta^{15}N$ of surface sediments in the deep zone of the lake to adjust for the last decade. In Lake Biwa, the deep sediment organic matter consists mainly of autochthonous (i.e., phytoplankton) products (Murase and Sakamoto 2000), so we considered it as an index of the food web base. There was a strong positive correlation of the decadal average $\delta^{15}N$ between the chronological sediment samples and concurrent archival specimens of primary consumers (copepods and gammarids) ($r = 0.84$, $n = 8$, $P = 0.009$), with the mean difference of 3.4‰ (±0.8 SD) which was equivalent to the literature average (3.4‰ ± 1.1 SD) from a variety of taxa in aquatic ecosystems (Minagawa and Wada 1984), confirming that the sediment $\delta^{15}N$ is appropriate for the baseline adjustment.

To view the long-term trophic dynamics of each species, we took its decadal averages and then calculated its *TL*, using a single source model of the $\delta^{15}N$. Grazing and filter-feeding macrozoobenthos showed *TL*s typical of primary consumers throughout all decades (gastropods: 2.07 *TL* ± 0.47 SD, bivalves: 1.48 *TL* ± 0.41 SD). By contrast, we found great temporal variation in the fish *TL*s (*Fig. 2*). For lack of systematic samplings, data were highly fragmented from the 1910s to the 1950s. When comparing variations in individual species' *TL*s among decades, there was no significant temporal trend in the first half of the twentieth century during which the lake ecosystem did not suffer from notable anthropogenic disturbances (Analysis of variance [ANOVA], $F_{4, 45} = 0.31$, $P = 0.87$). In the latter half of the century, in contrast, their *TL*s showed significant decadal changes (ANOVA, $F_{4, 82} = 8.77$, $P = 0.0001$). This trend remained highly significant after considering consecutive changes within the same species (repeated measure ANOVA, $F_{4, 32} = 19.05$, $P = 0.0001$). In most fish species, their *TL*s reached a peak in the 1970s with an increase on average of 0.45 relative to that in the 1960s and was among the highest in any decades (repeated measure ANOVA, post hoc Scheffe's F-test, all $P < 0.05$). However, their *TL*s drastically decreased on average by 0.89 between the 1970s and 1990s. In 11 of 15 native species, whose data are available for systematic comparisons, the lowest *TL* was recorded in the 1990s. In shrimps, in contrast, such a temporal trend was not found in their *TL*s (3.05 *TL* ± 0.40 SD, *Fig. 2*).

In Lake Biwa, which was originally oligotrophic, nutrient loadings have enhanced primary productivity since the late 1960s, consequently supporting a larger biomass of secondary and higher consumers. As reported by some ecologists (Thompson and Townsend 2005; Doi et al. 2009), resource availability might have a positive effect on the fish *TL*s, possibly through the increased availability of preys with higher *TL*s during the 1970s. Such a bottom-up effect can cascade to the top predators' *TL*s, resulting in an extended food chain length. After this time, however, the food web drastically shrank, reaching the bottom in the 1990s. This shrinkage cannot be attributed to temporal

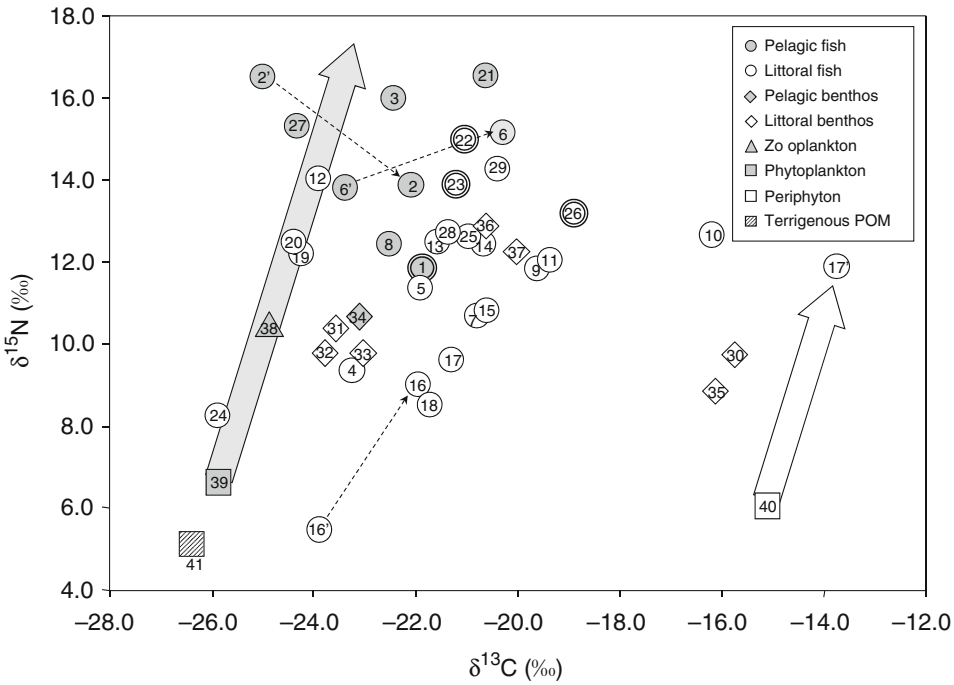

Fig. 2

The long-term trophic dynamics of fishes and shrimps in Lake Biwa. Each plot represents the decadal averages of *TL* for each species (see Appendix 1 for functional feeding groups) and its consecutive decadal changes are linked by *solid lines* between neighboring two plots.

changes in *TL*s of primary consumers because macrozoobenthos showed relatively constant trophic dynamics, suggesting that the fish inclined toward single chain omnivory (*sensu* Pimm and Lawton 1977), that is, feeding shift to preys with lower *TL* within a food chain. During the period of the 1980s–1990s, this lake experienced a variety of severe human disturbances, such as eutrophication, littoral habitat modification, exotic species introduction, and global warming, leading to remarkable population declines in native species. In Lake Biwa, the food web shrinkage may be due to decreased availability of preys with high *TL*s for fishes and consequently to lack of intermediate trophic pathways, for which ultimate drivers must be human disturbances.

Stable Isotopes as Ecological Tools

Our stable isotopic approach provided a new insight for ecological and conservational studies as well as food web studies. In Lake Biwa, native fishes are well known to shift their habitats and trophic niches through their life history. Such life historical patterns were reflected in their isotopic changes with their growth (*Fig. 1*): for example, a crucian carp migrates from peripheral temporary waters (16′) to the main lake (16), some adults of a dwarf ayu change their pelagic migratory behavior (2′) into a sedentary lifestyle in the littoral zone (2), and a pelagic carnivorous three-lips shifts its feeding habit from zooplanktivory (6′) to piscivory (6) with the increasing reliance on the benthic food chain. In this lake, most of the native fishes utilize multiple habitats throughout their life history (Yuma et al. 1998). Although some ecologists point out the possibility that human disruption of habitat networks led to their recent population declines in this lake (Sect. 7.2.1(2)), our scientific knowledge is too limited to assess how it can affect their population dynamics and to what extent habitat restoration is effective in helping them recover from their population collapses. Considering marked isotopic variation across habitats in lakes (France 1995; Maruyama et al. 2001; Shibata et al. 2011), the SIA can be helpful to understand their unexplored migratory behavior and life history,

providing basic ecological information for biodiversity conservation.

Although the present study revealed that the Lake Biwa food web shrank due to a variety of human disturbances, we also found it has turned to recovery in the last decade (*Fig. 1*). The reason for this remains unknown but the local government has just started to practice some environmental policies for biological conservation and ecosystem management (Sect. 7.2). We finally recommend not only ecologists, but also policy makers to adopt our isotopic approach for their assessment of ecosystem properties and their evaluation of the cost to benefit of conservation activities.

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3.3 Warming and Hypoxia in Lake Biwa

Toshiyuki Ishikawa · Michio Kumagai

Abstract The water temperature of Lake Biwa has been changing simultaneously with air temperature. Long-term observation of temperature is limited to several decades due to inconsistency of measuring devices; nevertheless, these data indicate a clear warming tendency of Lake Biwa. Several studies have suggested that biodiversity in Lake Biwa is related to temperature variation. In addition, we found that thermal stratification has become stronger in spring and fall. Therefore, it is highly likely that the temperature stratification period has been extended. Implications of these changes are discussed.

Keywords • Hypoxia • Global warming • Thermocline • Convection

Background

Lakes are considered an ecosystem that may be strongly affected by human activity. Eutrophication is one of the biggest issues in changes induced mainly by human activities in lacustrine watersheds. Acidification and invasive species are large issues in many lakes the world over. In addition, evidence indicates climate change, namely global warming, has been affecting lake ecosystems (Williamson et al. 2009). Effects of climate can be divided into direct and indirect changes. For example, rise in temperature and alteration of thermal structure are direct effects. In contrast, hypoxia induced by reinforcement of thermal stratification is an example of indirect change.

In this chapter, we introduce our current understanding on warming and hypoxia in Lake Biwa. We also try to speculate on the relationship between these two phenomena.

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Long-Term Observations in Lake Biwa

Limnological survey of Lake Biwa has been conducted by research institutes of local government and limnological laboratories of universities. The longest lasting observation has been conducted by Shiga Fishery Experiment Station (SFES) since 1914. The Center for Ecological Research (CER), Kyoto University (formerly Otsu Hydrobiological Station, Kyoto University), and Lake Biwa Environmental Research Institute (LBERI, an integrated institute of Lake Biwa Research Institute and Shiga Prefectural Institute on Public Health and Environmental Science) also have conducted long-term observation of Lake Biwa. Observation sites of each organization are different, covering both Imazu basin (~90 m) and Omimaiko basin (~75 m) (*Fig. 1*).

Warming of Lake Biwa

In 1999, two papers (Hayami and Fujiwara 1999; Endoh et al. 1999) indicated a clear rise in water temperature in Lake Biwa. Both authors analyzed monitoring data from the 1960s to 1990s and showed a clear difference of water temperature by the mid-1980s. Hayami and Fujiwara (1999) estimated that water temperature at the 77-m layer rose by 0.04°C/year from 1965 to 1997. Endoh et al. (1999) estimated that water temperature of Lake Biwa integrated vertically from observation data rose by 0.04°C/year during 1965–1997. Both papers mentioned the obvious relationship between rise in water temperature and air temperature. Their analysis showed that water temperature in deep hypolimnion strongly relates with winter air temperature, whereas surface water temperature relates with annual air temperature.

To explore the rate of temperature rise after analysis of these two 1999 papers, we compared water temperature of lake and air. Here, we used the data of the LBERI station off Imazu during 1979–2008. To compare weather conditions, we used the data reported by Japan Meteorological Agency observed at Hikone, Shiga Prefecture.

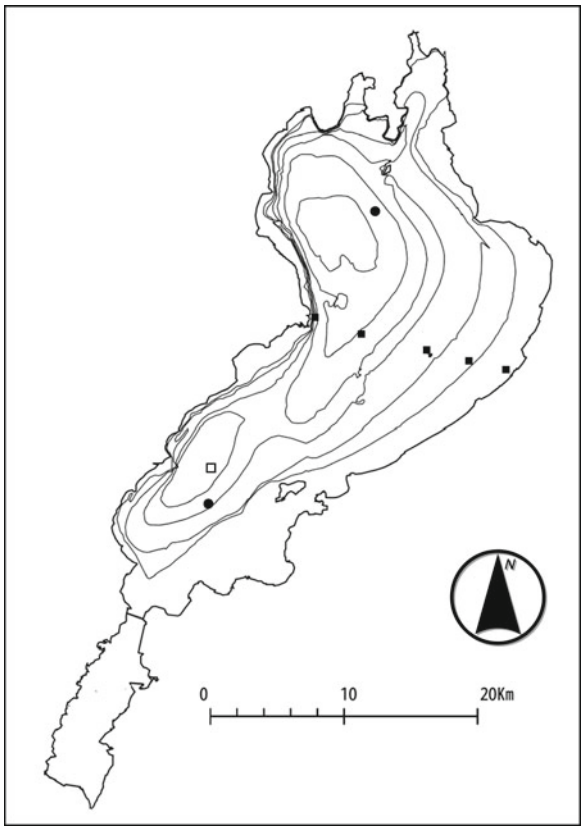


Fig. 1

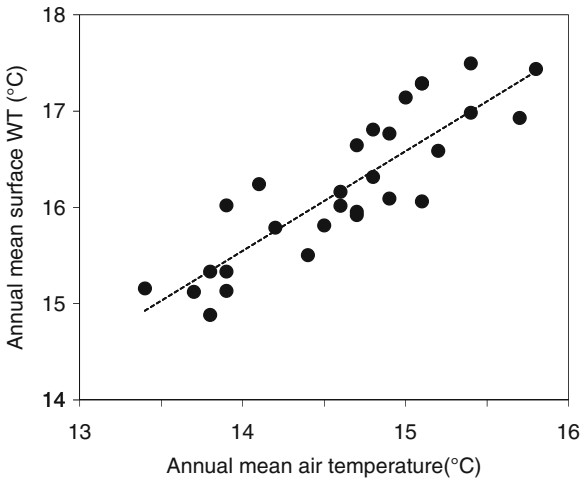


Fig. 2

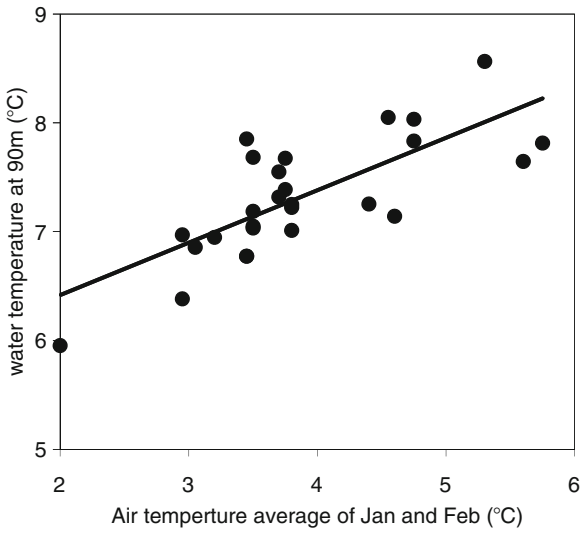


Fig. 3

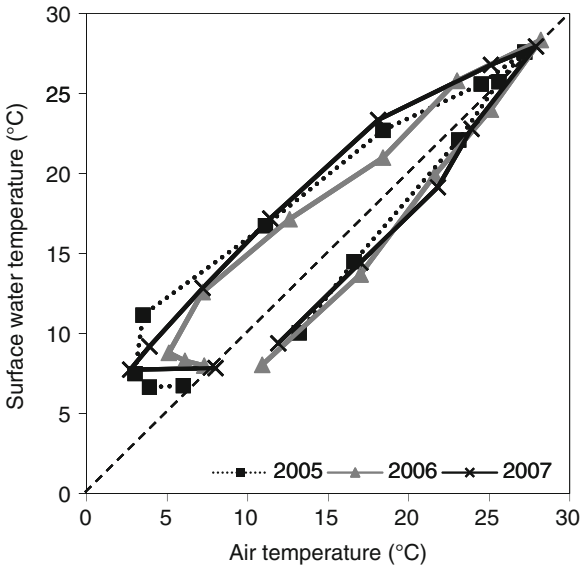
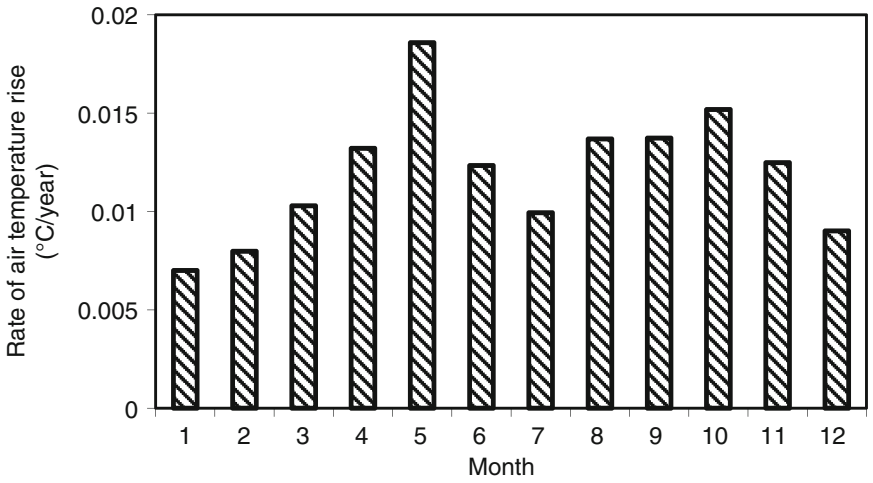


Fig. 4

As shown in *Fig. 2*, surface water of Lake Biwa strongly correlates with annual air temperature at Hikone. However, bottom water of Lake Biwa strongly correlates with average air temperature in January and February, not to the annual mean (*Fig. 3*). This reflects the timing of holomixis of Lake Biwa. After the holomixis event, bottom water temperature does not change remarkably (at most 1°C increase in the stagnant period). In contrast, surface water of Lake Biwa changes seasonally. As shown in *Fig. 3*, surface water follows change in air temperature. When a thermocline is formed after holomixis, surface water of Lake Biwa is slightly lower than air temperature. Usually, water temperature equates to air temperature in August, then, it is slightly higher than air temperature until

Fig. 5



holomixis in January or February. Therefore, the line in *Fig. 4* shows a counterclockwise rotation.

Thus, we conclude that water temperature of Lake Biwa changes seasonally following changes in air temperature. In *Fig. 5*, we calculated rate of air temperature rise from 1894 to 2008 at Hikone. The results show warming of air temperature each month. In spring, around May, and autumn, around October, there was a remarkable increase in air temperature. Although cold and hot seasons are important to the viewpoint of circulation of lake water and biological tolerance, our results suggest an importance of the transitional season when considering effects of warming of lake water.

Effects of Warming on Lake Biwa Ecosystem

Warming of lake water certainly affect lake ecosystems in various ways. Because most organisms in the lake are poikilotherms, rise in temperature affect life cycle, metabolism, distribution, behavior, interaction between species through feeding activity, and so on. In Lake Biwa, a paleolimnological study clarified that changes in water temperature affect life cycle of daphniid species (Tsugeki et al. 2009). In addition, fish species in Lake Biwa show different performance under different temperatures, especially in their metabolism (Suzuki et al. 1967). Furthermore, Hidaka and Takahashi (1987) showed that changes in temperature affect species interaction of fish species in Lake Biwa. Hidaka and Takahashi (1987) investigated competition of space for reproduction between two gobies, Isaza (*Gymnogobius isaza*) and Yoshinoboi (*Rhinogobius* sp.). These authors' study showed that the competition winner was dependent on water temperature.

A rise in water temperature might change the thermal structure of a lake. Lake Biwa is a monomictic lake with winter overturn. Rise in water temperature in stratification period might reinforce its thermocline, as mentioned above.

Magnitude of thermocline is usually expressed by energy to break down thermocline (Schmidt index; Idso 1973) or maximum buoyancy in thermocline (Brunt-Vaisala frequency). To compute these indices, observation of water temperature with high vertical resolution is necessary. Unfortunately, historical data does not have such a high resolution. In order to discuss thermocline strength as Schmidt index or Brunt-Vaisala frequency, we must interpolate the data or use another index. Instead, we here simply calculate difference of density of water between surface water and bottom water (*Fig. 6*), estimated with water temperature. In the data shown in *Fig. 6*, a remarkable rise in thermocline strength was found in late autumn around November. Another rise is also found in spring around May. Therefore, it can be said that the thermocline has become strong earlier in spring and has become weak later in autumn, which suggests that the stratification period has become longer in these three decades.

Reinforcement of thermocline might affect a lake ecosystem in several ways. Firstly, stronger thermocline prevents nutrient flux from hypolimnion to epilimnion. During the stagnant period, this flux provides an internal supply of nutrient to phytoplankton. Secondly, stronger thermocline might exist for longer periods resulting in a shorter holomixis. Because this concerns bottom hypoxia, we will discuss in detail later. Thirdly, stronger thermocline might tend to extinguish the shallower

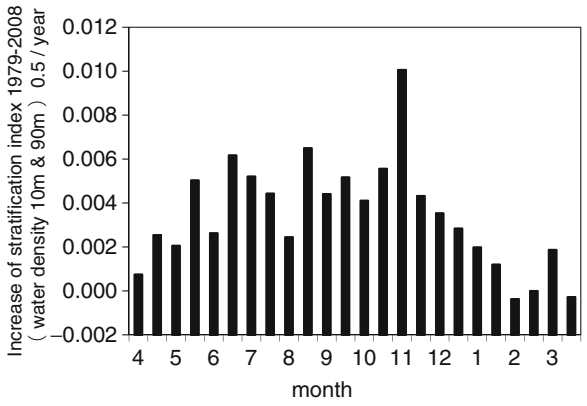


Fig. 6

layer. All this might affect distribution of lake-dwelling organisms. In Lake Biwa, compensation depth of phytoplankton exists around 15–20 m, which is slightly shallower than the thermocline. Therefore, chlorophyll maximum usually exists above the thermocline. However, in 1994, the chlorophyll maximum appeared below the thermocline due to high transparency of surface water (Yoshiyama and Nakajima 2002). Such alteration of vertical structure of primary producer might change lake trophic structure. If the thermocline is formed in a shallower layer with its reinforcement, a chlorophyll peak will form below thermocline as happened in 1994. Because there is an active swimmer with large biomass below the thermocline, *Jesogammrus annandalei* (Ishikawa and Urabe 2002, 2005), formation of chlorophyll peak in hypolimnion surely alters trophic relationships in Lake Biwa.

Other Phenomenon Concerning Climate/Weather Change

In addition to temperature change, climate and/or weather might change condition of wind, solar radiation, precipitation, snow fall, and so on. Tsugeki et al. (2010) showed that phytoplankton composition was affected by wind velocity in winter, with a decreasing trend using the data since 1967 to 1997. For solar radiation and precipitation, Tsugeki et al. (2010) reported that there was no clear increase or decrease in the twentieth century.

In the discussion on the effect of climate/weather change above, we have focused upon the pelagic ecosystem. If we consider a littoral ecosystem, we must add several factors into consideration; for example, changes in water level, littoral vegetation, river water flow, and so on. To explore these effects, we must collate observation of both field data and laboratory experiment for species characteristics.

Bottom Hypoxia in the North Basin

In 1973, Naka (1973) indicated a tendency of decrease in dissolved oxygen (DO) concentration for the first time at SFES station (*Fig. 1*). Naka (1973) concluded that the DO decrease tendency was affected by eutrophication because plankton biomass increased with DO decrease.

To understand DO dynamics in lake water, we must understand balance of oxygen supply and consumption.

$$\Delta \mathrm{DO} = (\mathrm{DOsupply}) - (\mathrm{DOconsumption})$$

Therefore, DO concentration can be written as follows:

$$\mathrm{DO} = \mathrm{DO}_{\mathrm{initial}} - \int \Delta \mathrm{DO} \mathrm{d}t$$

Here, time (t) is duration of oxygen decrease or, simplistically, the period without enough supply. As shown above, the minimum DO concentration is decided by the balance of DO supply and DO consumption.

DO Supply in Lake

In epilimnion, DO is supplied mainly from air and from product of photosynthesis by phytoplankton, which keeps DO concentration around saturation throughout a year. In hypolimnion, DO supply is mainly from surface water in holomixis in winter, which is considered to be driven by convection and density current from shallow area. In the stagnant period, DO supply from surface water is highly limited. Therefore, DO supply in this period is considered to be restricted to supply within hypolimnion driven by water flow. Changes in water flow in hypolimnion affect DO decrease rate via changes in DO supply rate.

DO Consumption

Respiration of organisms is an important process of DO consumption. Except for anaerobic bacteria, organisms respire with oxygen. In addition to respiration, there are DO consumption processes without organisms. Abiotic degradation of organic matter, for example, photolysis, sometimes consumes oxygen. Reducing agent produced in anoxic condition, especially in sediment, consumes DO in the water column. Therefore, sediment containing much reducing agent consumes much oxygen in the water column.

Long-Term Changes in Bottom Hypoxia in Lake Biwa

The annual minimum DO concentration in four long-term monitoring stations is shown in *Fig. 7*. As pointed out by Naka (1973), remarkable decrease in DO was observed from the 1950s to 1970s at the SFES station. Since the 1980s, there was no monotonic decrease in DO but there was a sporadic decrease (e.g., in 1992 and 2002). At CER station (1965~) and LBERI-60m station (1986~), there was no clear decrease tendency in DO. Rather, the annual minimum DO seems increasing in LBERI 60m station.

At the LBERI-90m station, the deepest station with long-term data, sporadic decrease of DO concentration has been seen, in the 1980s (1985, 1986, 1987) and 2000s (2002, 2007, 2008).

The Cause of Hypoxia in Lake Biwa

Here, we discuss the cause of hypoxia at LBERI-North station. At first, we have to understand current hypoxia in Lake Biwa is not a whole-lake phenomenon. Remarkable hypoxia is limited in LBERI-North station. However, this does not mean the area of hypoxia is small. If sporadic hypoxia at SFES station relates hypoxia at LBERI-North station, the area of hypoxia might occur in areas where depth is deeper than 78 m. The area deeper than 78 m in north Lake Biwa is twice larger than in the south basin of the lake. This limitation of hypoxia area helps us to make hypothesis.

Hypothesis Concerning DO Supply

Lake Biwa is a monomictic lake usually with a winter over turn from January to March. In this period, not only the water column, but also the bottom sediments might recover oxygen content.

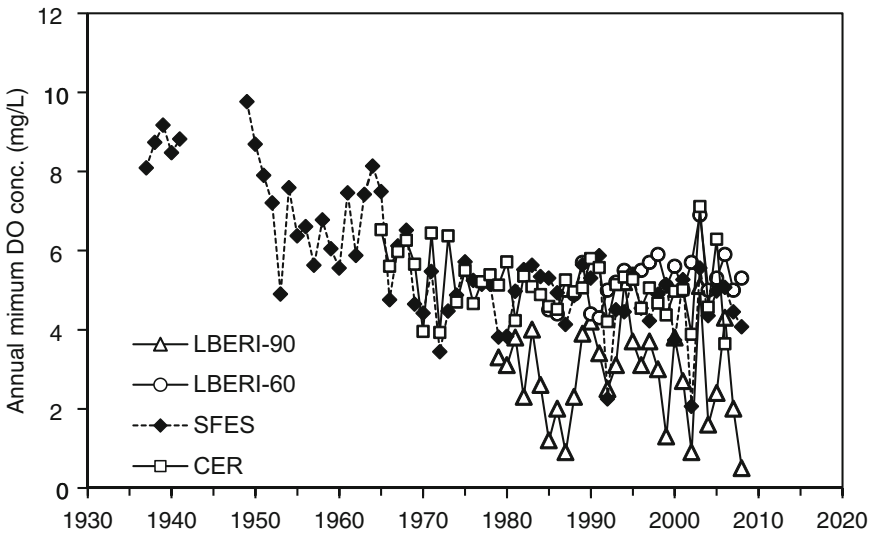
If this holomixis is stopped, old thermocline would persist in deep strata and new thermocline would be formed in shallow strata. Below old thermocline, DO might remain low and decrease. It is very likely that the water below this old thermocline becomes anoxic. The volume and area of this anoxic water depend upon the position of the old thermocline. Therefore, it is difficult to predict whole-lake effect of holomixis stopping due to limitation of predictability of the amount of anoxic water.

Even if the holomixis occur, shortness of holomixis period seems to have negative effect on DO concentration in the bottom water. This is because recovery of DO concentration and redox condition of bottom sediment could be affected by period of exposure to oxygen-rich water. This relates to both slow diffusion between sediment and water column, and formation of bottom boundary layer.

Hypothesis Concerning DO Consumption

Biological process is an important factor concerning DO consumption. Both biological activity and organism resources regulate DO consumption. Because most aquatic organism are poikilothermous, water temperature directly affect their metabolic activity. However, it is

Fig. 7



not clear that 1°C or 2°C increase in water temperature causes substantial increase in respiration rate. Because slight changes in temperature need precise measurement of respiration, further research should be done on this in the future.

Projection of Hypoxia Under GCM Scenario

Most global climate models project global warming with several degrees until the end of the twenty-first century. Under such condition: (1) it is highly probable that thermoclines become stronger and duration of oxygen decrease will become longer, which would lead to decrease in minimum DO value; (2) it is likely that holomixis events happen later because of stronger thermocline; and (3) it is probable that holomixis is stopped. However, it is difficult to predict when holomixis will be stopped because of several conditions such as temperature of hypolimnion that reflect winter air temperature of previous year, annual weather, or hydrology. Also, as mentioned above, depth of old thermocline will be a key factor to predict the area of anoxic water.

2007 Warm Winter Event

Although it is not clear whether global warming had an effect or not, there was a remarkably warm winter in 2007. In contrast, there was a remarkably cold winter in 2006. Due to cooler water in hypolimnion and warm air temperature, the thermocline was still recognized even in early March in 2007. This affected DO concentration near the bottom, keeping it further below saturation level until early March. DO value reached near saturation level late March, but in early April, a thermocline was recognized in surface water. Therefore, it can be said that holomixis in winter 2007 was very weak.

Around November in that year, DO concentration near bottom at LBERI-north station decreased below 1.0 mg/l. In December, autonomous underwater vehicle "Tantan" found a number of dead fish and shrimp. Lately, the dead fish and shrimp were identified to be Isaza (*Gymnogobius isaza*) and Sujiebi (*Palaemon paucidens*) (Kumagai et al. 2009).

Debatably, there is a connection between a warm winter event and fish kill in late autumn. One possibility is weak recovery of redox condition of bottom sediment in warm winter. Also, stability of thermocline in 2009 seemed to be stronger again.

Effect of Hypoxia in Lake Biwa

Organisms living in profundal zone and hypolimnion in Lake Biwa consist of several species including endemics. Bottom hypoxia might have negative effect on them in the form of direct mortality, decrease in activity, fragmentation of habitat, and so on. These effects might affect community structure of benthic organism in the Lake. As for abiotic factors, it is well known that hypoxia induces release of materials from sediment. These include manganese, iron, phosphorus, and arsenic (Takamatsu et al. 1985).

Conclusion

Warming and hypoxia in Lake Biwa is an ongoing issue in Lake Biwa. Because both phenomena affect biotic and abiotic components in the lake ecosystem, many aspects of research and monitoring are necessary. Because water temperature in the lake and bottom hypoxia have heterogeneity and time variation, improvement of monitoring framework is highly important. In addition to monitoring, understanding of life history, physiology, behavior of each species, and interactions among them are crucial.

Acknowledgements

We are grateful to all who had participated in monitoring activity in Lake Biwa. We thank every member of Lake Biwa Research Institute for critical and helpful discussion on topics raised here.

Topic 7 An Analysis of the Lake Biwa Shoreline Changes using GIS

Yoshihiro Azuma · Masaru Tatsumi

Introduction

Lakeshores of Lake Biwa comprise various factors of the lakeshore topography, such as deltas, swamps, and attached lakes, and have served as nursing grounds for diverse organisms.

The lakeshores have also long been utilized by people as a place for living and have been subject to alteration. Particularly in recent years, the lakeshore environment has been changed greatly due to reclamation, landfill, establishment of lakeshore embankment, and so on; however, quantitative analysis of such change has not been made sufficiently. For example, varied figures ranging from 699.96 to 721.46 km^2 have been published since 1868, of the area of Lake Biwa in the period when numerous attached lakes existed in the lakeshores (Nishino 2005). These varied figures seem to indicate not only the actual change in the area, but also the difference in statistical methods (i.e., whether the areas of attached lakes were included or not).

In this chapter, we summarize the results of the survey conducted using GIS on the Lake Biwa shoreline changes observed in old topographical maps surveyed from the 1890s onward as well as in past aerial photographs. Further, we briefly introduce the results of GIS analysis conducted on the results of the survey aimed at a type classification of current lakeshore topology (see Sect. 3.1.1).

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Lake Shoreline Changes over the Last 100 Years

Based on the topographical maps of four periods (i.e., topographical maps of 1890s on a scale of 1:20,000, maps of 1920s and those of 1960s on a scale of 1:25,000, and digitized topographical maps of 1990s) and aerial photographs taken by US forces in the late 1940s, GIS data of five periods, including the period up to recent years, on the water area of Lake Biwa and its attached lakes were developed. Paper-based topographical maps were transformed into digitized image data using a scanner, and then underwent geometrical correction and alignment. Orthoimages created in Azuma (2004) were used as aerial photographs of the late 1940s. *Table 1* shows the change from the 1890s to recent years in the water area of Lake Biwa and its attached lakes evaluated from the created GIS data. Further, *Fig. 1* shows the spatial distribution of Lake Biwa and its attached lakes in respective periods.

The water surface area of the north basin, that of the attached lakes of the north basin, and that of the south basin reduced with time, except for that of the attached lakes of the south basin. The reduction in the water surface area of the north basin up to recent years was about 9.9 km^2, whereas the reduction in the area of the attached lakes of the north basin was 30.9 km^2 and much greater. In contrast, the reduction in the area of the south basin was conspicuous and turned out to be about 9.5 km^2, which was comparable to the amount of reduction in the area of the north basin, which is much larger in area.

Lakeshore Classification Based on the Recent Survey

Based on the field survey conducted in 2007 and using aerial photographs taken in the same year, observation of the lakeshore topology was made throughout the entire lakeshore areas, and the results were transformed into the geographic information system (GIS) data for analysis.

Table 1

Change in the water area of Lake Biwa and its attached lakes from the 1890s to recent years

	Unit :km^2				
	1890s	1920s	1940s	1960s	1990s
Main lake					
Lake Biwa total	688.1 (100.0%)	684.1 (99.4%)	677.8 (98.5%)	672.1 (97.7%)	668.7 (97.2%)
South Basin	60.2 (100.0%)	58.0 (96.3%)	56.9 (94.5%)	53.6 (89.0%)	50.7 (84.2%)
North Basin	627.9 (100.0%)	626.1 (99.7%)	620.9 (98.9%)	618.5 (98.5%)	618.0 (98.4%)
Attached lakes					
Lake Biwa total	35.2 (100.0%)	33.0 (93.8%)	23.3 (66.2%)	5.4 (15.3%)	5.3 (15.1%)
South Basin	0.3 (100.0%)	0.3 (100.0%)	0.5 (166.7%)	0.6 (200.0%)	1.3 (433.3%)
North Basin	34.9 (100.0%)	32.7 (93.7%)	22.8 (65.3%)	4.8 (13.8%)	4.0 (11.5%)

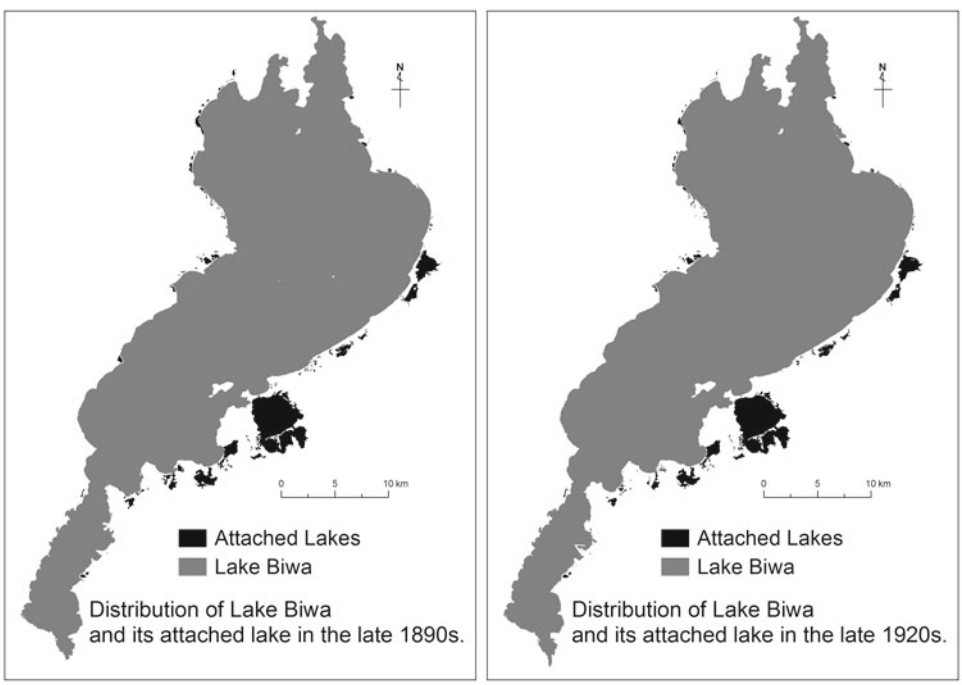

Fig. 1

Spatial distribution of Lake Biwa and its attached lakes from the 1890s to recent years.

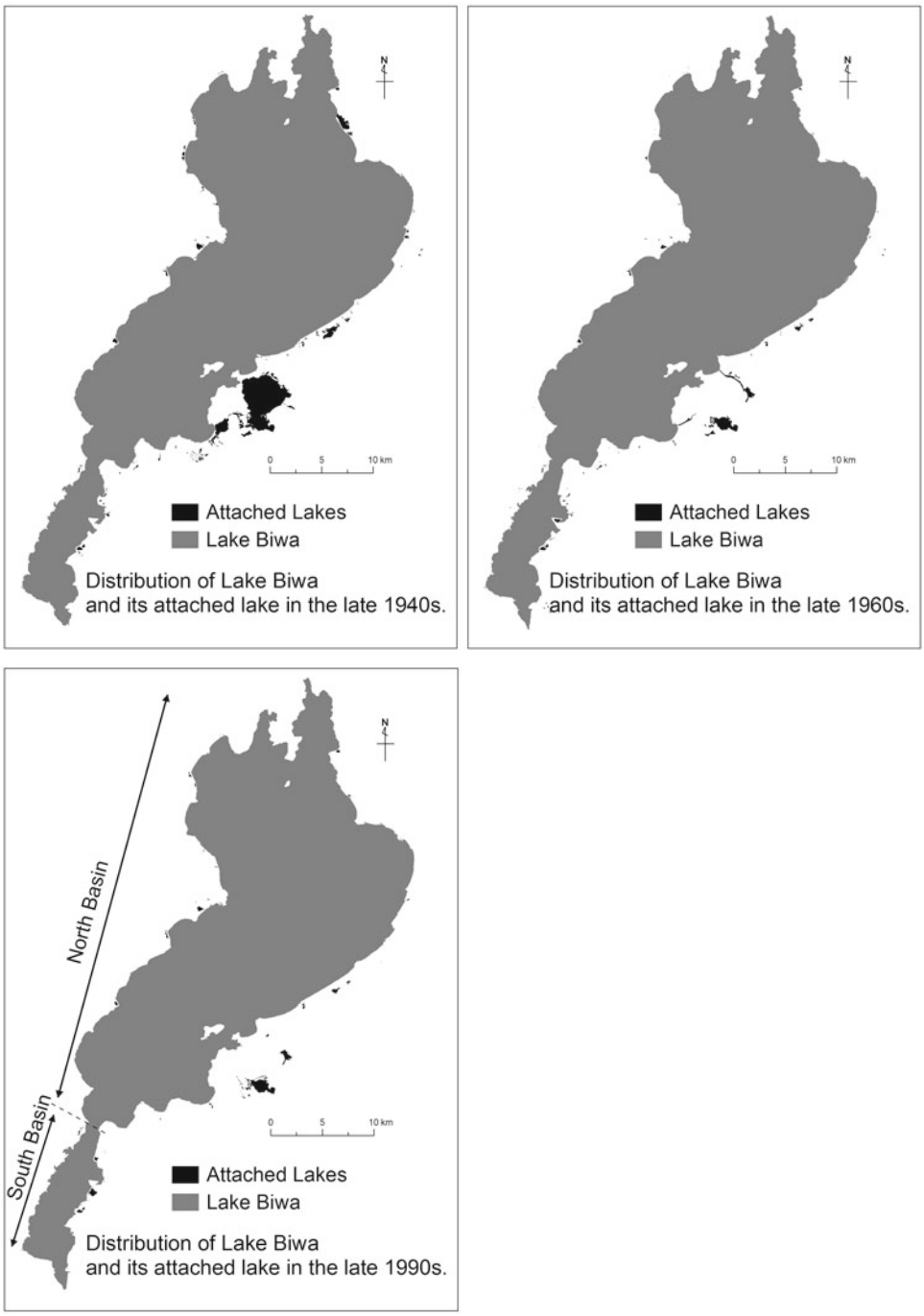

Fig. 1
(continued).

With regard to the altered shorelines, the types of structures that had altered the shorelines were classified into concrete, stone, and others, and collectively such lakeshores shall be hereinafter referred to as the "artificial lakeshore." The lakeshores in which natural structures are preserved with little alteration shall be referred to as the "natural lakeshore." The "natural lakeshore" was further classified into the "sandy lakeshore" consisting of relatively

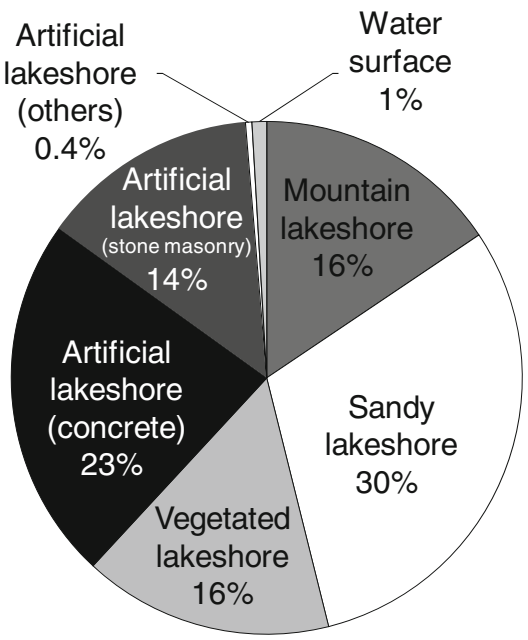

Fig. 2
Proportion of each type classification calculated as a percentage of the total shoreline length of Lake Biwa.

fine-grained unconsolidated sediments such as the sand beach and the cobble beach adjacent to the shoreline; the "mountain lakeshore," a steeply inclined lakeshore facing the mountain slope behind; and the "vegetated lakeshore" covered with vegetation such as *Phragmites* spp. and willow coppices. Further, the mouth of the influent river measuring 20 m or more in width was classified as the "river mouth area." *Fig. 2* indicates the proportion of each type classification calculated as a percentage of the total shoreline length of Lake Biwa, and *Fig. 3* indicates the proportion of each type classification calculated as a percentage of the total shoreline length of the south basin, and that of the north basin, respectively.

In the shorelines of Lake Biwa consisting of various types of classifications, the artificial lakeshores, comprised of concrete, stone masonry, and other materials, were found to occupy about 37%. Comparing the proportions in the north basin with those in the south basin, we found that the south basin had a larger proportion of the artificial lakeshore (i.e., 26% in the north basin and 72% in the south basin).

Lastly, *Fig. 4* indicates the shoreline locations in the late 1940s and in the 1990s and the spatial distribution of

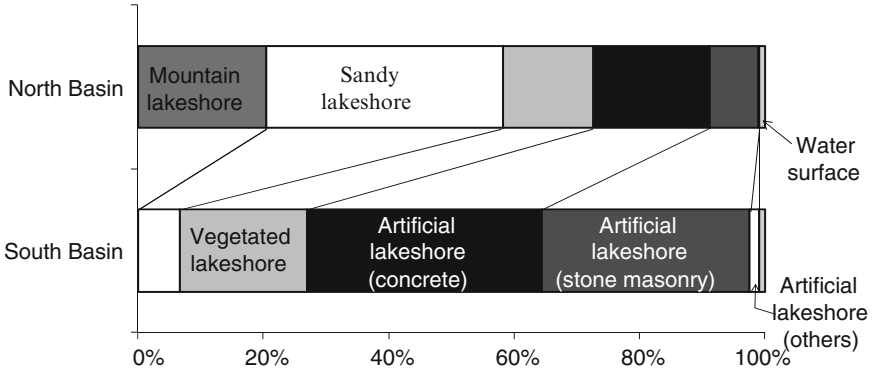

Fig. 3
Proportion of each type classification calculated as a percentage of the total shoreline length of the south basin, and that of the north basin, respectively.

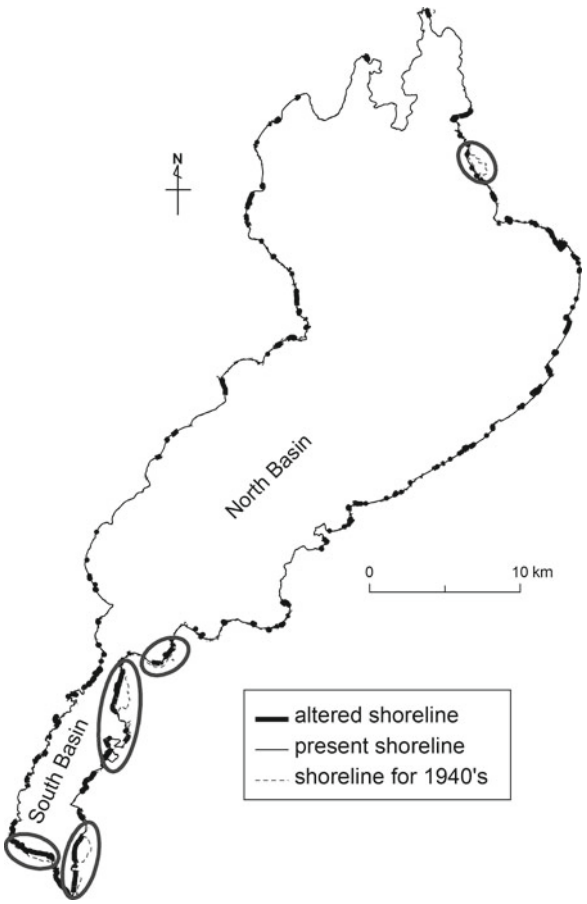

Fig. 4
Shoreline locations in the late 1940s and in the 1990s. The lakeshore areas encircled by solid ellipses indicate areas where a lot of shoreline alterations were observed.

the shorelines classified as the "artificial lakeshore." Many of the artificial lakeshores scattered throughout the entire lakeshore areas on a scale of several hundred meters are related to port improvements. The areas whose shoreline locations have altered on a scale of several kilometers suggest a history of topographical alteration on a larger scale; such areas are notably observed in the southern shores of the south basin, the eastern shores of the south basin, the southern tip of the eastern shores of the north basin, and in some areas of the northern part of the eastern shores of the north basin.

Topic 8 Occurrences of *Uroglena* Red Tides and Cyanobacterial Blooms in Lake Biwa

Shigeo Tsujimura · Kanako Ishikawa

A major outbreak of the chrysophycean alga *Uroglena americana* occurred for the first time in the north basin of Lake Biwa, in May 1977 (Wakabayashi and Ichise 1977). This bloom turned the lake's water a reddish brown color and produced a fishy odor in the affected areas. This phenomenon was called locally a "freshwater red tide," and strongly shocked local residents because of the evident deterioration of water quality in Lake Biwa. The impacts led the residents to start a movement, called the "Soap Movement," to promote the replacement of phosphorus-containing synthetic detergents (see Chap. 7). Although the freshwater red tide seemed to suddenly appear in 1977, several remarkable phytoplankton events indicate that eutrophication in Lake Biwa had started before then, during Japan's high economic growth period (see Sect. 2.2).

Fig. 1 shows the number of days red tides occurred each year. While the occurrence of red tides has decreased in recent years compared with the 1980s, the number of days when treatment of lake water with activated carbon was necessary to remove fishy odor compounds produced by *Uroglena* has increased recently. The main reason for the increase in need for this type of treatment is the change in the growth pattern of *Uroglena*. The proliferation of *Uroglena* was previously restricted mostly to May and June of each year. However, recently, *Uroglena* has grown not only in late spring, but also in late autumn and winter (Yoshida et al. 2007). This growth is not prolific enough to produce a noticeable red tide, but attains a level requiring activated carbon treatment. Thus, we still have the problems with *Uroglena* even though the occurrences of the red tides have decreased.

The occurrence of cyanobacterial blooms is another phenomenon that deeply impacted the local residents and the local government, because it is regarded as a symptom of eutrophication. Furthermore, many of bloom-forming cyanobacteria are known to produce hepatotoxins and/or neurotoxins, so that their proliferation causes public health concerns. *Microcystis* spp. and *Anabaena* spp., which are typical species that form cyanobacterial blooms, have been often reported as the dominant species in phytoplankton communities in lakeshore areas of the south basin since the 1960s (Negoro 1969). The first officially recorded cyanobacterial bloom in the south basin of Lake Biwa occurred in 1983. Subsequently, *Microcystis* blooms have been observed at several ports of the north basin since 1994 (Yoshida et al. 1996). Recently, several other cyanobacterial species, such as *Oscillatoria kawamurae* and *Aphanizomenon flos-aquae*, have been recorded as new constituents of cyanobacterial blooms in Lake Biwa (Ichise et al. 1998, 2000).

While nutrient concentrations have decreased, especially in the south basin, during the last several decades as the result of various measures to reduce nutrient loading, the number of days of the occurrence of cyanobacterial blooms are not showing a decreasing trend (*Fig. 2*). This seems to indicate that it is difficult to extinguish the bloom-forming cyanobacteria or control the bloom development only by the reduction of external nutrients after cyanobacterial blooms have first occurred. Cyanobacterial blooms are formed mainly in stagnant water areas, such as in fishing ports, and specific countermeasures suitable for these types of areas are needed. Recent studies have shown that physical conditions strongly affect the growth of bloom-forming cyanobacteria (Nakano et al. 2001). Considering the present nutrient levels of Lake Biwa, physical management of stagnant water areas could be an important control method of cyanobacterial blooms.

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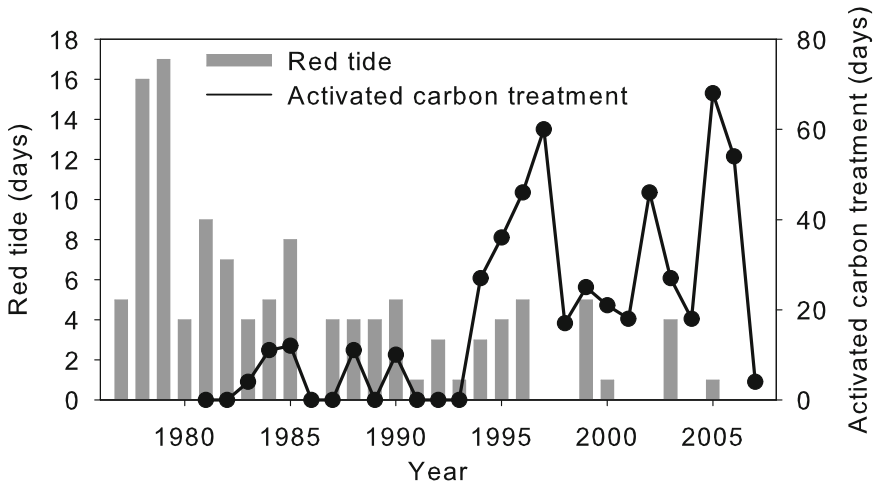

Fig. 1
Occurrences of red tides in Lake Biwa, and treatment of lake water with activated carbon for the removal of fishy odor compounds produced by *Uroglena americana* at the Kyoto Municipal Keage Waterworks (Kyoto City, 1979–2008; Shiga Prefecture 1979–2008).

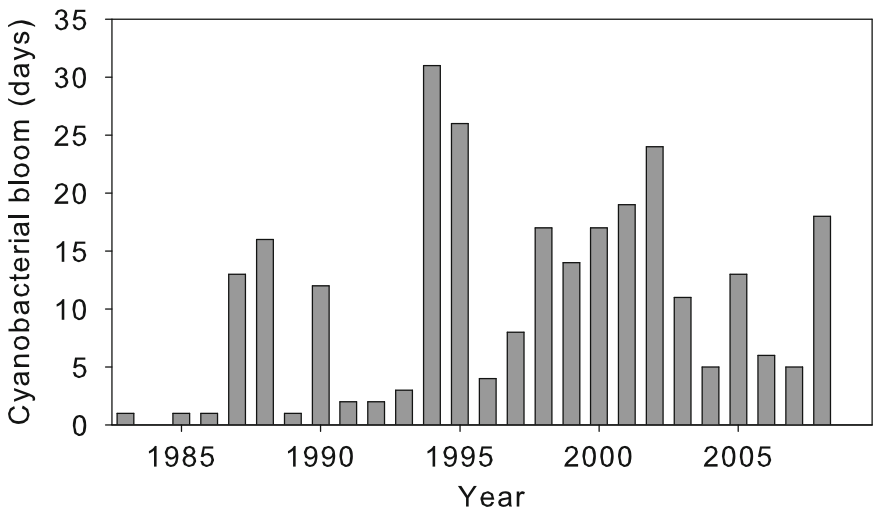

Fig. 2
Occurrences of cyanobacterial blooms in Lake Biwa (Shiga Prefecture 1979–2008).

Topic 9 Impacts of Water Movements on Dissolved Oxygen Concentrations in the Central Basin of Lake Biwa

Chunmeng Jiao

Introduction

Because of Lake Biwa's topography, the deep central basin of the lake is subject to periods in the late summer when dissolved oxygen concentrations (DO) are low (sometimes hypoxic with oxygen concentrations below 2 mg/l). The most pernicious of these problems is the release of phosphorus from the large inventories in the bottom sediments. An apparent increase in the occurrence of this low oxygen situation in recent years has led to increased public concern and scientific interest.

The dissolved oxygen concentrations in the central of the north basin were low during the 1970s, which seemed to be caused by progressive eutrophication associated with rapid urbanization and industrialization in the Lake Biwa watershed (Naka 1973; Matsuda and Morishita 1975). During the past few years, the hypolimnetic oxygen depletion has accelerated with large interannual variations, leading to a record-breaking DO concentration of 0.5 mg/l at 90 m depth in the north basin of the lake in November 2008. The hypolimnetic oxygen depletion this time seems not to be triggered by eutrophication.

Investigation shows that physical mechanisms drive the dynamics in large lakes and can be decisive influences on processes that determine water quality and other environmental values (Harris 1986). It seems that the problem of hypoxia in the hypolimnion of the central basin of the lake is partially caused by fluctuations of the lake's physical dynamics.

In the present study, we analyzed the long-term variations and short-term fluctuations of DO and water temperatures in the central basin of the lake, and investigated their relationships with water hydrodynamics. Our goal was to find other causes for the hypolimnetic oxygen depletion other than organic consumption.

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Study Site and Methods

Lake Biwa (*Fig. 1*) is a large (670 km^2), deep lake with a maximum depth of 104 m and an average depth of 41 m, located in central Japan. The total volume is 2.75×10^{10} m^3, and the hydraulic retention time of the lake averages 5 years.

The lake never freezes over, and the mean surface water temperature in the north basin ranges from a minimum of 6°C in early March to a maximum of 28°C in late August. The lake is warm and monomictic, and mixing is strongest during late winter to early spring. Stratification starts from April and lasts until late autumn/early winter. However, complete homothermy (turnover) may not be reached until late March, as was the situation in 2007. During summer stratification, the temperature gradient between the epilimnion and the hypolimnion is usually very sharp, which results in a narrow metalimnion that ranges from a depth of 15 m to below 25 m.

In order to detect the long-term variations and short-term fluctuation of dissolved oxygen concentration and water temperature in the central basin of Lake Biwa, three high-quality, automatic digital thermometers and DO meters (with 0.002°C accuracy for thermometers and 1% accuracy for DO meters) were moored at three sites with water depth of over 90 m (*Fig. 1*). Chlorophyll-*a* and total phosphorous (TP) data from 1979 onward can be obtained from Lake Biwa Environmental Research Institute's web site (http://www.lberi.jp/root/jp/22db/suisitu/bkjhsuisitu_top.htm#data).

These chlorophyll-*a* and TP data were averaged spatially and temporally for statistical analysis. The data were tested for normality (Kolmogorov–Smirnov) also when

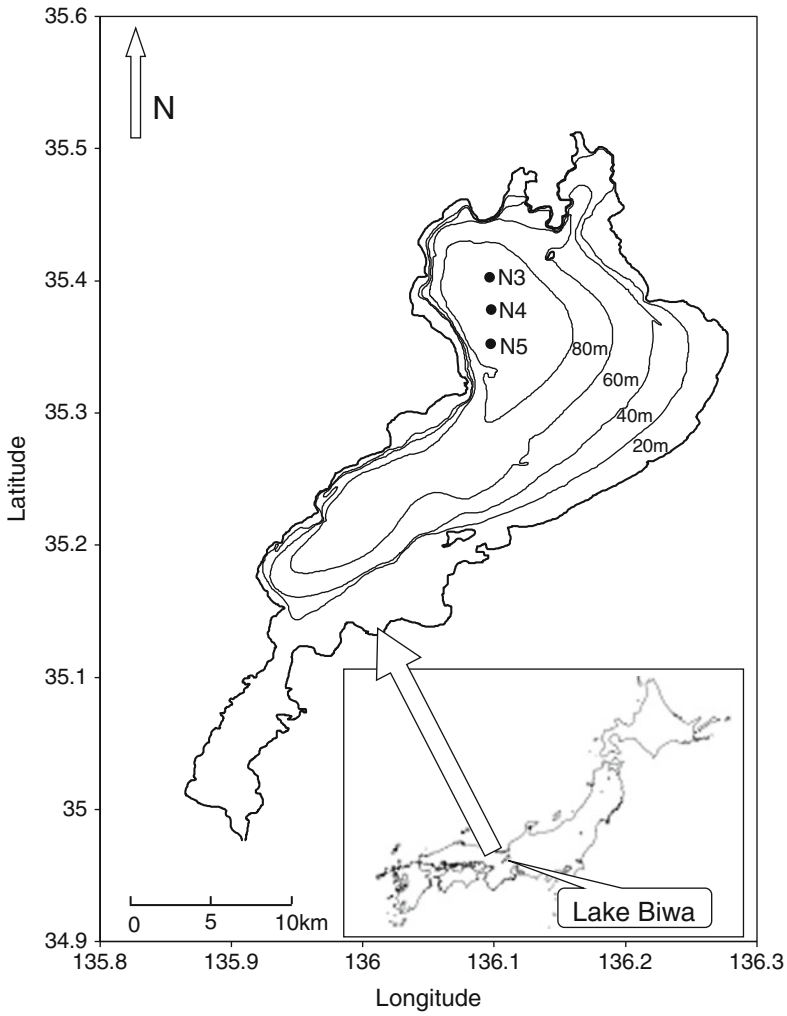

Fig. 1
Map of Lake Biwa with its geographical position in Japan, showing depth contours and monitoring sites (N3, N4, and N5).

performing regression analysis against time. Robustness was tested using Mann–Kendall's tau. Following suggestions by Yue and Wang (2002), prewhitening to eliminate influences of serial correlation on the Mann–Kendall test has not been applied. The long-term variations of dissolved oxygen concentrations and water temperatures were calculated by LOcally WEighted Scatter-plot Smoothing (LOWESS) (Cleveland 1979), and their short-term fluctuations were acquired by taking the difference between the original and the LOWESS data.

Results

The lake's water quality has improved significantly in both the north and the south basins because of the significant reduction of external nutrient loading.

Annually averaged chlorophyll-*a* in the south basin decreased 0.25 mg/l/year ($n = 29, P < 10^{-4}$ by Mann–Kendall test, *Fig. 2a*) and annually averaged TP in the south basin decreased 0.4 mg/l/year ($n = 29, P < 2 \times 10^{-9}$ by Mann–Kendall test, *Fig. 2a*) from 1979 to 2007. The annually averaged chlorophyll-*a* in the south basin was highly related to the annually averaged TP in the south basin ($r = 0.86$ $n = 29$, $P < 10^{-4}$). Similarly, annually averaged chlorophyll-*a* in the north basin decreased 0.06 mg/l/year ($n = 29$, $P < 10^{-4}$ by Mann–Kendall test, *Fig. 2b*) and annually averaged TP in the north basin decreased 0.1 mg/l/year ($n = 29, P < 3 \times 10^{-6}$ by Mann–Kendall test, *Fig. 2b*) from 1979 to 2007. The annually averaged chlorophyll-*a* in the north basin was significantly related to the annually averaged TP in the north basin($r = 0.70, n = 29, P < 10^{-4}$).

In order to understand hypolimnetic oxygen depletion associated with water physical dynamics, the data from the

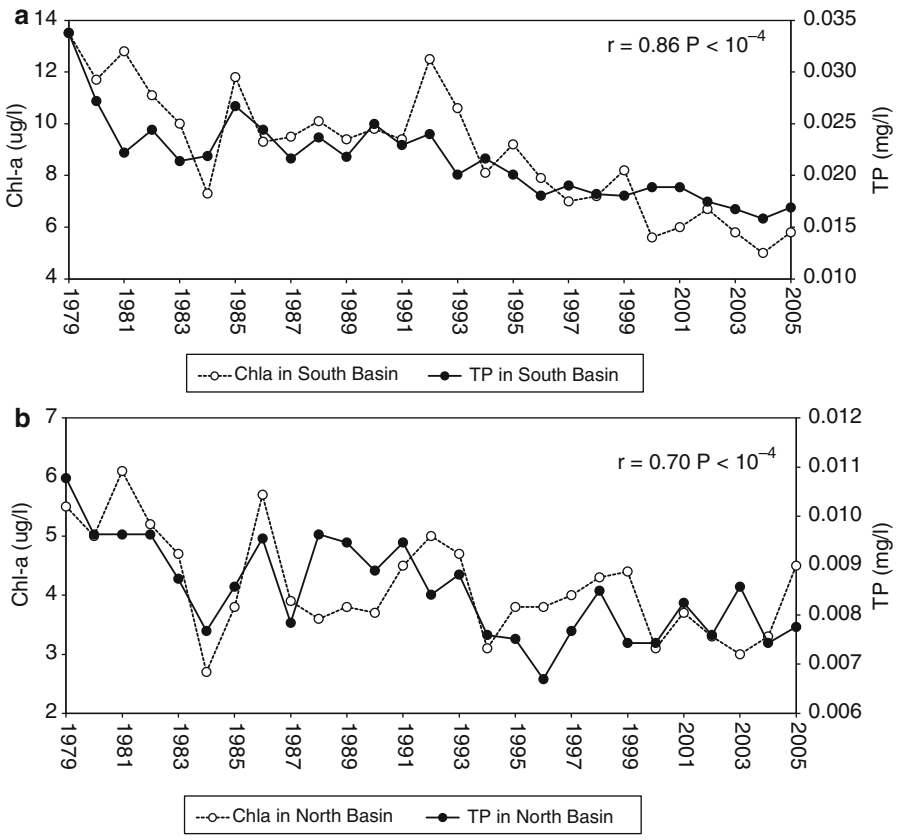

Fig. 2
Annually averaged chlorophyll-*a* (*white circles*) and averaged TP (*black circles*) in the south basin (a) and in the north basin (b) of Lake Biwa from 1979 to 2007, respectively.

three automatic digital thermometers and DO meters at depths over 90 m (*Fig. 1*) were used. The long-term variation of DO and water temperature can be seen by data's LOWESS (not shown here), and short-term fluctuation can be illustrated by the difference between raw data and their LOWESS (*Fig. 3*). At site N3, at a depth of 90 m at the north edge of the basin, the DO was positively correlated with water temperature ($r = 0.818$ $n = 2324$, $P < 10^{-6}$, *Fig. 3a*). A similar scenario was observed at site N5, at a depth of 90 m on the south edge of the 90 m depth basin, were the DO also positively correlated with water temperature ($r = 0.755$ $n = 2324$, $P < 10^{-6}$, *Fig. 3c*). However, at site N4, at 90 m depth in the middle of the basin, the correlation was much weaker (*Fig. 3b*).

Discussion

There has been great success in achieving a variety of water quality targets, notably chlorophyll and phosphorus, for the offshore lake waters of Lake Biwa (*Fig. 2*). Hypolimnetic hypoxia had been overcome for several years, but the severity of hypoxic events may actually have increased in recent years. The reappearance of these conditions is similar to the situation in Lake Erie, where a variety of water quality targets, including chlorophyll, phosphorus, and DO, have been met in the offshore waters (Charlton et al. 1999), but in recent years, hypolimnetic hypoxia has worsened (Charlton and Milne 2004).

In the central basin of Lake Erie, oxygen levels in the hypolimnion decrease to between 2 and 4 mg/l. Interannual variations are heavily influenced by the effects of water temperatures and thermocline depth on the hypolimnion thickness (Lam et al. 1987). A thin hypolimnion (2–6 m) results in strong DO depletion, strong interannual variation in late summer DO concentrations, and a heavy dependence on the sediment oxygen demand.

In the 90 m deep central basin of Lake Biwa, the DO concentration fluctuations were highly coherent with that of water temperatures, especially at the edge of the basin (*Fig. 3a, c*) (i.e., DO short-term fluctuations were directly dependent on the hydrodynamics of the lake). It is

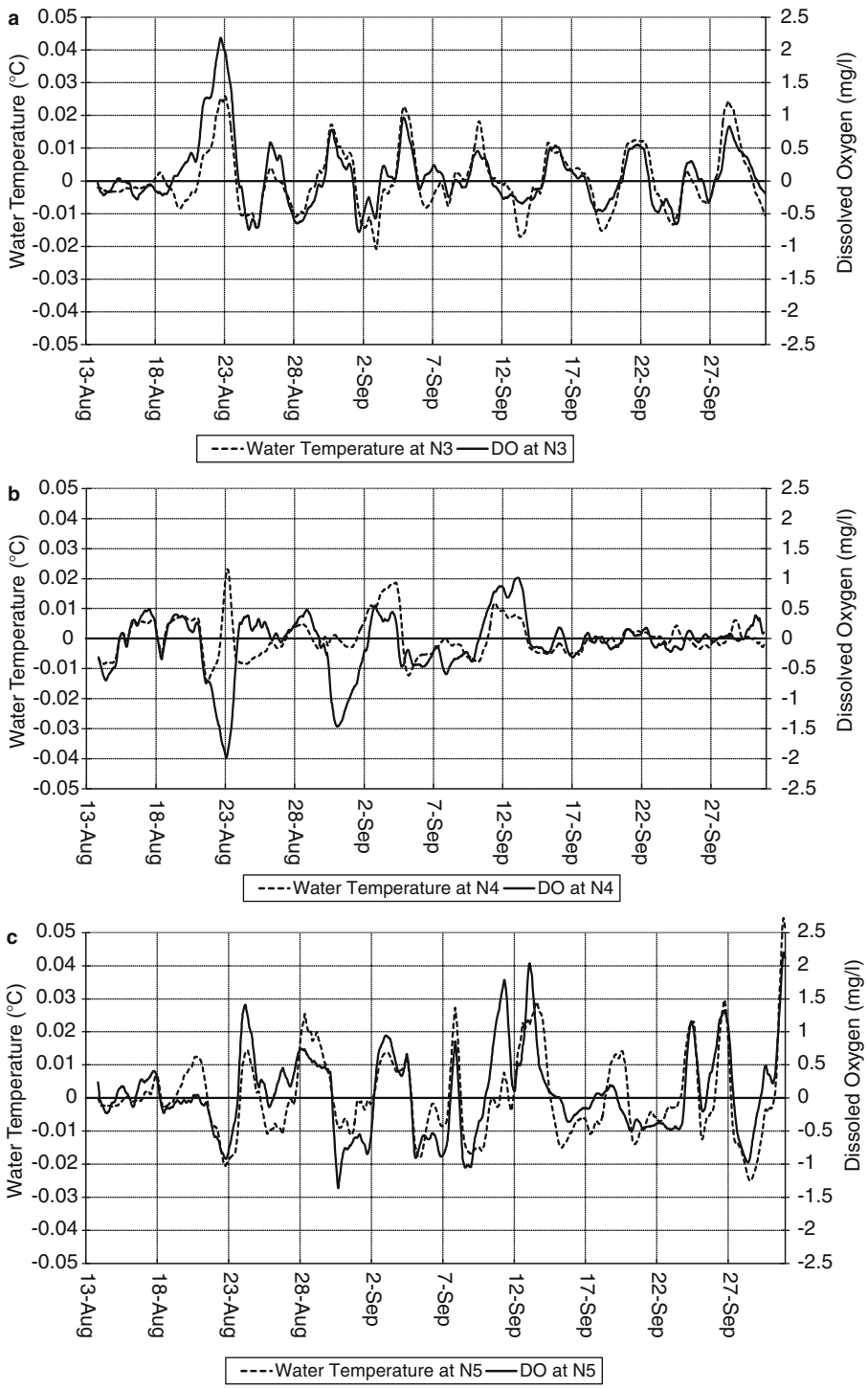

Fig. 3

Difference between raw data and its LOWESS, showing short-term fluctuations of dissolved oxygen concentrations (solid lines) and water temperatures (dashed lines) at N3 (a), N4 (b), and N5 (c) of the central basin of Lake Biwa, measured by three high-quality, automatic digital thermometers and DO meters.

interesting that DO short-term fluctuations in the middle of the central basin were not related with that of water temperatures so much (*Fig. 3b*), which implies that DO short-term fluctuations depend on lake bottom topography. Therefore, the late season oxygen minimum will be under physical control. Interannual variability in the hydrodynamics of the lake is a major driver in late summer oxygen conditions.

Charlton (1987) concluded that even a 50% productivity decrease would still leave Lake Erie with a problem, and Lam et al. (1987) estimated that hypoxia would persist for many years even if nutrient loading targets were fully met. These findings emphasized the importance of climate change.

Our observations and analyses provide a basis for further investigations of oxygen depletion characteristics in the 90 m depth central basin, and the causal mechanisms for interannual fluctuations of low DO in Lake Biwa.

Topic 10 Microbes as Indicator Species in Low Oxygen Environments

Kanako Ishikawa · Seiko Furuta · Takuo Nakajima

Microbes differ from each other in terms of requirement for, and resistance to, oxygen. Therefore, the composition of flora in a given habitat is affected by any change in oxygen content. The habitat of sulfur- and manganese-oxidizing bacteria is an aerobic/anaerobic interface in natural environments. Such bacteria oxidize inorganic compounds reduced in an anoxic zone, with oxygen and/or nitrate.

Recently, the existence and heavy growth of a filamentous sulfur-oxidizing bacteria, *Thioploca*, and deposits of manganese oxides, *Metallogenium*-like particles, have been found in the bottom sediment of the hypolimnion (the lower layer of water) of Lake Biwa. These bacteria can be used as an index for low oxygen conditions because of their niche and their conspicuous and easily determinable morphological characteristics under a microscope.

Filamentous Sulfur-Oxidizing Bacteria, *Thioploca*

Viscid filaments seemed to cover fishing equipment in the late 1980s, and dense mats of *Thioploca* spp. (*Fig. 1*; filamentous, gliding, sulfur-oxidizing bacteria) were first found on sediments in the deep water area (water depth: 90 m) of Lake Biwa in 1991. Similar occurrences had already been observed in eutrophic to oligotrophic freshwater lakes (e.g., Lake Constance, on the German-Swiss-Austrian border; Lake Erie, United States; and Lake Baikal, Russia) in other parts of the world (Nishino et al. 1998). The main species of *Thioploca* spp. in Lake Biwa was identified by morphological microscopic observation as *Thioploca inglica*. Phylogenetically, the strain in Lake Biwa showed very few mismatches in the 16 S rRNA sequence as compared to *T. inglica* from Lake Constance, and brackish Randers Fjord, Denmark (Kojima et al. 2003). The ecology of freshwater *Thioploca* species is not well known since they are viable but non-culturable (VNC) bacteria. However, some information is available from mats of marine *Thioploca* species that underline the oxygen minimum zone (<5 μM O_2, i.e., <2% air saturation) in the upwelling region on the Chilean shelf near Concepcion (Fossing et al. 1995), which was considered to also indicate H_2S and low oxygen conditions.

Monthly monitoring in the 90 m depth area of Lake Biwa was carried out between 1997 and 2000. The biomass was homogeneous at an average of 10^6 μm/cm^3 of sediment in the deep area and did not linearly correspond with the oxygen concentrations and temperatures of the bottom water. Oxygen concentrations have fluctuated, but their cumulate depletion has become increasingly severe over the last 10 years. The biomass of *Thioploca* spp. decreased significantly to the level of 10^5 μm/cm^3 of sediment in the 0–2 and 2–5 cm layers of a sediment core taken in the 90 m depth area in 2007 (*Fig. 2*), which may suggest that the oxygen level has gone below the suitable level for microaerophiles such as *Thioploca* spp.

Metallogenium-like Particles

The appearance of *Metallogenium*-like particles (*Fig. 3*) at the center of the south basin of Lake Biwa was reported for the first time in 1992 by Miyajima (1992a, b). Later, in November 2002, *Metallogenium*-like particles (1,360 pieces/ml) were observed at the center of the north basin of Lake Biwa (off Imazu; water depth, about 90 m). Since then, they were observed every consecutive year, from summer to autumn between 2004 and 2009 in the north basin (off Imazu; water depth, about 90 m) (*Fig. 4*). These *Metallogenium*-like particles were found in the micro anoxic bottom layers during the periods when the lake was thermally stratified, and their occurrence has been connected to the reduction of dissolved oxygen (*Fig. 4*).

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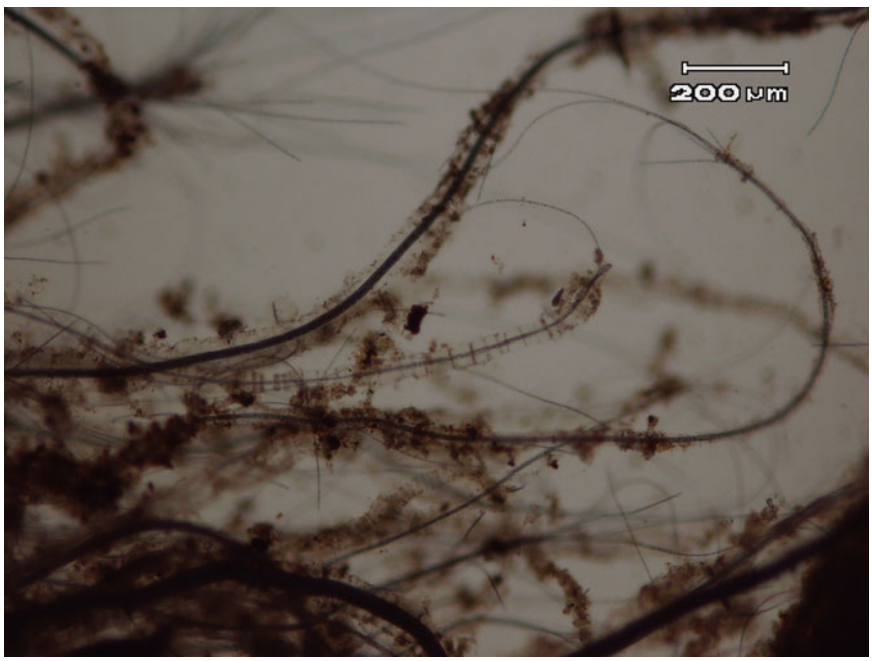


Fig. 1
Filaments of *Thioploca* spp. from Lake Biwa. The diameter of individual trichomes was 3–5.6 mm; the length was from 18 to 75 mm (Kojima et al. 2003).

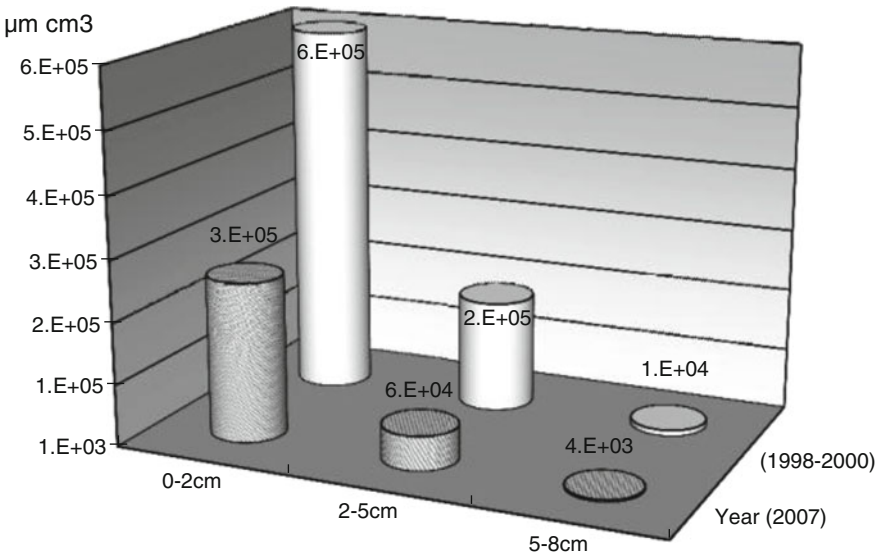


Fig. 2
The biomass of *Thioploca* spp. in Lake Biwa in the 90 m depth area.

Metallogenium-like particles are blackish brown and trichospherical structure particles of manganese oxide, of sizes usually 20–40 µm, but in similar cases, 10 µm small *Metallogenium*-like particles may exist (Furuta 2007). *Metallogenium*-like particles are blackish brown and trichospherical structure particles of manganese oxide. *Metallogenium*-like particles sizes are usually 20–40 µm. But *Metallogenium*-like particles sizes are 10 µm according to the site of incidence and the occurrence time (Furuta et al. 2007).

Besides Lake Biwa, *Metallogenium*-like particles were also found in Lake Yogo (located just to the north of Lake Biwa). Additionally, there have been many reports of *Metallogenium*-like particles in other places, such as in

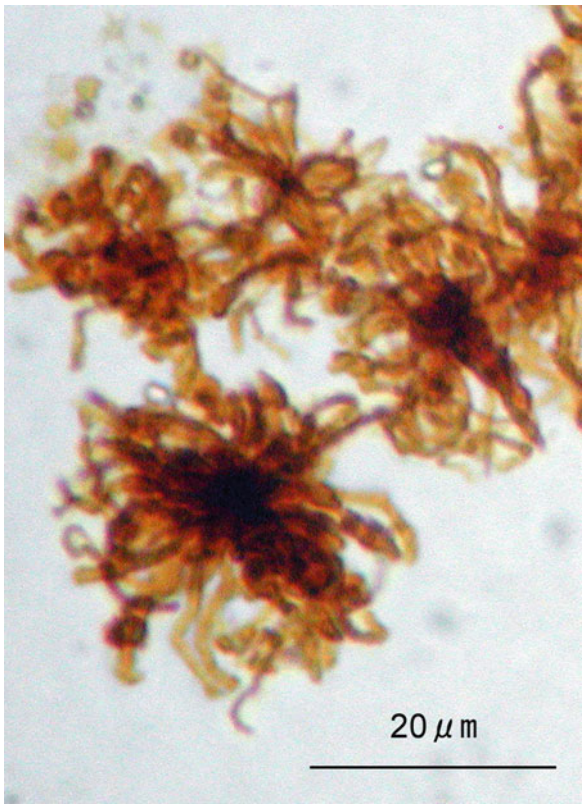
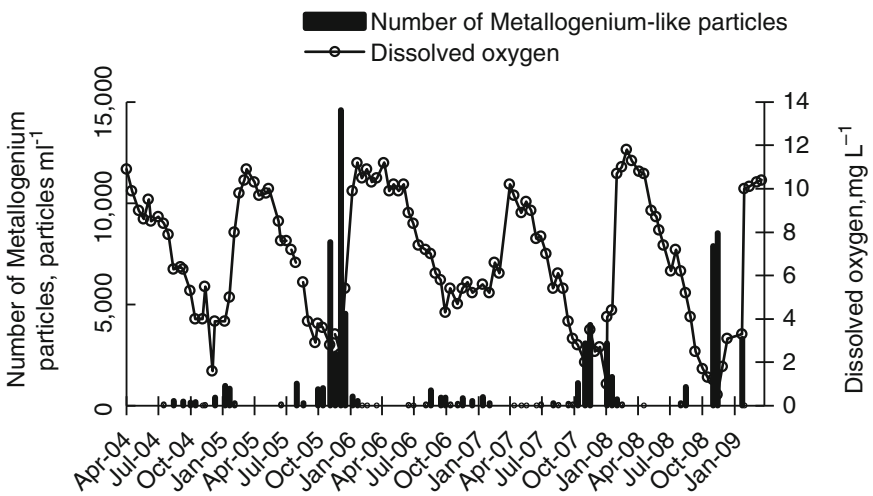


Fig. 3
A light micrograph of naturally occurring *Metallogenium*-like particles collected on October 6, 2008 from Lake Biwa.

Lake Washington (United States), Lake Geneva (France and Switzerland), the Baltic Sea, and others.

Though *Metallogenium*-like particles are produced by biological manganese oxidation, the process of production is still not well known (Nealson 2007). Physical and chemical forms of manganese existing in lake water are severely affected by ambient redox conditions, and *Metallogenium*-like particles are oxidized in the condensation precipitation process. *Metallogenium*-like particles are not interpretable.

Fig. 4
Number of *Metallogenium*-like particles and dissolved oxygen at the central point of Lake Biwa, off Imazu; water depth, about 90 m.



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4 History of the Relationship between People and Lake Biwa

Masaharu Yoda

Several knife-shaped stone implements typical of the late Paleolithic period have been recovered from the bottom and shores of Lake Biwa, indicating that humans were in the area during this period, approximately 20,000 years ago. From the early Jomon Period, the neopaleolithic period of the Japanese Islands that started approximately 15,000 years ago, there is evidence that people had further colonized the areas around the lake. Such evidence includes the discovery of more than 30 Jomon dugout canoes (*maruki-bune*), the largest number discovered in Japan, along with the existence of over 100 underwater sites, including the world's largest freshwater shell-mound, the Awazu shell-mound. This reveals that humans have thrived around the lake since ancient times.

Lake Biwa and its surrounding basin-shaped landform, namely, the water catchment area of the Lake Biwa system, is approximately as large as the former Omi Province, which is the present-day Shiga Prefecture. Hence, the lives of the local residents of Shiga Prefecture have been closely tied with the Lake Biwa watershed throughout history.

This chapter will provide an overview of the relationship between humans and Lake Biwa from several different perspectives through three time periods—the period of coexistence, utilization, and exploitation.

The period of coexistence refers to the stage before the formation of the ancient state that occurred in approximately the seventh century, when Lake Biwa was mainly utilized for people's daily activities.

The period of utilization refers to the time following the ancient state formation to the end of the Edo Period, during which the lake mainly functioned as a transport route, managed and controlled by pre-modern political powers.

Finally, the period of exploitation refers to modernization, including the industrial use of water resources and tourism following the Meiji Restoration in the late nineteenth century until today.

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4.1 Period of Coexistence

Masaharu Yoda

Several Paleolithic stone implements have been discovered at the bottom of Lake Biwa and on the riverbed of its outlet, the Seta River; and this reveals that people started establishing villages on the shores of the lake since the beginning of the Jomon Period. Some of archeological sites found in the Lake Biwa area, in particular the Awazu shell-mound of the middle Jomon Period (about 5,000 years ago), the Shigasato site of the late Jomon Period (about 3,000 years ago) and the farming villages found at the Dainakanoko-minami site of the middle Yayoi Period (about 2,100 years ago), are important at revealing the history of the Japanese Archipelago.

In addition, some ceremonies that began in ancient times around the lake were continued for long periods. The Tsuzuraozaki underwater remains at the northern end of the lake provide evidence of ceremonies using pottery that continued from the beginning of the Jomon Period (about 6,000 years ago) to the Kamakura Period (about 800 years ago).

During the Kofun Period, which began in the third century, ancient tombs that were primarily large sized keyhole-shaped tombs (*kofun*) were constructed facing major ports of Lake Biwa. While water transportation began to be managed by powerful families under the royal authority of the Yamato Regime, not many significant changes were brought into the people's livelihoods on the shores. The continuous use of dugout canoes, starting in the early Jomon Period (about 6,000 years ago) until the middle Yayoi Period (about 2,000 years ago), is an example of how people's lives were closely linked with the water environment.

Lake Biwa was the gateway and transport route connecting with the Sea of Japan transport routes departing from mainland China and the Korean Peninsula toward the center of Yamato, and also it was an important crossroads for transportation within Japan. The areas around Lake Biwa and the Seta River often became the arena of wars, such as the Jinshin Disturbance (a succession dispute following the death of Emperor Tenji) that broke out on the night before the ancient state formation in 672. At the end of the Kofun Period, during the seventh century, and while the spread of ancient Buddhism and establishment of the Ritsuryo system (a centralized political system based on law) were in progress, the capital was transferred to Otsu on the shore of Lake Biwa in 667. This was due to the changing situation in East Asia including mainland China and the Korean Peninsula, and from then on a full-scale ancient state started to form. The capital transfer to the inland located Otsu was a preparation against the invasion via the Seto Inland Sea lane by forces from mainland China and the Korean Peninsula, and it was intended to take advantage of Lake Biwa and Seta River for establishing the first national level defense system.

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4.1.1 Life in the Jomon and Yayoi Periods

Fumio Ueda

Abstract During the Jomon Period, people actively conducted fishing, hunting, and plant gathering in swamps along the shores of Lake Biwa; and they migrated from one place to another in response to the availability of food. Then, they gradually advanced to alluvial plains along the rivers, and they developed the ability to settle in one place due to the advancement of food storing technology. Wet-paddy rice cultivation was later introduced, and it served as the foundation of Yayoi communities, which developed in the swamps near Lake Biwa shores or attached lakes. However, as population growth and community expansion gradually progressed, people started opening up the alluvial plains along the major rivers and moderate uplands. In each basin, a main community led by a chief emerged. These communities were highly skilled with production of metallurgy and farming tools, and such technologies were introduced from mainland China and the Korean Peninsula. Japan entered into the Kofun Period, as the rulers of waterside areas started building square mound burials and larger-scale burials called *zenpokohofun*. Water transportation on Lake Biwa, its attached lakes, and associated rivers played an indispensable role in post-Yayoi history.

Keywords Freshwater shell mound • Continental culture • Wet-paddy rice cultivation • *Zenpokohofun*

Jomon Waterside People

More than 100 archaeological sites have been discovered at the bottom of Lake Biwa that date from the early Jomon Period (7,000 BC) onward, corresponding to the early Neolithic era. Over 150 pieces of Jomon pottery have been recovered by fishermen in nets hauled from the bottom of the lake at a depth of 70 m at Tsuzuraozaki in Nagahama City. Shell mounds were formed by accumulation of food waste, which also served as the dumping-ground for daily utensils. In this article, the early Jomon people living around Lake Biwa are introduced based on the information obtained by excavations, and then the community along the river plains in the late Jomon Period are described to provide an overview of the local lifestyles in the Neolithic age.

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Awazu Lake Site (7,500 BC)

When the Lake Biwa line of the Japan Railway Co. crosses the bridge over the Seta River in Otsu, the lake comes into view on the north side. It is here that the Awazu shell mound site is located, now submerged below the surface of the water (*Fig. 1*). This freshwater shell mound covers an area of 100 × 70 m, which falls into the largest class in Japan, a size that is also rarely seen worldwide. The site was investigated in detail by enclosing it with iron sheets and pumping the water out, forming a cofferdam. As a result, a mound consisting of an accumulation of chestnut shells, dating back to the beginning of the early Jomon Period (7,500 BC), and a clam shell mound (the third shell mound of Awazu), dating back to the beginning of the middle Jomon Period (3,000 BC), were excavated.

The chestnut mound was found in a gravel layer at a water depth of 3 m, where once a river with a width of 15 m flowed. The mound was 0.5 m thick and covered an area of 7 × 5 m. Besides pieces of pottery, there were stone implements, such as spear-heads and hammers, and a large amount of plant remains, such as basket-shaped weaving, pointed wooden tools, carved wood, ropes, and gimp found in the mound. Food remains, including calabash, green bean species, and walnuts, were also excavated. The calabash remains were found underneath the mound, and were among the oldest in Japan. Since calabash plants did not grow naturally in Japan, it was highly possible that they were brought here and cultivated.

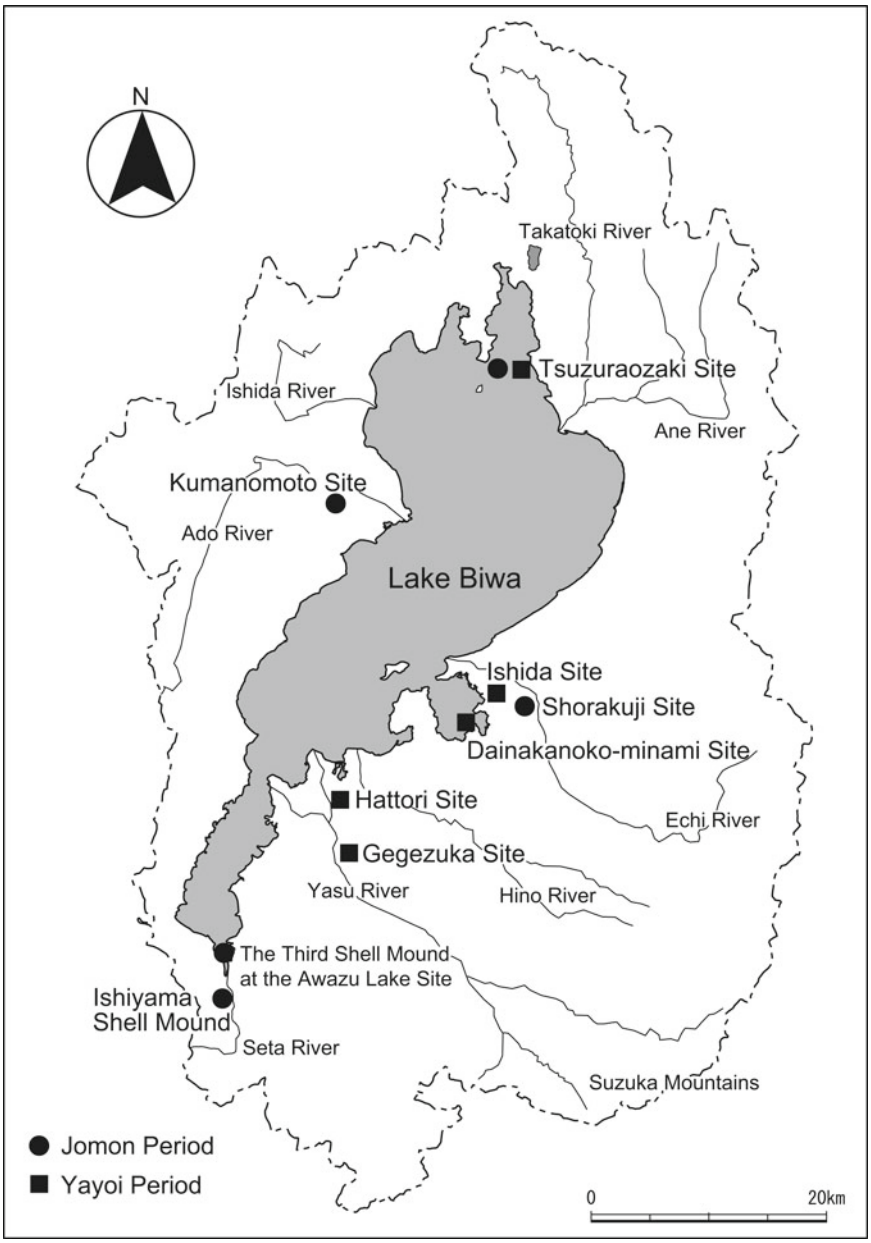

Fig. 1
Archaeological sites of the Jomon and Yayoi periods around Lake Biwa.

Ishiyama Shell Mound (6,000 BC)

The Ishiyama shell mound is located on the west bank of the Seta River in Otsu, near the southern edge of the Awazu shell mound (*Fig. 1*). The *Seta-shijimi* clam (*Corbicula sandai*) accounted for 79% of the entire species found here, *nagatanishi* (a species of freshwater snail) for 12%, and Pleuroceridae species for the rest. Fishes, such as *koi* (carp, *Cyprinus carpio*) and *funa* (crucian carp, *Carassius* spp.); reptiles, such as soft-shelled turtles, and pond turtles; birds, including pheasants; and bones of mammals such as Japanese monkeys, deer, boars, wild rabbits, bears, and raccoons, were also discovered. Animal bones were found with even the bone marrow sucked out. Among the artifacts

discovered, there were stone implements such as axes, arrowheads, knives, and grinding stones.

A unique feature of Ishiyama shell mound is that the bone tools and accessories made of deer horns, animal bones, or shells. These include ornamented hairpins made of bone with detailed carvings, hexagonal-shaped pendants made of deer horn, and necklaces made of bear fangs with a through-hole in each. There were also necklaces with small beads made with slices of snail shells and white bracelets made by hollowing out bivalve shells. Since these bivalves came from a warm part of the ocean, it seems like the local residents were in contact with people who lived by the sea.

The Third Shell Mound at the Awazu Lake Site (3,000 BC)

The third shell mound was found north of the chestnut mound, mentioned above, at approximately the same depth below the water surface (*Fig. 1*). It was crescent shaped, measuring 35 m from north to south and 15 m from east to west, and with a thickness of 0.5 m. Approximately 170 layers of plants were discovered, as well as layers of clams, such as the *seta-shijimi* clam, pebbles, and plant remains, such as acorns. The *seta-shijimi* clam again accounted for the majority, forming 78% of the entire number of shells found at the Awazu shell mound. Edible snails, such as *kawanina* (*Semisulcospira libertina*) and *tanishi* (Viviparidae), were the next most abundant shells. The *seta-shijimi* clams found here were over 3 cm in size, which is bigger than those seen today. Analysis of their growth curves indicate that *seta-shijimi* fishing took place during the summer period between July and September.

As for the fishes found here, species of the carp family such as *funa*, *koi*, *ugui* (Japanese dace, *Tribolodon hakonensis*) and *moroko* (willow minnow, *Gnathopogon caerulescens*), which are still inhabitants of the lake today, accounted for 61% of all and *funa* alone for 37%. *Gigi* (forktail bullhead, *Pelteobagrus nudiceps*), *namazu* (Far Eastern catfish, *Silurus asotus*), and *ayu* (Biwa-ayu, *Plecoglossus altivelis* sbsp.) followed them in number. Fish species found are almost the same as seen in Lake Biwa today. As an exception, pharyngeal tooth remains of the xenocypridine fishes were also identified, contrary to the belief that they have gone extinct 400,000 years before.

While the bones of amphibians and reptiles include frogs, snakes, and hard- and soft-shelled turtles were found, most of them belonged to soft-shelled turtles, which were enough to make up 48 individuals. Birds were probably not consumed often since only a few of them, such as pheasant and swan, were found.

Mammals' remains were from Japanese monkeys, wild rabbits, wolves, raccoons, dogs, black bears, otters, boars, Japanese deer, and serows. When not counting the fishes, boar accounted for 32% of the vertebrate remains, soft-shell turtle for 17%, and deer for 8%. We can tell that some of today's luxury foodstuffs were commonly eaten at that time.

Plant remains consisted of three types—oaks accounted for 40% as well as horse chestnut (*Aesculus turbinata*) and freshwater chestnut (*Trapa japonica*) accounted for about 30% each. Among the types of acorns, the acorns of *Quercus gilva* (an oak species), which are edible without astringency removal treatment, were found in large volumes, from which we can guess that *Quercus gilva* forests were abundant at that time. Few chestnuts (*Castanea crenata*) were found here. During the 4,000 years from the early to middle Jomon Period, oak forests seem to have replaced chestnut forests as the climate gradually warmed. Fruits such as bayberry and porcelain berry were also consumed. Water chestnuts, an aquatic plant, are still frequently seen today in the area, including attached lakes of Lake Biwa. In general, acorns were the main staple of Jomon people, but the fact that water chestnut accounted for 30% of the food plant remains shows that the acquisition of food was inseparable from the lakeside environment.

Artifacts found include pieces of pottery, stone implements, clay figures, and accessories. A large number of grinding stones and stone plates (saddle querns) for the cooking of acorns were excavated as well as stone implements such arrowheads, knives, and fishing net sinkers. Bone tools found included spears, hooks, and curved pendants, while bracelets made of oyster shells and necklaces made by piercing a hole in a clam shell were also recovered. Rarely, pearls, amber, lacquered wooden bangles, ornamental combs, and walnut pendants were found. An ornamental comb coated with red lacquer was the second oldest found in Japan. Products such as woven baskets were also discovered.

Evidence that would indicate the presence of settled communities, such as house remains, has not been found from the beginning to the middle of the Jomon Period, although traces of affluent lifestyles are seen at Lake Biwa and in swamps along its associated rivers. Therefore, it can be considered that people still migrated from one place to another depending on the availability of food instead of forming permanent settlements during this stage of history.

Shorakuji Site (2000 BC)

The Shorakuji site is located slightly inland in an alluvial area along the Echi River in Higashi-Omi City (*Fig. 1*). It is about 96 m above sea level and approximately 12 m above the water level of Lake Biwa. Traces of communities with a zonal distribution are present along the 30 m wide river. Jomon communities in eastern Japan had a circular arrangement enclosing an open space, while a belt-like distribution of communities characterizes those found in western Japan. Remains of a pit house, pillar-supported structure, acorn-storing hole, stone workshop, public space, and wood circle (standing timber columns arranged in a circle) were discovered. In addition, a large amount of Jomon pottery, clay masks, earrings, ornamental combs, and buried human bones were excavated from the river.

The diet of the Jomon people living on the Japanese archipelago is characterized by the consumption of wild plants. Acorns that ripen in autumn were the best food because they could be stored, providing a secure food source all year round. In other words, the eating and storing of acorns revolutionized the lifestyle of the Jomon people. The total number of acorn storing holes found here numbers 130, and each of the oval-shaped holes was filled with grinding stones and stone plates. The holes were about 1 m in diameter, 0.5 m in depth, and in most cases they had a flat bottom.

A total of 41 stone arrowheads were also excavated from this site. In the remains of three stone workshops discovered nearby, 16 arrowheads were found together with the waste of their raw material, sanukite that originated from Mt. Nijo, today located on the border between Nara and Osaka.

Stone implements consisted of grinding stones, stone plates, and hammers. Grinding stones were made by grinding down granites or sandstones from the Suzuka Mountains (*Fig. 1*). There were different types of stone hammers; some used for making stone tools, while others were for cracking nut shells such as walnuts. A total of 107 stone plates were excavated. Chipped stone axes for digging out roots of starch-rich plants were also discovered. This shows that plant roots were an important food source besides acorns at that time. Other than those, 19 stone axes were found, which were used for the cutting and processing of trees. Since their sizes vary, it seems that these were used separately depending on the purpose and stage of processing.

Several pieces of accessories were found, including a pendant made from deep green nephrite stone, in the shape of an inverted trapezoid measuring 2.8 × 2.9 cm. Two holes were made on the top of the pendant to string it around the neck. It originally had a shape of an inverted triangle, but it was modified into an inverted trapezoid when the tip was fractured. A similar piece to this was a pendant made by piercing a hole through a shark tooth, and the nephrite pendant is considered as an imitation of the shark tooth pendant. Nephrite was obtained from the same vein as a highly valued jade in the Hime River in Niigata Prefecture. In addition, two pieces of ornamental combs for women to bind their hair were excavated. These combs had teeth made of bunches of thinned plant branches, and their surfaces were covered with red lacquer.

Among the unearthed articles, a clay mask is particularly notable. The upper one-third of the original mask is intact, revealing part of the right and left eyes, eyebrows and left ear with a stringing hole. When restored, the mask has a near round shape with a diameter of about 20 cm. It is about 1 cm thick with the center part slightly curved, and it is actually wearable on the face. The eyebrows and nose were drawn by sticking clay strings on the mask, and elliptical holes were made for portraying the eyes. The eyebrows are raised with a severe knitted expression, and stringing holes were made on the ears. There is a trace of red paint on the forehead, which suggests that it was originally colored.

In an open space near these excavation sites, six pillar holes making a circle with a diameter of 6 m were discovered, the remains of a wooden circle. Traces of bonfires in the center of the circle indicate that it is the remains of a ritual pillar site. Similar remains have been widely reported all over the northern hemisphere from the Neolithic to the modern era (e.g., totem pole, etc.), and which are considered to represent a universal spiritual culture of modern humans (Ueda 2008). Therefore, the discovery of these highly diverse traces of life confirmed the beginnings of human settlements.

In the Jomon Period around Lake Biwa from 7,000 to 2,500 BC, fishing, hunting and gathering were actively conducted in lakeside swamps. People lived nomadically depending on the availability of food. When people advanced to the alluvial plains along the rivers in 2,000 BC, settlement was enabled with the development of food storing technology. Priests emerged to control the regularly held religious services utilizing clay masks and wooden circles. Furthermore, the formation of communities on alluvial plains along the major rivers led to another food innovation in the coming era, the adoption of wet-paddy rice cultivation (Ueda 2000).

Continental Culture and Development of Yayoi Society

Wet-paddy rice cultivation spread from Southeast Asia to Japan. It originally started in the mid- and downstream basins of the Chang Jiang River in China. This area had a warm and humid monsoon climate, and it formed a cultural zone equivalent to the wheat-growing areas that spread from West Asia. It also coincided with the region where people wrote with Chinese characters and ate with chopsticks.

The landscapes around Lake Biwa are ideal for wet-paddy rice cultivation. The major rivers flowing into the lake formed alluvial plains, and the intricate creek system developed in the low-lying areas was beneficial for irrigation. Yayoi communities evolved in areas along such rivers. Particularly, large communities were established in the drainage areas of the Takatoki and Ane Rivers north of the lake, the Echi and Hino Rivers in the east, the Yasu River in the south, and Ado and Ishida Rivers in the west (*Fig. 1*).

The Yayoi communities around Lake Biwa originated about 500 BC as small groups living adjacent to estuaries and attached lake areas 83–84 m above sea level. However, development of large-scaled paddy fields and water channels had not yet started at that time. Wet-rice cultivation seems to have been a supplement for the life infrastructure of the Jomon Period.

Large-scale paddy fields and water channels were developed around 300 BC, evidenced by the Hattori site, located in an alluvial area along the Yasu River in Moriyama City, and the Dainakanoko-minami site, an alluvial area along the Echi River in Omihachiman City (*Figs. 1* and *2*). At the Hattori site, about 260 patches of wet paddies with an average area of 72 m^2 were discovered over an area of 18,700 m^2. At the Dainakanoko-minami site, paddy fields and water channels were bordered with wooden stakes and boards, and each patch was large, with an area of 9,200 m^2. Since the Hattori site was located on a moderate incline, the paddy fields were divided into small patches. On the other hand, at the Dainakanoko-minami site, large patches of paddy fields were developed on a flat landscape, indicating that the technology was already highly developed in the early stage of the adoption of rice cultivation. This is also evidenced by a large number of wooden farming tools in various shapes discovered from the area.

The adoption and development of wet-paddy rice cultivation promoted the formation of settled communities. At the same time, labor-intensive agriculture allowed for the emergence of distinctive leaders. The centripetal force of the leaders was characterized by the construction of large-scaled tombs consisting of a square structure surrounded by a ditch (*hokeishukobo*). The performance of agricultural rituals to pray for good harvests was also used for maintaining a centripetal force. Wooden figurines found at the Dainakanoko-minami site and the Yunobe site in Yasu City

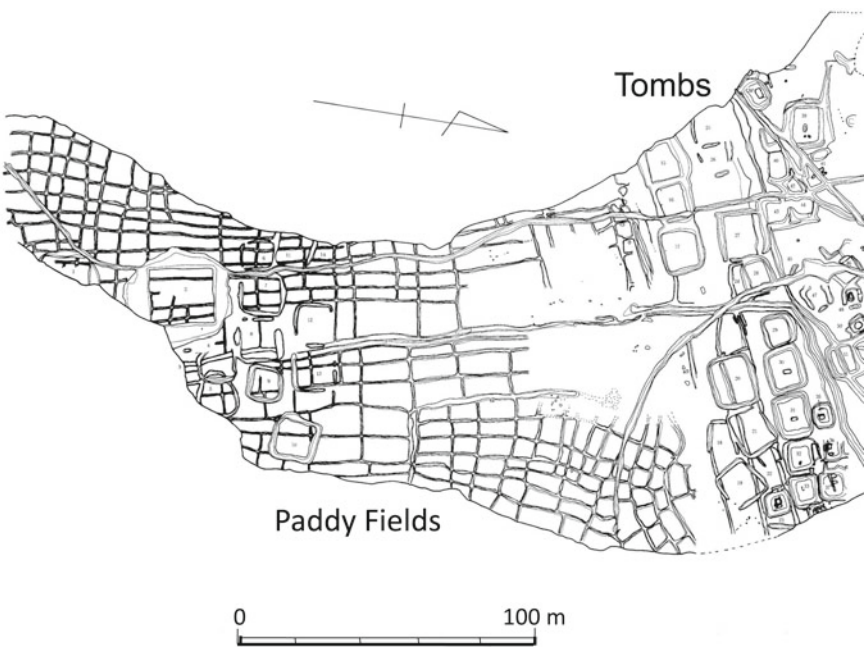

Fig. 2
Paddy fields of the Hattori site.

are considered to have been used to portray ancestral spirits, the rice spirits. These were religious tools unique to the Yayoi people who lived around Lake Biwa.

Organization based on wet-paddy rice cultivation continued to grow, resulting in an increase in population. The demand for new lands for residence and production consequently initiated the exploitation of the moderate upland areas 90–100 m above sea level. Thereafter, a community that plays a leading role in each basin unit, or a powerful community with a leader started to develop. For example, at the Ishida site in Higashi-Omi City (*Fig. 1*), traces of *kango* communities dating back to 100–200 AD were discovered. This type of community was surrounded by a ditch for irrigation, or defense against enemies. The Ishida site was 250 m from north to south and 250 m from east to west. Crude plows and hoes were found soaked in water (to soften the wood for ease of processing) within the surrounding ditch. This reveals another aspect of water usage that was closely related to people's life other than defense. Instead of the pit houses commonly seen since the Jomon Period, the remains of high-floored, pillar-supported structures were discovered. This was possibly the only building type at the Ishida site, which was very similar to those of an early stage farming community at the Kaboto site in Zhejiang Province, China.

An L-shaped tuyere (bellows opening) about 32 cm long with a tip diameter of 3 cm and a base diameter of 5.5 cm was unearthed in near-perfect condition, and is evidence of bronze casting, a very advanced technology at that time. The tip is tarnished by heat, and adhesion of copper residue is seen on its inner surface. A lump of bronze residue about 3 cm in diameter was also excavated nearby. Bronze residues form because of high-heat foaming generated when the copper melted at high temperature touches the inner surface of a clay container. Ingredients of bronze (copper, tin, and zinc) were detected in the excavated residue by fluorescent x-ray analysis.

Part of a mold was also discovered at the Ishida site. Molds in a similar shape to this were also excavated at the Gegezuka site in Yasu, and the Hattori site in Moriyama. Both sites are located in the Yasu river basin near Mt. Oiwa, where 24 bronze bell-shaped vessels, which played an important role in religious services during the Yayoi Period, were excavated. Besides producing small items like arrowheads, the casting of large items such as bronze bell-shaped vessels was possible by joining molds together.

Besides bronze, development of highly skilled communities capable of processing iron in the Lake Biwa area around 100 AD are evidenced at the Kumanomoto site in Takashima City (*Fig. 1*). Bronze technology was brought to the shores of Lake Biwa from Kyushu via the Seto Inland Sea and Yodo River, while iron technology arrived directly from the Sea of Japan across the mountains. Both are considered as continental cultures from mainland China. The rulers of waterside areas who held control over these advanced technologies started to construct large-scaled squared keyhole-shaped tombs in a unique orientation of two conjoined rectangles (*zenpokohofun*), as Japan entered into the Kofun Period (Ueda 2007).

The adoption and development of wet-paddy rice cultivation in lakeshore swamps in the early Yayoi Period, and the metallurgical technologies acquired by the powerfully grown local chiefs in the late Yayoi Period were historical achievements brought about by the presence of Lake Biwa, its attached lakes and associated rivers.

4.1.2 Technologies and Roles of Ancient Watercrafts on Lake Biwa

Yozo Yokota

Abstract Watercrafts played a crucial role in the establishment of transportation routes in the Lake Biwa area, starting with *maruki-bune* (dugout canoes) during the Jomon Period. As Lake Biwa became part of the major transportation route connecting the Kinai area (the capital area) to eastern Japan, Lake Biwa watercrafts were faced with a demand for increased carrying capacity to distribute goods, and this played an important role in the boat-building history of Japan.

Keywords *Maruki-bune* [dugout canoes] • Semi-built-up boats

Dugout Canoes (*maruki-bune*) of the Jomon Period (14, 000–900 BC)

Based on the currently available evidence, the use of watercrafts on Lake Biwa started as early as the Jomon Period. The trunks of conifers, such as *Cryptomeria japonica*, *Chamaecyparis obtusa*, and *Abies firma*, were hollowed out to make dugout canoes, which ranged in length from 5 to 7 m, and in width from 50 to 60 cm, with a carrying capacity of 1–3 people. The size and shape of a dugout canoe were determined by the trees available. However, a dugout canoe over 1 m in width has not been discovered so far despite the presence of trees large enough to make such large-sized canoes, indicating that there might have been certain limitations in timber processing with stone tools at that time. Dugout canoes were later adopted as the bases of more advanced boats, many of which were over 1.5 m in width. This indicates that trunks with a diameter over 1 m were commonly available. Thus, the size and shape of a boat were not necessarily determined by the trees available, but rather determined by its use and purpose.

Approximately 30 dugout canoes have been discovered at various sites along the shores of Lake Biwa, the majority of which were from sites facing attached lakes, rather than those facing the main lake. Therefore, dugout canoes are considered to have been used for fishing, gathering, and transportation near the shore (*Fig. 1*).

Trials of a Dugout Canoe

Among the discovered dugout canoes, the one found at the Onoehama site in Nagahama City was in a good state of preservation. Utilizing it as a model, a dugout canoe was reconstructed to carry out a trial. The reconstruction has a length of 5.5 m, a width of 50 cm, and a depth of 30 cm, and can be operated by one person, but can stably carry up to 3 people.

The purpose of this trial was to examine the seaworthiness of a dugout canoe, and how far it might go on the broad water surface of Lake Biwa. A route about 5 km long was chosen, from Onoe, near the location of where the original dugout canoe was found, to the island of Chikubushima, located at the northern end of the lake. When traveling east–west from Onoe to the opposite shores of Lake Biwa, the island is located at one-third of the distance. Such a route passes near the Tsuzuraozaki site, which is famous for the occurrence of pottery, dating from the Jomon Period to medieval times, on the lake bottom at depths up to 70 m. Another purpose of this trial was to examine whether the formation of the Tsuzuraozaki site could be attributed to the waterborne commerce that began during the Jomon Period.

The trial was conducted under the assumption that crossing the lake by dugout canoe is not impossible, but risky and not practical since it could capsize repeatedly. Therefore, escort boats and spare paddlers were prepared. However, contrary to expectations, the canoe, propelled by two paddlers, ran smoothly to reach the island of Chikubushima in

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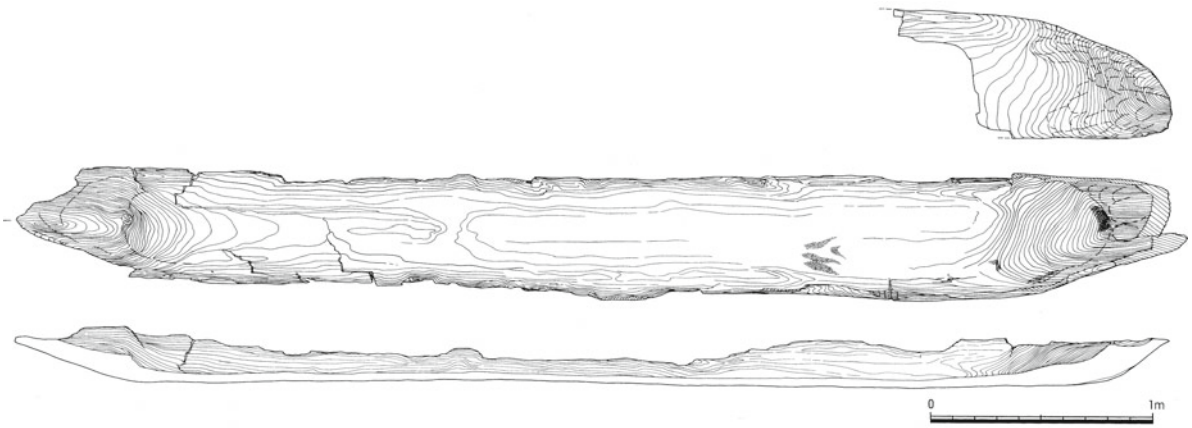

Fig. 1
A *maruki-bune* excavated from the Onoehama site dating to the Jomon Period (this was made by hollowing out a fir trunk, and represents the general size and shape of *maruki-bune* discovered on the shores of Lake Biwa).

two hours, without capsizing, replacing the paddlers, or the need for the paddlers to take any breaks.

Thus, it was proved that crossing the lake by dugout canoe is not adventurous, and can be done on a daily basis in calm weather. This suggests that waterborne transportation could have been well-established in the Jomon Period with the use of dugout canoes. However, an important thing to note is that most of the excavated canoes are small and would have been operated by one person, rather than larger canoes that would require a group of people to operate them.

Emergence of Semi-built-up Boats

"Semi-built-up boats" are those that are constructed by adding elements such as washstrakes (wooden planks attached along the length of a boat to stop waves swamping it) to a dugout canoe to enhance performance. The emergence of semi-built-up boats dates to the Yayoi Period (900 BC–250 AD), which dramatically increased the flexibility in boat design.

Around Lake Biwa, semi-built-up boat remains have been discovered at the Irie-naiko site in Maibara City, the Matsubara-naiko site in Hikone City, the Ishida site in Higashi-Omi City, the Demachi site in Omihachiman City, and the Shimonaga and Akanoihama sites in Moriyama City. A bow found at the Akanoihama site dates to the early Yayoi Period, which is the oldest semi-built-up boat related find in Japan.

Semi-built-up boats are roughly categorized into two groups based on their structure—the "end-plank type" and the "through-beam type." Most of the unearthed remains fall into the former.

Nail-Free Semi-built-up Boats

The typical structure of *wasen*, the wooden boats of modern Japan including semi-built-up boats and built-up boats, includes a key member (stemhead) leaning forward from the boat's bottom, on which the washstrakes are fixed by ship nails to form the bow shape. In order to make a sharp bow, the washstrakes are secured after being heated and bent in a vise, but their spring back force is still quite strong. Ship nails are hammered in from the outside to press the strakes down and secure them.

However, traces of nails have not been found on the semi-built-up boats of the Yayoi and Kofun Periods. Since ship nails are much longer and bolder than spikes 5-inch (about 15 cm) long, holes are made in advance into which the nails are driven until the heads are flush with the wood surface. Therefore, even if the nails themselves are missing, noticeable traces of their existence would remain. In fact, when looking at the exterior siding of buildings that were constructed using the dismantled hulls of *wasen*, nail holes can be observed. On the other hand, such nail holes are not found on the unearthed parts of semi-built-up boats from the Yayoi Period.

End Plank Type Semi-built-up Boats

The bark method was often used for joining the timbers of semi-built-up boats, before the nail method was developed. Strips of bark were passed through rectangular holes bored through both the washstrakes and the hollowed out trunk to tie them together. However, as previously mentioned, the washstrakes have a strong spring back force, requiring an especially firm join. The bark method is not as secure as the nail method. Therefore, end planks were adopted to obtain a secure join between the timbers. The end plank is equivalent to the stemhead of the *wasen*.

A semi-built-up boat was reconstructed to establish the effectiveness of the design. In order to fit onto the front of the hollowed out trunk, the lower part of the end plank is shaped with two projections on its lower part (A on *Fig. 2* that fits into two corresponding recesses carved into the trunk. The end plank is designed to tilt forward at an angle (B on *Fig. 2*). On the inner surface, the end plank has a groove 2–3 cm wide and 2–3 cm deep running length-wise near each edge (C on *Fig. 2*). These grooves receive the ends of the bent washstrakes. A similar end plank is also constructed at the stern of the boat. After embedding the two end planks onto each end of the hollowed out trunk, wooden pegs are hammered into grooves cut into the two projections of the end planks (D on *Fig. 2*) and the recesses carved into the hollowed-out trunk. These pegs stop the end planks from sliding out. The washstrakes were made of 2 cm thick cedar boards with a strong spring back force. During the reconstruction of the boat it was a tough job to fit these into the grooves on the end planks, but once in place, they were firmly assembled. The structural strength was ensured by bending the washstrakes, thus creating a tension to generate internal stress, which is the same for *wasen*. A 2-cm thick, 6-m long cedar board itself is quite thin and weak, but when assembled in this manner it has sufficient tension and strength (*Figs. 2* and *3*).

Semi-built-up Boats Found Around Lake Biwa

End planks of semi-built-up boats have been discovered at sites in the Lake Biwa region such as the Irienaiko site in Maibara City, Matsubaranaiko in Hikone City and the Ishida site in Higashi-Omi City, dating from the Yayoi to Kofun Periods. Their height ranged from 20 to 60 cm, indicating that boats were constructed in various sizes.

An end plank found at the Kyuhoji site in Osaka Prefecture has a height of 180 cm, which is estimated to be part of a boat with a hull length of 20 m and a width of 2 m, which was at that time quite a large boat capable of sailing on the sea. On the other hand, semi-built-up boats found near Lake Biwa thus far are mainly small to medium sized. However, it is important to note that some larger boats did exist besides small, individual boats. Watercrafts of the Jomon Period were limited to a certain size (individual canoes);

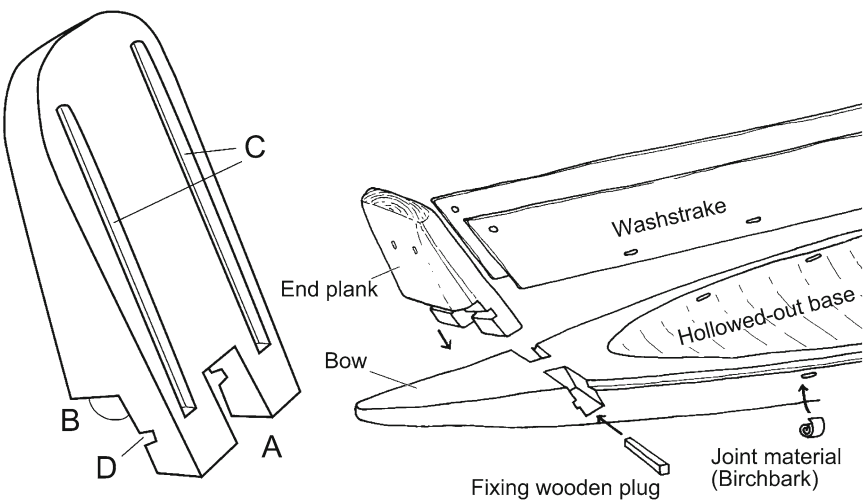

Fig. 2
Basic structure of the end plank of a semi-built-up boat.

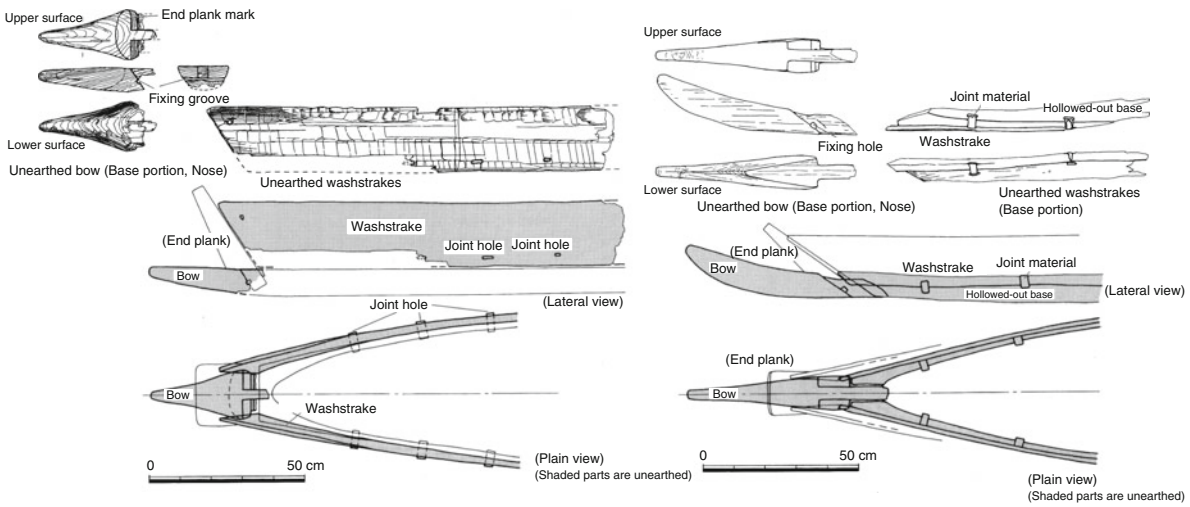

Fig. 3

***Left*: Semi-built-up boat elements excavated from the Akanoihama site (dating to the Yayoi Period) and diagram of its reconstruction. *Right*: Semi-built-up boat elements excavated from the Shimonaga site (dating to the Kofun Period) and diagram of its reconstruction.**

however, the technical improvements in the processing of timber (with the use of iron tools) and adoption of new designs (semi-built-up boats) during the Yayoi Period enabled the construction of larger boats. In contrast to one-person boats, large boats not only require a group of people to crew them, but also port facilities with features such as piers. The growth in boat size reflects changes in social demand, which further indicates the transformation of Lake Biwa into a full-fledged trade route.

Structural Versatility

A comparison is made here between the end plank discovered at the Kyuhoji site and the one discovered in the Lake Biwa area. The former is 180 cm high, while the latter is less than 50 cm high. Despite the significant difference in the size, their structures are identical. In short, they have the same shape but different sizes. The same boat-building technology was used to construct small one-person boats to large ocean-going boats, by which the versatility of the end plank type semi-built-up boats is indicated.

Comparisons of the early Yayoi Period semi-built-up boat found at the Akanoihama site in Moriyama City with younger examples clearly shows that the basic structure had been identical since the emergence of this type of boat. The basic structure of the end plank had been exactly the same since its emergence in the Yayoi Period through the subsequent Kofun Period (from middle of third to seventh century AD). The fact that an already established design is recognized on the earliest found semi-built-up boat remains indicates that this technology was not domestically developed but was adopted from mainland China. The long period of use of semi-built-up boats shows their high versatility throughout the ages.

Lake Biwa, where the use of semi-built-up boats can be confirmed in the early days of its human history, was a water body that lent itself to the instantaneous adoption of advanced boat-building technology and the launch of large and small boats for various purposes.

Through-Beam Type Semi-built-up Boats

It was not only the end plank type that was adopted as the basic structure for semi-built-up boats. Another type that was adopted was the "through-beam type." In this structure, through-beams are applied instead of end planks to forcibly pull the washstrakes toward each other and tie them down. The utilization of bark to secure joints instead of nails was the technical restriction in common with the end-plank type.

However, through-beams are unable to completely pull together the two washstrakes, hence leaving the ends open. In order to keep water from entering the open ends,

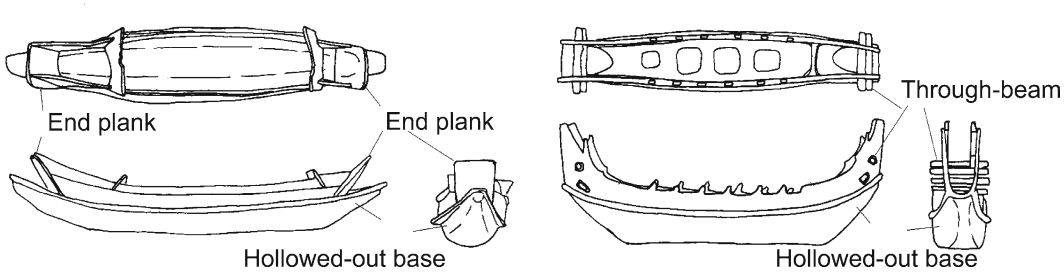

Fig. 4

Two types of semi-built-up boat structures seen in the boat-shaped clay model *Left*: The end-plank type semi-built-up boat model. *Right*: The through-beam type semi-built-up boat model.

the bow and stern were required to rise up. The "end-plank type" and the "through-beam type" structures are also recognized in boat models. When looking at the lateral shape, the former has a nearly horizontal base, while the latter has washstrakes that rise up at the ends. As for the planar shape, the former has a sharp bow and stern, while the latter has less sharp, square ones (*Fig. 4*).

Semi-built-up Boats in the Kofun Period (250–538 AD)

There are clay models of boats from the Kofun Period, some of which are highly decorated, and some have a number of rowlocks, conjuring up the image of large-sized boats requiring a number of oarsmen. These boats are also semi-built-up boats. Such clay models are considered to represent the power of the king, reflecting the latest designs of large boats at that time.

Besides the end-plank type or through-beam type, a combination of both was also recognized in the clay models. With an end-plank type fore and a through-beam type aft, it is possible to make up for each other's deficiencies. This hybrid structure was not only seen in the clay models but also in the silhouette of large and small boats drawn on a wooden tablet excavated at the Hakaza site in Hyogo Prefecture, showing that it was a widely adopted design at that time.

Boat-Shaped Clay Model Excavated from the Fourth Tomb of the Shingai Kofun Group

A clay model discovered at the fourth tomb of the Shingai Kofun Group in Ritto City (built at the end of fifth century) is different from those mentioned above, adopting a two-story structure with an end-plank type semi-built-up boat as the base and a through-beam type on top. It was possible to vertically stack two washstrakes using this structure. The boat-shaped model found at the second tomb of the Nagahara-takamawari Korun Group (built at the end of forth century) in Osaka Prefecture, conjuring up the image of a large boat, also has this shape. It is easy to assume that the stacking up of washstrakes enabled the construction of even larger boats.

If the clay model from the fourth tomb of the Shingai Kofun Group is indicating the launch of large boats on Lake Biwa, it suggests the growth in significance of transportation on the lake (*Fig. 5*).

Boats After the Kofun Period

There are very few historical materials in the Lake Biwa area and nationwide to illustrate the boats after the Kofun Period. Evidence implying the potential existence of people who built large boats at Lake Biwa is from Echihatano Takutsu, a man from Omi Province (now Shiga Prefecture), who was in-charge of boat-building at the battle of Baekgang that took place on the Korean Peninsula in 663. Additional evidence is that Omi was one of the provinces ordered to construct boats for Japanese official diplomatic delegations sent to China during the Tang dynasty in the eighth century.

Many of the boats in the Kamakura Period (1185–1333), the structures of which can be seen in pictures, were still semi-built-up boats with a hollowed out base. Semi-built-up boats remained to be the mainstream type during the medieval times. However, the structural features mentioned above, such as the end planks and through-beams, were no longer used. These were replaced by a smoothly conjoined outer surface, for which the use of ship nails were indispensable. Traces of abundant use of ship nails for the joining of washstrakes onto the hull are recognized on a medieval semi-built-up boat discovered in Kobe City.

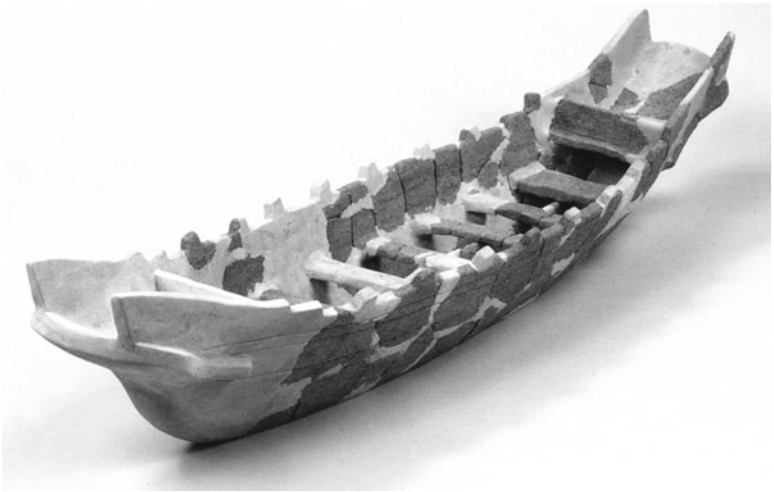

Fig. 5

A boat-shaped clay model excavated from the fourth tomb of the Shingai Kofun Group dating to the Kofun Period (based on its two-story structure with an end-plank type semi-built-up boat as the base and a through-beam type on the top, and a number of rowlocks on the washstrakes, it represents a large boat that required many oarsmen).

Fig. 6

Miniature built-up boats (wooden sailing boats) excavated from the Shiotsu port site dating to the Heian Period (the *top* is an ordinary model boat and the *bottom* is an accurately made model boat of the same period. These two models have the same shape and mast position, and are considered to represent wooden sailing boats of the same type).

Boats and the *Shiotsu* Port: An Important Port of Lake Biwa

In an administrative document of the ninth century, the routes and costs for transportation of taxes are recorded. According to this, goods from the Hokuriku region (the northwestern part of the main island facing the Sea of Japan) were loaded onto boats at the northern end of the lake in Shiotsu, and unloaded at Otsu, near Kyoto, which implies that the Lake Biwa route was the backbone of the distribution network in Japan at that time.

Excavation and research at the Shiotsu port site in recent years lead to the discovery of shrine remains and a precisely made miniature boat dating to the end of the twelfth century. This appears to be a faithful copy of the actual boats of that time, and is considered to be a flat-bottomed built-up boat based on its shape. Since a hole to install a mast is recognized on the fore cross member, this is assumed to be a sailing boat. Although semi-built-up boats were still the mainstream, the design of vessels plying the Shiotsu-Otsu route is considered to have moved away from it. The miniature boat is evidence that Lake Biwa supported the commodity distribution in Japan by placing in service the most advanced built-up sailing boats with enhanced capacity and speed (*Fig. 6*).

4.1.3 The Leaders of the Kofun Period and Transportation on Lake Biwa

Shuhei Hosokawa

Abstract In the middle to late fourth century, three large *kofun* tombs were constructed in the Lake Biwa area. These were especially large among those constructed in the area around the same period, and are all located near the lake. They are considered to be the burials of leaders who held power in the southern lake area by taking control of the transportation on the lake. Thus, study of these outstanding leaders in the community indicated importance of lake water transportation back in those days.

Keywords *Zenpokoenfun* [keyhole-shaped tomb]

Introduction

The Kofun Period refers to the period of approximately 400 years from the middle of the third to the middle of the seventh century. During this period, mainland China was experiencing turbulent times due to the transition from the ancient to medieval society (from the Qin and Han eras to the Sui and Tang eras). While being influenced by this, the Korean peninsula and Japanese archipelago were in the early stages of state formation. Thus, it is considered that the Kofun Period of Japan was one aspect of the period of dramatic social change of East Asia.

In the preceding Yayoi Period, from the tenth century BC to the third century AD, the social center of Japan was located in northern Kyushu (southwest Japan). Due to its proximity to the Korean peninsula and mainland China, it had an advantage over other areas of Japan in acquiring the latest materials and information from the continent. In the Kofun period, however, the center of society was transferred to the Kinai area (Kyoto, Osaka, and Nara). This is evidenced by the discovery of a large number of bronze mirrors and iron implements along with the fact that most of the large tumuli were constructed within this area. It is considered that in the third century AD, a maelstrom of war involving an area from northern Kyushu through to the Seto Inland Sea area, or even as far as the San'in area finally came to an end here in the Kinai area, and it became a new social center. Subsequently, a social system of concentration and redistribution of wealth was developed from the Kinai area. This was the real nature of the Kofun Period, and that was when the state formation began in the Japanese archipelago.

Considering the above, it was clear that the location of Lake Biwa was of importance. Besides the fact that the lake was closely located to the Kinai area, it also links the area with the broad Togoku region (eastern Japan). Moreover, the calm inland waters allowed boats to be a quite convenient means of shipment and transportation. Besides northern Kyushu, communication between the Korean Peninsula and the Japanese archipelago became actively conducted along the coastal areas of the Sea of Japan, such as in Izumo in Shimane Prefecture and Tango in Kyoto, which resulted in a concentration of goods in the area. These goods could be shipped via Lake Biwa to the Kinai area or the eastern provinces on the Pacific side of the main island.

In other words, Lake Biwa was a key junction of transportation that linked the north and south, and the east and west areas of the Japanese archipelago, while the Kinai area, the new center of the social system, was located to the west. Supposing the social structure of the Kofun Period was characterized by the concentration and redistribution of wealth centering on the Kinai area, Lake Biwa obviously had a significant role in promoting and maintaining this structure. An understanding of the transportation on the lake during the Kofun Period is indispensable in understanding the nature of Kofun society.

Zenpokoenfun with a Length of over 100 m

The social structure of the Kofun Period was characterized by the construction of large-scaled tombs, called *kofun*, by the local leaders who took part in maintaining the society.

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The combination of the scale, configuration, and funerary goods of *kofun* represented their position, rank, and occupational ability (Hirose 2003). Burials were primarily constructed in a unique configuration combining a circular and a squared mound, called *zenpokoenfun* (keyhole-shaped tomb). The largest one located in Osaka had a length of 486 m, which was one of the biggest burials found in the world. A total of 5,200 keyhole-shaped tombs and "two conjoined rectangles"-type tombs (*zenpokohofun*) are found in the Japanese archipelago. Among these, 36 were over 200 m, and 302 were over 100 m. This indicates the eagerness of the leaders to construct large burial mounds, and their struggle in maintaining and developing the social system symbolized by construction of the tombs.

In the Lake Biwa area there are three keyhole-shaped tombs that are more than 100 m in size, and these were constructed from the middle through to the late fourth century (*Fig. 1*). Since other tumuli in the area only had a scale of 50–70 m, these three were clearly outstanding.

The Azuchi-Hyotanyama Kofun was the first of the three to be constructed, and it is located at Miyazu in Azuchi town in Omihachiman City on the east side of the north basin. It was a keyhole-shaped tomb with a length of 136 m, constructed by reshaping an end of a hill ridge. This was the largest tumulus in Shiga Prefecture with a construction style dating back to the mid-fourth century. The deceased was wearing iron armor, a product of the most advanced technology at that time, and weapons such as swords, and bangles for protection against evil were found. The iron armor was one of the funerary goods to symbolize the strength of the central government of that time in the Kinai area, known as the Yamato Regime, which would even consider using military force against the Korean Peninsula (Takahashi 1993).

The Kojinyama Kofun is located at Hinatsu town in Hikone City, also to the east of the north basin. The keyhole-shaped tomb is situated near the top of an isolated hill close to Lake Biwa, and has a length of 124 m. The tumulus is located with a great view of the lake, and was surrounded by *haniwa* (large cylindrical clay objects for the decoration of burial mounds) placed like a fence. The hillside was covered with stones carried up from the foot of the hill. From its style, it was considered that it was constructed in the late fourth century after the Azuchi-Hyotanyama Kofun.

The Zeze-Chausuyama Kofun is located near the southern end of the lake at Zeze in Otsu City. Constructed on a hilltop overlooking Lake Biwa, the keyhole-shaped tomb has a length of 120 m. Considering the characteristics of the *haniwa*, it was probably constructed around the same time as the Kojinyama Kofun in the late fourth century. Although smaller at two thirds of the size, the Zeze-Chausuyama Kofun was constructed using the same plan as the Sakimisasagiyama Kofun in Nara Prefecture, which could have been the burial of a great king. The Goshikizuka Kofun in Hyogo Prefecture, Izumi-Mayuyama Kofun in Osaka, and Iga-Mihakayama Kofun are also known to have a similar shape to the Sakimisasagiyama Kofun (Shimogaki 2005). The locations of these tombs were at transportation hubs for various regions of the Kinai area.

The *leaders* Who Took Charge of the Transportation on the Lake

The large three keyhole-shaped tombs constructed in Shiga one after another in the mid to late fourth century had features in common, namely that they were over 100 m in length and had been consciously located close to the lake. When the Azuchi-Hyotanyama Kofun was constructed, wetlands were spread around the shores of Dainakanoko and Shonakanoko lakes, two attached lakes of Lake Biwa, up to near the foot of the burial. It was highly possible that the burial site was approachable by boats utilizing the attached lakes and creeks. This place was also where the Jorakuji port was located in medieval times (from the eleventh to sixteenth century).

The Kojinyama Kofun was constructed at a point slightly below the summit of an isolated hill, which made it possible to retain a view of Lake Biwa rather than a view on the plain side. The construction of this tumulus was obviously inseparable from the leader's interest in the lake. The Satsuma port was located around this area in medieval times, and the location had significance for merchants around the lake.

As mentioned above, the Zeze-Chausuyama Kofun is situated on a hilltop overlooking Lake Biwa at Zeze, an area south of the lake. The most convenient route between Lake Biwa and the Kinai region passes through this area. In the Edo Period (1600–1867), Zeze Castle was located on the shore serving as an important junction of the southern lake area. At Zeze-Chausuyama Kofun, Akiba Shrine was established to protect Zeze Castle town from fire disasters. This exemplifies how important the location of Zeze-Chausuyama Kofun was for control over the southern lake area, even during the Edo Period.

Thus, the three keyhole-shaped tombs were not simply constructed at locations overlooking the lake, but also near places suitable for important port facilities.

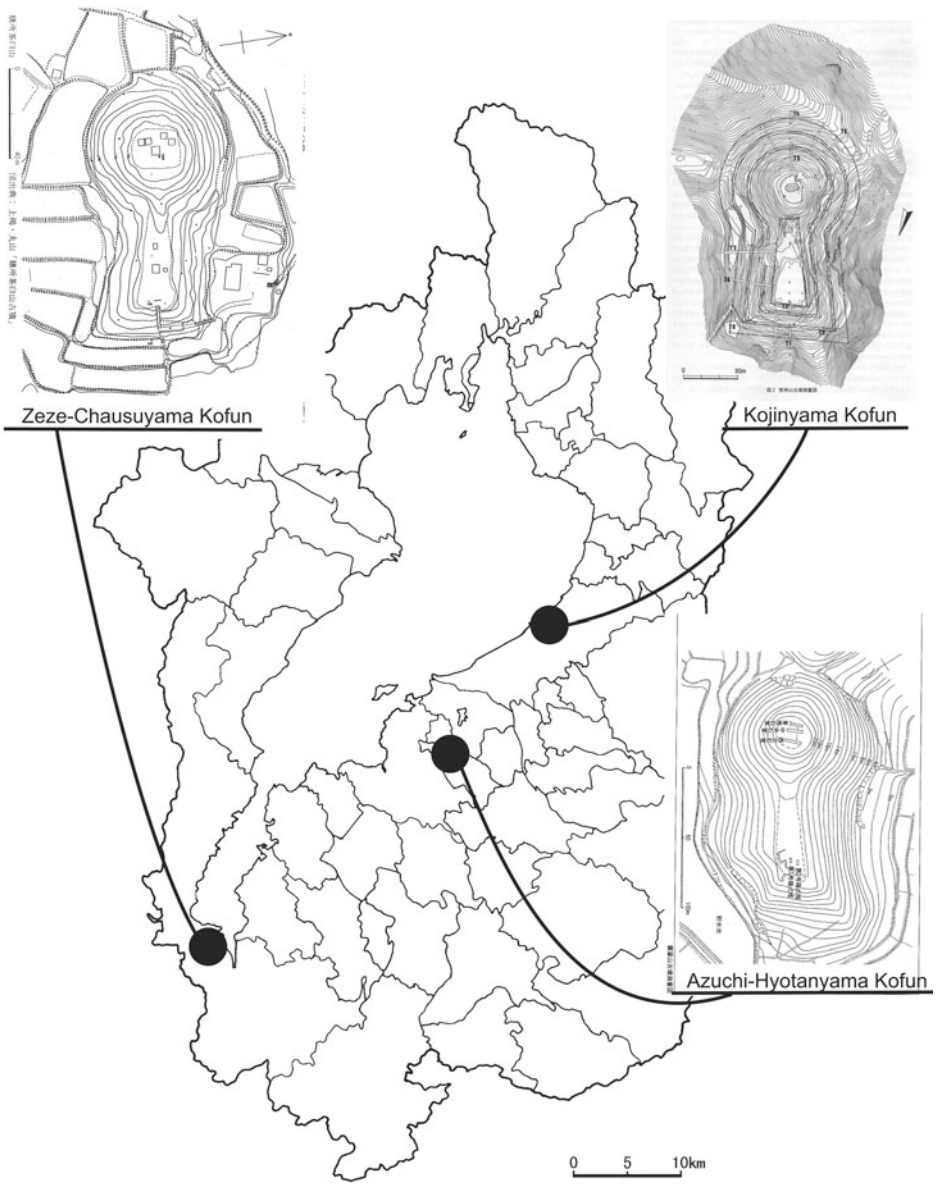

Fig. 1
Three major keyhole-shaped tombs.

The Zeze-Chausuyama Kofun was located at a transportation hub connecting the Kinai area to eastern Japan via Lake Biwa. The Azuchi-Hyotanyama Kofun and Kojinyama Kofun were located on the east shore, which was one day's sail from the Zeze-Chausuyama Kofun at that time. Traveling up the Echi River from either of these two tumuli toward inland areas was the shortest route to the north Ise area on the other side of the Suzuka Mountains. People went by water from the Zeze-Chausuyama Kofun area to the Azuchi-Hyotanyama Kofun or Kojinyama Kofun areas, from which they traveled overland to cross the Suzuka Mountains. Then, from north Ise, it was possible to continue by water by taking the sea transportation route from Ise Bay (Hosokawa and Kido 2009).

There was another common characteristic of these three large keyhole-shaped tombs. In the surrounding area, no similarly large tombs were constructed before or after these three. Moreover, the existence of large ancient communities locally with a scale appropriate to the size of the tumuli have not been confirmed yet. It is possible that these tumuli were constructed at key locations on the shores by leaders from somewhere else, with the intent of taking control and managing transportation on the lake in place of the local leaders (Hosokawa and Kido 2009).

Given the above perspective, it is understood that these three tombs were constructed one after another for the same purpose; namely, that those deceased leaders had a political role of controlling the transportation of the lake.

Social Situation in the Early Fourth Century

Since the beginning of the Kofun Period, there was a trend to select places overlooking the lake or advantageous in utilizing the lake for the construction of *kofun* tombs. This was particularly notable in the southern area of the west shore and the northern lake area.

In the northern district of Otsu, located in the southern area of the west shore, there are the Tsubokasa Kofun (a circular tomb with a diameter of 48 m), and Ojiyama Kofun (a "two conjoined rectangles"-type tomb with a length of 70 m). To the north, in the Katata district, located on the west shore of the narrowest point of Lake Biwa, Wani-Otsukayama Kofun (a keyhole-shaped tomb with a length of 70 m), and the first and twelfth tomb of the Kasugayama Kofun Group (keyhole-shaped tombs with a length of 60 and 54 m, respectively) are located. Thus, *kofun* tombs were constructed around the transportation hubs between the Kinai area and Lake Biwa, or at locations overlooking the narrowest point of the lake. The leaders of such areas reigned over people, managing and controlling the transportation on the lake (Hosokawa and Kido 2009).

In the northern lake area, on a hill stretching along the shore, there is the Kohori Kofun Group, which consists of more than 100 tumuli including 16 keyhole-shaped and "two conjoined rectangles"-type tombs. Prior to the mid fourth century, Komatsu Kofun, with a length of 60 m, was the largest, and most other tombs had a scale smaller than 40 m. However, since the place was a major transportation hub between the lake and the Sea of Japan area, many leaders competed with each other for the construction of tumuli, and they took part in managing the transportation on the lake (Hosokawa and Kido 2009).

Thus, in the early fourth century, there was a system where the leaders of local transportation hubs ran and managed part of the transportation on the lake. However, the tumuli built by these local leaders were not particularly large when compared with the Yukinoyama Kofun (a keyhole-shaped tomb with a length of 70 m located in Higashi-Omi City), and Tatsugahana Kofun (a "two conjoined rectangles"-type tomb with a length of 46 m located in Nagahama City), which were constructed around the same time in inland areas. Since the lineages of local leaders were highly valued, it was not likely that there was a cross-regional cooperation by the leaders for the construction of tumuli.

As mentioned above, there was a system until the early fourth century that the leaders of the hub areas around the lake ran and managed the lake transportation of their own areas. On the other hand, there was neither a great leader to take over the transportation of the whole lake nor such an across-the-board system.

Conclusions

It was in the middle of the fourth century when a top leader emerged to take charge of the overall management and operation of the transportation on the lake, which used to be carried out separately by the local leaders. This person at least had influence over an area larger than the southern lake, by having the transportation in hand rather than taking over the local lands and people. It was a political institution specially appointed by the Yamato Regime for managing the transportation on the lake, or a government bureaucratic position created in the early stages of the state formation, rather than a local leader.

The existence of such a top leader was quite rare in the mid fourth century. Throughout the entire Japanese archipelago, only a few of them were found outside the central part of the Kinai area, such as in the Tango area in northern Kyoto, a base for the Sea of Japan shipping, and the Settsu area in eastern Hyogo Prefecture on the coast of the Seto Inland Sea. These were, respectively, the transportation hubs to the north, west, and east of the Kinai area (Hosokawa 1994).

There was a great improvement in the social structure during the approximately 80–100 years after the beginning of the Kofun Period, and the ancient state was about to establish its internal order. At the same time, in order to further strengthen the structure, taking control of the transportation routes became a major aim. Therefore, leaders specially appointed by the Yamato Regime were placed at least at the transportation hubs on the main routes connecting the Kinai area to the north, west, and east. Namely, government bureaucrats were placed at the

helm of transportation. The Lake Biwa area was the transportation hub connecting the Kinai area to the east, which consequently led to the construction of those three large keyhole-shaped tombs—Azuchi-Hyotanyama Kofun, Kojinyama Kofun, and Zeze-Chausuyama Kofun. The iron armor, a product of advanced technology found in the Azuchi-Hyotanyama Kofun, was a symbol representing a part of the personality of the deceased.

As indicated above, the presence of Lake Biwa was highly valued by the Yamato Regime, and advanced efforts were continuously put into developing the area. This was not only because of the closeness of Lake Biwa to the Kinai area but also its geographical significance on the Japanese archipelago. We need to analyze the trend of leaders' burials in the Lake Biwa area in order to understand the trend of the whole society during the Kofun Period.

4.2 Period of Utilization

Masaharu Yoda

The capital transfer to Otsu in 667 had initiated a full-scale ancient state formation in the Lake Biwa area. Located near the capital, Lake Biwa became a supplier of tribute to authorities such as the Imperial Court of the ancient state or powerful shrines and temples. Aquatic products from the lake, including fresh fishes, traditional fermented fish product called *funazushi*, and rice produced utilizing the abundant local water resources, were provided to the capital. Lake Biwa was also utilized to transport tribute from provinces further east and north of the capital, and the waterway connecting the north and south of the lake especially came to play an important role. In the ninth century, major ports were under control of powerful temples such as Enryakuji and Onjoji, which belonged to the Tendai sect, a rising Buddhist sect of that time. During the medieval period, starting from between the twelfth and thirteenth centuries, villages in the Katata area, located at the narrowest point of the lake, began to expand their power upon the lake.

During the medieval period, fisheries in Lake Biwa prospered to become an important industry of the times, and Katata started dominating fishing rights besides the waterways on the lake. The fishing privileges of Katata were taken away by the *shugo daimyo* (provincial military lords in the Muromachi Period) in the late medieval period starting in the fifteenth century, which later became known as the *sengoku daimyo* (provincial military lords in the Sengoku Period). In particular, Oda Nobunaga, a powerful leader in the Sengoku Period in the late sixteenth century, took the most advantage of the location and functions of Lake Biwa to enhance his power. He constructed a huge fortress/castle in Azuchi on the lakeshore of Lake Biwa, and he often utilized its waterways when traveling to the capital Kyoto. Toyotomi Hideyoshi, who replaced Nobunaga, created the *funabugyo* (boat magistrates) as a new control institution, and he always had 100 boats in Otsu ready for emergency use.

Since the early modern period, wooden sailing boats with a design unique to Lake Biwa, called *maruko-bune*, were the main transportation vessel type until the early twentieth century. From the late seventeenth century, the westbound route from the northern provinces along the coast of the Sea of Japan via Shimonoseki to Osaka and other destinations was taken instead for cargo shipment; Lake Biwa, however, remained as the main daily transport route. During the Edo Period from the seventeenth century to the nineteenth century, it is said that Otsu had the largest population among the post stations on the Tokaido road connecting Edo and Kyo (today's Tokyo and Kyoto).

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4.2.1 Ancient Ports of Lake Biwa

Nobuya Ohashi

Abstract Among the benefits we have received from Lake Biwa, water transportation and associated trade activities are the ones that have almost finished their role today. However, before railroads and automobiles became the main modes of transportation during the 1950s, the significance of Lake Biwa in local transportation and commodity distribution is larger than what we now imagine. Ports served as the key junctions of water transportation on the lake as well as commerce and commodity distribution. In ancient times, in particular, Lake Biwa, where boats fully loaded with people and goods came and went, was a part of the main artery of the Japanese Archipelago.

Keywords Ancient times • Ports • Wooden tablet • Water transportation

Tsu, Minato, Suimon, Tomari, Ura (Different Words Referring to Ports)

Poems in *Manyoshu*, the oldest existing anthology of poetry compiled in the eighth century, indicate the significance of Lake Biwa in ancient water transportation. As described in a poem, there used to be many ports around Lake Biwa, and we can picture the scene that people came and went by water. In fact, there are many descriptions about ports in ancient literatures. Such an example is *Ryonoshuge*, a commentary on the law written in the ninth century, and *Wamyoruijusho*, Japan's first encyclopedia compiled in the tenth century.

Moreover, descriptions of ports are frequently seen in *Manyoshu*, including Shiga-tsu, Hira-no-minato, Katsuno, Ado-no-suimon, Shiotsu, and Sugaura, which also appear in other literatures. Among those *tsu* (ancient ports) above, Otsu and Katsuno-tsu are mentioned in *Engishiki*, a statute book compiled in the tenth century, as the main junctions for the shipping of various goods from provinces via the Hokurikudo (a main road that ran through northwestern provinces along the Sea of Japan coast).

Goods from Wakasa, Echizen, Kaga, and Ecchu to the north of Lake Biwa were transported to Tsuruga-tsu via the Hokurikudo road and then to Katsuno-tsu or Shiotsu, from where they were shipped to Otsu before reaching the capital, Kyoto. Similar records about provinces along the San'indo road (a main road that ran through southwestern provinces facing the Sea of Japan) indicate that Lake Biwa was a part of the main transportation network connecting the areas of the Sea of Japan to the Kansai region (the central region of Japan where the capital was located).

In addition to being a transport route for public goods, Lake Biwa was also utilized to transport construction materials for palaces and temples at the capital in Nara. Water transportation was also utilized for private trade, which is shown in the *Nihon Ryoiki*, the oldest collection of Buddhist legends.

In one such legend, a merchant named Iwashima, a resident of Heijokyo, the eighth century capital in Nara, borrowed money from the funding for Daianji Temple and went to Tsuruga in Echizen province to purchase merchandise. He crossed mountains and took waterways to head back but became ill on the way. He then tried to borrow a horse to get home, leaving the merchandise behind. Unfortunately, when he got to Karasaki and looked behind him, he noticed that three demons were coming after him to take his soul. Iwashima, eventually, saved himself by bribing the three demons. This story confirms that merchants in the Nara period carried out trade over a wide area, utilizing the water transportation on Lake Biwa.

People Who Played Important Roles in Commodity Distribution on the Lake

So far, we reviewed the commodity distribution network centered around the water transportation by analyzing the roles of the local ports and cities. Here, we will look at what kind of people played the roles in water transportation. One piece of information on this was found on a

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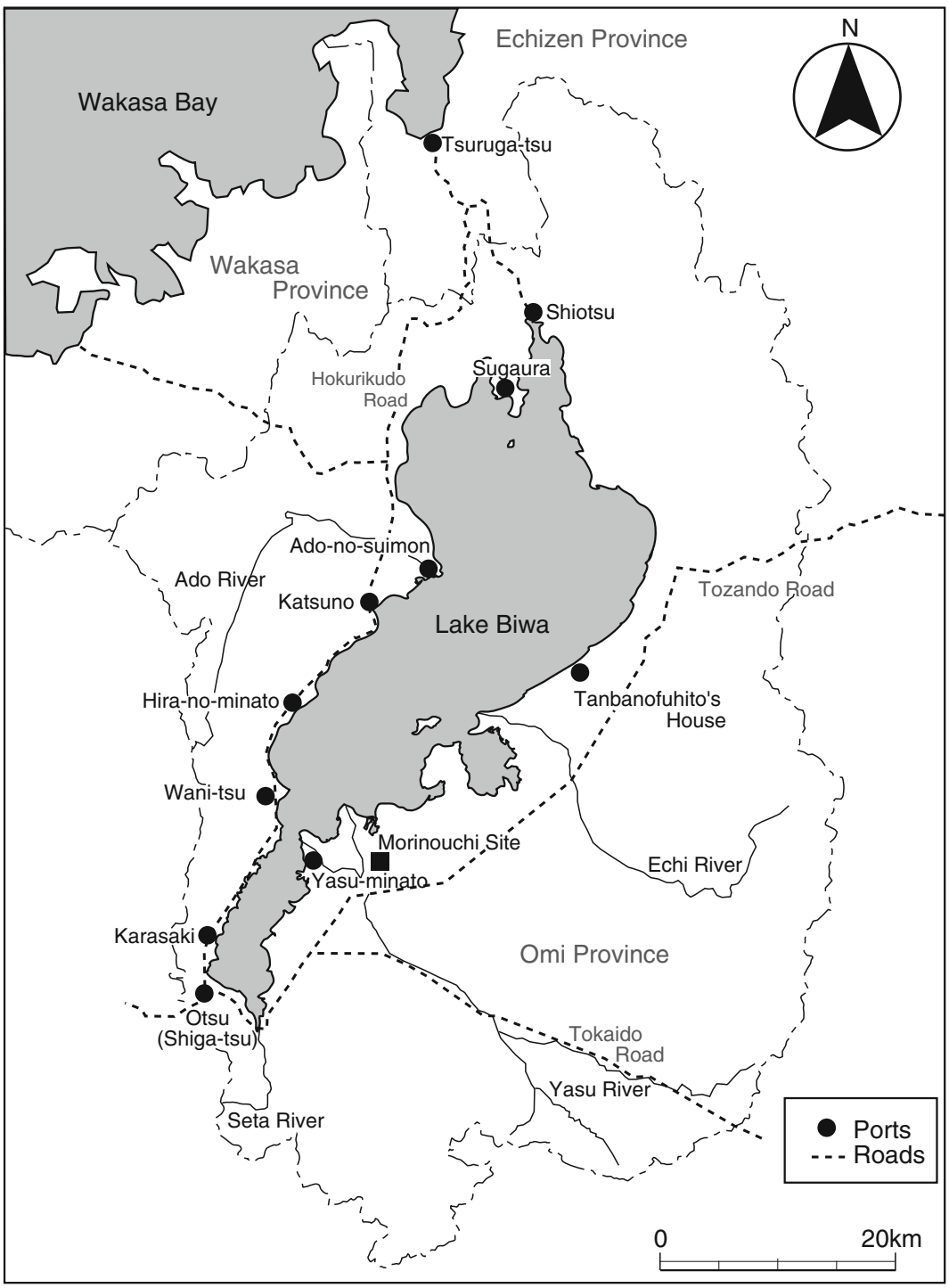

Fig. 1

Ancient ports and roads in the seventh century.

couple of wooden tablets excavated at the Morinouchi site in Yasu—the first one dated back to the late eighth century, and the second one dated back to the late seventh century (*Fig. 1*).

The Morinouchi site is located near the mouth of the Yasu River on its north bank, and it is close to the port of Yasuminato, which was utilized to transport timbers for the construction of Ishiyama-dera Temple in 762. The remains of an administrative institution were found here on the lakeshore (possibly the country office of Yasu or its local agency or associated facility). On the first wooden tablets the names of residents of a village in the Umamichi Township of Yasu district are listed, and it is considered to have been a sort of tax registry. Besides the powerful local figures, most of the residents are considered descendents of immigrants from the Korean Peninsula who had moved here from the southern part of Shiga district in Omi province (northern Otsu).

The second wooden tablets dates back to the late seventh century. It is a letter sent from Kuranoatai to Urabe who lived in the area of the Morinouchi site. Kuranoatai made an attempt to carry home a load of rice, but came back empty-handed, unable to find horses for transport. The load was left at Tanbanofuhito's house in the Heru Township of Echi District (today's Inasato in Hikone City), and he is asking Urabe to send a boat and carry it back. Tanbanofuhito also belonged to an immigrant family (Shigano-ayahito) based in the Furuichi Township in Shiga District. This indicates the presence of a waterway transportation route run by the network of the Shigano-ayahito clan living on the shores of Lake Biwa (Yamao 1990). We can also presume that a land route for transportation of goods by horses was utilized in combination with the waterway. By analyzing historical literature and written material on wooden tablets, we can deduce that the Shigano-ayahito clan resided mostly in lakeside ports, with a few living in inland regions. They were probably concentrated in northern Otsu for the Yamato Regime (based in today's Nara prefecture) to collect and transport goods from Hokuriku (northwestern part of the main island facing the Sea of Japan), San'in (southwestern part of the main island facing the Sea of Japan), and Togoku (eastern part of the main island) regions to the center of Kansai. Thus, the Shigano-ayahito clan settled in various areas in Omi and expanded their power locally. In the Heian period (794–1185), some of them were appointed local governors (Ohashi 1995).

Above, we have seen that the ports of Lake Biwa not only played an important role for the transportation of goods for the local area of Omi, but also for the central government. Although there is no complete record of the functions of the lake transportation in people's life in ancient times, the close relationship between people and Lake Biwa has been passed down from generation to generation.

4.2.2 Medieval Social Relationships and Lake Biwa Fisheries

Michinori Hashimoto

Abstract Recently, fish ecology and fishing techniques have been the focus of research on Lake Biwa's medieval fisheries. This research, based on the seasonality of fish consumption in the former capital Kyoto, found that there were two peaks of consumption of crucian carps (*Carassius* spp.) in a year: the breeding season (from April to June) and during winter. Even nonprofessional fishing operations were strongly influenced by this consumption trend in Kyoto. However, the fishing operations were in conflict with the Buddhist prohibition against taking life, which might have led to the initiation of professional fisheries.

Keywords Medieval period • Lake Biwa, *Carassius* • Consumption • The former capital Kyoto • Fishery • Katata • Prohibition against taking life

Introduction

In the past, research on the medieval (from the late eleventh century to the late sixteenth century) Lake Biwa fisheries was focused on the privileges held by professional fishing groups. Its main subject was about the people of Katata during the seventeenth century, who claimed themselves as chiefs of the area. Amino (1984) argued that the Katata fishermen held rights to conduct fishing activities freely in the Lake Biwa area since ancient times. To his understanding, fishing operations by unprivileged village communities probably started in the late eighteenth century.

However, counterviews to this were brought up in recent years. Sano (2008) studied the history of the Lake Biwa fisheries in a different way by focusing on the association between geography, fish ecology, fishing techniques, and the livelihood of communities. Paying attention to the diverse ecosystem of the waterside, Sano (2008) analyzed fish ecology, such as the migrating behavior during the spawning period, in relation to fishing techniques. She argued that the waterside was shared by specific and limited groups in the villages, which were the predecessors of the Commons in Japan.

Likewise, Hashimoto (2001) took notice of the diverse fisheries at the waterside where the boundary between the land and water constantly changed. First of all, Hashimoto (1999) deduced that a new type of *eri*-trap fishing (*Fig. 1*) based on a different principle was introduced by village communities in the thirteenth century, which destroyed the order of the traditional *eri*-trap fishing. Hashimoto (2009) also revealed that fishing privileges were not strictly enforced at the waterside, and fishing by diverse groups, including local lords and people of the manor, competed and coexisted. Fisheries were from the beginning of the medieval period included into the productive structure of medieval waterside village communities (Hashimoto 2001).

The Buddhist prohibition against taking life was another important contention (Kada and Hashimoto 2001). A comprehensive view of Lake Biwa's fisheries could not be presented without looking at the physical and psychological conflicts associated with the prohibition on taking life, which was one of the Buddhist precepts.

Based on the above research trends, this paper presents the general configuration of Lake Biwa fisheries centered around the consumption of fish in the neighboring Kyoto, and dwell on its characteristics.

Consumption of Fish in Kyoto

In medieval period, a well-known local product of Omi (today's Shiga Prefecture) was crucian carps ('*funa*' in Japanese, *Carassius* spp.) from Lake Biwa. Three *funa* species are found in the lake—*Gin-buna* (*Carassius* sp.), *Nigoro-buna* (*Carassius auratus grandoculis*), and *Gengoro-buna* (*Carassius cuvieri*). Among these, *Nigoro-buna* and *Gengoro-buna* are endemic species adapted to offshore habitats. Their ecology has only recently been revealed,

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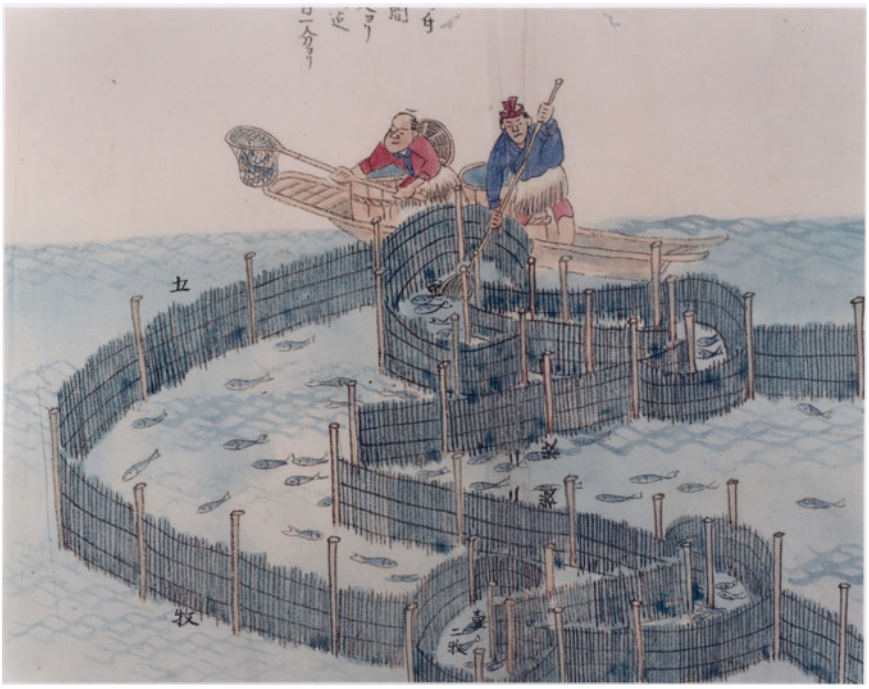

Fig. 1
***Eri*-trap fishing in the nineteenth century (Shigaken Kanka Omi-no-kuni Rokugun Bussan Zusetsu [An Illustration and Explanation of Local Products of Six Districts in Omi Province under Shiga Prefecture] owned by Lake Biwa Museum).**

and it has become clear that they migrate to the northern part of the lake from summer to winter (Yamane 2009).

Funa fish from Lake Biwa were given as gifts to the family of the emperor and also to the Ashikaga Shogun, the highest authority of the fifteenth century. The diary of the Yamashina family, an aristocracy during the fifteenth century whose head served as the chief of the imperial kitchen, reveals interesting facts about the tribute of fish, gift-giving, and diets of that time (Shibutani 2010).

The diary was recorded using the lunar calendar, and for research purposes the dates were converted to the Gregorian calendar for the articles related to *funa*, whether or not they were caught in Lake Biwa. As a result, two peaks of consumption of *funa* were confirmed (Hashimoto, unpublished). One was from April to June when *funa* migrated upstream for spawning. The other was from December to February when *Nigoro-buna* and *Gengoro-buna* migrated to the northern part of the lake.

There was another important aspect behind this winter demand; the giving of the 'first *funa*' as a tribute to the Shogun family. On February 20th, 1481, Kyogoku Takakiyo, the governor of the northern Omi province, presented the first *funa* fish caught in the year as a gift to Ashikaga Yoshimasa, father of the Shogun Yoshihisa who was in power. The Ise Clan, who served as Mandokoro butlers in charge of cooking for the shogun family, gave *funa* as a gift to Yoshimasa twice—on March 9th and December 30th, 1481 (Haruta 2008). *Funa* was in season during its spawning period and in winter, the same periods for giving ritual offerings to the shrines (Hashimoto, unpublished).

Waterside Fisheries

During the medieval period, there were professional fishing groups called *ama* or *amiudo* in the Lake Biwa area. Katata fishermen were included among them. The activities of the Katata *amiudo* have been confirmed to have taken place along the western side of the lake in Adogawa and the areas around Otowa manor, and in the eastern side of the lake in Okushima. They certainly conducted fishing over a wide area of the lake (*Fig. 2*).

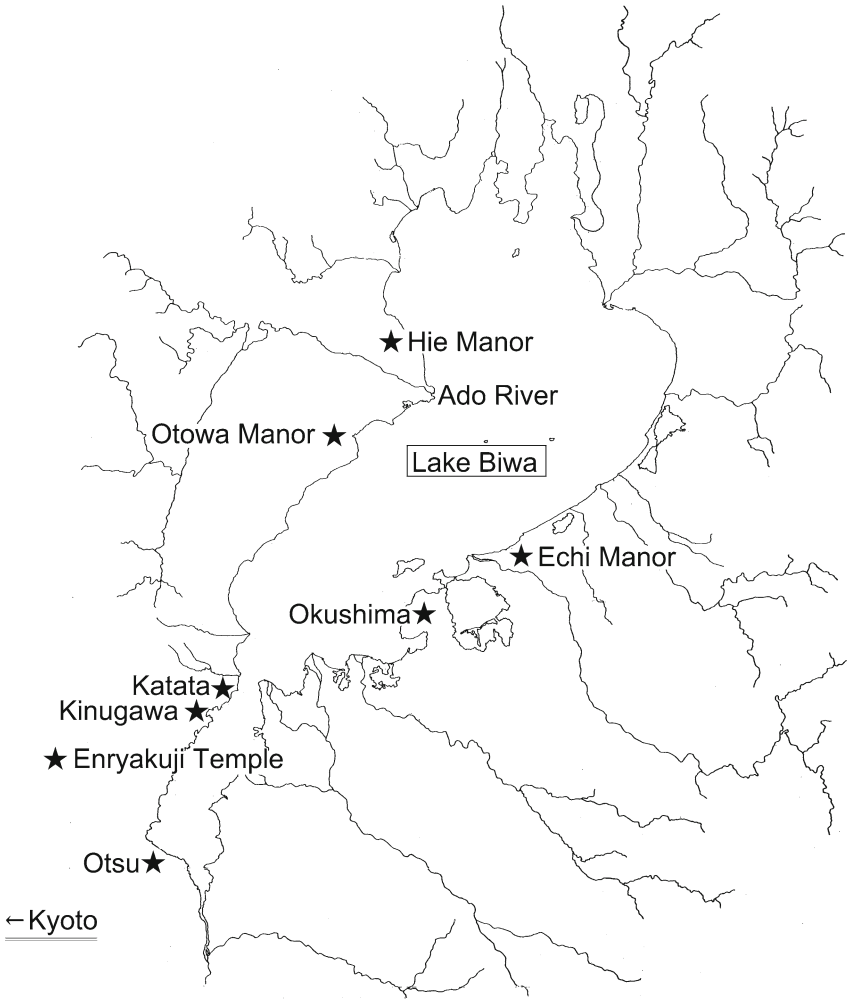

Fig. 2
Lake Biwa and its water system.

However, it should be noted that in the thirteenth century, net fishing was carried out by *amiudo* within restricted areas called *aji* or *amiba* (fishing territories). Therefore, Amino's perspective (1984) that they were allowed to conduct fishing anywhere in the Lake Biwa system is considered to be wrong.

It is an important fact that Katata fishermen were capable of making offerings of fish to shrines not only in the spawning period but also in winter. Additionally, they were able to satisfy the needs for offerings that occurred in other seasons. The offerings to shrines were required to be a certain size of fish, and Katata was distinguished from other fishing communities by its ability of offering fishery products of predetermined size regardless of the season.

On the other hand, different type of fisheries also existed along the waterside of Lake Biwa. On the eastern side of the lake at Echi manor, even when the property was divided into two parts by the owner, there was an agreement to allow mowing, gathering of wild rice and sedges, and fishing along the deserted shore of the lake (ecotone) across the border of the two areas. At the ecotone, the boundary between the land and water, the conditions alter seasonally and also from year to year. With a rich diversity of life, it is considered that it was a space where various resources have been utilized in different ways (Sano 2008). Fishing is one example of this, which targeted the fishes when they migrated upstream during spawning periods.

However, the medieval Lake Biwa fisheries are not only characterized by those two contrasting types of fishing mentioned above. In the western region of the lake, Yoshinao, a resident of Hiei manor, was sued by Kamigamo Shrine in Kyoto for fishing without permission on June 1st, 1232. It is highly possible that he conducted a large scale *yana*-trap fishing method, targeting the fishes migrating upstream to spawn, since he was accused of seriously damaging the upstream fishery by Adogawa fishermen belonged to the shrine. The fishing that Yoshinao conducted was possibly related to the rituals at Hiyoshi Shrine (Hashimoto 2009).

On January 29th (in the lunar calendar) of an unknown year, a lower officer of Katata manor sent out a letter requesting an immediate trial on a fishery territorial issue. Since this is considered as a letter referring to the conflict between the residents of Katata and Otowa manor, it was probably written in the winter of 1196. It is clear that the residents of Otowa manor had their own fishing territories besides the one in conflict with Katata (Hashimoto 2009). This indicates that the residents of Otowa manor also had *aji* fishing territories with the capacity of producing fishery products during the winter.

The fisheries conducted by the residents of the manor mentioned above were as competitive as those by professional fishing groups, and they were capable of meeting the two seasonal demands in the city. The presence of diverse fisheries supporting such demand was what distinguished the Lake Biwa fisheries from other areas.

Fishing Regulations Around Temples

As is indicated by the phrase "the pond of Tendai-yakushi," (the Medicine Buddha), which refers to Lake Biwa, the utilization of the lake was strongly affected by Enryakuji Temple on Mt. Hiei. Fishing and hunting in the areas "north of Otsu, south of Kinugawa-go" were banned because of the prohibition on taking life. This was based on a Buddhist precept that forbade killing. However, in reality, it was difficult to completely avoid taking life, thus the prohibition was enforced on specific dates or by limiting it to specific areas around the temple.

A good example of prohibition on hunting and fishing around Buddhist temples is that of Chomeiji Temple located at Okushima in the eastern part of Lake Biwa (*Fig. 3*). In the year 1262, a dispute concerning *eri*-trap fishing occurred between Chomeiji Temple and Oshima Shrine, both located at Okushima. Shinto being of much greater antiquity than Buddhism in Japan, fishing for

Fig. 3
Okushima in the nineteenth century (Omi Kinai Meisho Zukan [An Illustration of Places of Scenic Beauty in the Omi and Kinai areas] owned by Lake Biwa Museum).

ritual offerings to Shinto shrines was generally excluded from the Buddhist prohibition on taking life. Nonetheless, it is important to note that the *eri*-trap belonging to Oshima Shrine was set within the prohibition zone enforced by Chomeiji Temple. The dispute was settled with the agreement that Oshima Shrine would limit its catch to a thousand fish a year. Thus, even fishing in the name of the gods was restricted by the prohibition.

When looking at the relationship between the prohibition enforced by the temple and the fishing for making offerings to the shrine, the difference in the idea of killing was an issue that cannot be overlooked. The story below was found in the collection of Buddhist stories, Shasekishu, written in the thirteenth century.

> A monk of Enryakuji Temple released a funa caught at Lake Biwa by a fisherman. Then, the funa came into the monk's dream, complaining to him by saying, "I thought I could finally reach enlightenment by being offered to Kamo!'"

This story was obviously to justify fishing for the purpose of making offerings to Kamo Shrine. It is considered that the appearance of a monk of Enryakuji Temple and Kamo Shrine in this story had a significant meaning. This was accurately reflecting what was going on with Lake Biwa of that time, namely that the fisheries were being conducted under a strong conflict between a group insisting on the prohibition of killing, and a group against it. Katata fishermen gained power in the middle of this conflict, surpassing other full-fledged fishing groups in their ability of making offerings to Shimogamo Shrine regardless of the season.

Conclusion

During the medieval period, fishing in Lake Biwa was carried out as part of people's livelihood, as well as a profession intended to support the peak demands for fish in the capital Kyoto during the spawning period (from April to June) and winter. However, these were not the only characteristics of the medieval Lake Biwa fisheries. The highly developed nonprofessional fisheries were even capable of targeting fish during winter, competing with other fisheries and going against the prohibition on hunting and fishing. This was a characteristic unique to Lake Biwa.

Fishing organizations were formed not only by village communities but also by the officers or people of the surrounding manors. However, the development of fisheries centering on compact village communities surely contributed to their self-sustainability. It is our future task to ascertain the process of this and the establishment of the powerful fishing village Katata on the shores of Lake Biwa during the late medieval period.

4.2.3 Development of Water Transportation on Lake Biwa and Prosperity of the Port Towns

Eiji Hatanaka

Abstract At the end of the sixteenth century, a boat company called *Otsu Hyakusosen* and an administrative institution called *funabugyo* began taking control of the individually managed ports around Lake Biwa. From then on, most of the rice collected as land tax payments from the eastern parts of Japan started to be shipped to Otsu. For this reason, *kurayashiki*, buildings that combined storehouses with residences, were built in Otsu, and the price of rice at the local market became an index of the national rice market by the early seventeenth century. In the late seventeenth century, the shipping of rice from the Sea of Japan region via Lake Biwa decreased dramatically in response to the establishment of the western sea circuit departing from the coastal areas of the Sea of Japan toward Osaka via the Seto Inland Sea. Lake Biwa, however, retained the function as a canal, connecting the east and west, and north and south regions of Japan until being superseded by the railroad system.

Keywords *Otsu Hyakusosen* [a hundred boats of Otsu] • *Funabugyo* [commissioners in charge of boats] • *Kurayashiki* [a rice granary] • *Nishi-mawari* route [the western sea circuit]

Lake Biwa's Function in Transportation and Economy

Lake Biwa is located in the center of the Japanese Archipelago, which stretches a long distance from north to south. This is the narrowest point of land between the Sea of Japan on one side and the Pacific Ocean or Seto Inland Sea on the other. To the west a low pass separates it from Kyoto, which was the capital from the end of the eighth century to the nineteenth century. The establishment of a centralized government in the eighth century brought vast amounts of taxes, in the forms of rice and cloth, to the capital from across the country, and ports at the southern end of Lake Biwa, which were located close to the capital, became major landing sites of rice transported from the eastern half of Japan. Moreover, until around the tenth century, the lake was part of an international route from the Sea of Japan, used by emissaries from countries such as Goguryeo and Balhae, which existed near the current North Korea (Hatanaka 2009).

However, the lakeshore ports were too small to moor many boats at once, and the shallow waters did not allow large-sized, deep-draft boats to enter. Lake Biwa is connected to Osaka Bay, a gateway to the Seto Inland Sea, via its only outlet, the Seta River, which is known further downstream as the Uji River, and then the Yodo River. However, the rapidly flowing reaches from the Seta River to the Uji River were impassable by boat. It is, therefore, considered that Lake Biwa was a closed system in terms of transportation and economics (*Fig. 2*).

Reconstruction of Water Transport on Lake Biwa

Water transportation on Lake Biwa has played an important role for the area since ancient times, but it did not have a unified control framework until the end of the sixteenth century.

Otsu Hyakusousen

A warlord, Toyotomi Hideyoshi, who put an end to a series of wars that lasted almost a whole century since the late fifteenth century, rebuilt the war-torn capital of

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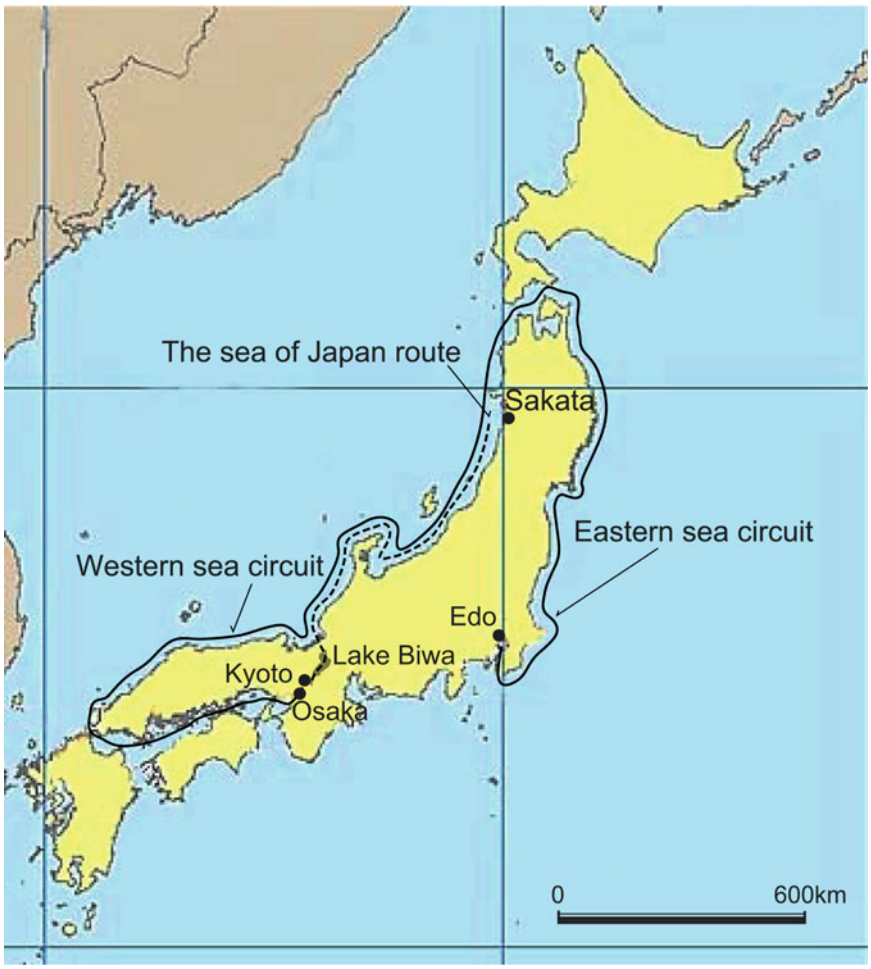

Fig. 1
Sea routes of Japan in the Edo Period.

Kyoto while constructing Osaka Castle on a hill overlooking Osaka Bay. He also developed the town of Fushimi located to the south of Kyoto. Since territories of the Toyotomi regime were ubiquitously distributed in eastern Japan, including the Lake Biwa area, there was a need for rapidly transporting rice collected there as tax to Osaka, Kyoto, and Fushimi. Therefore, Hideyoshi ordered his allegiant, Asano Nagayoshi, to build a castle in Otsu, the lakeshore closest to the capital Kyoto, and then in 1587 to organize a fleet named *Otsu Hyakusosen* (a hundred boats of Otsu). The boats at the port of Otsu alone were not sufficient to make a hundred, so the fleet was organized with the all-out mobilization of boats from other ports in the southern basin, including Sakamoto, Katata, and Konohama (Shimosaka 1980).

The role given to this fleet was to ship rice to the Toyotomi regime as its top priority, which was overseen by Asano Nagayoshi, the head of Otsu Castle. In return, the fleet was granted exclusive use of the port of Otsu together with tax exemptions at other ports.

Subsequent to Asano Nagayoshi, the role of the head of Otsu Castle was performed by Masita Nagamori, then Shinjo Naoyori, and later Kyogoku Takatsugu, while *Otsu Hyakusosen* was granted similar privileges each time. Even after the Tokugawa clan attained control of the government from the Toyotomi regime, the fleet continued to receive the same privileges for over a century.

Funabugyo

During the Edo Period, there were approximately 1,000 boats, large and small, operating on the lake other than the *Otsu Hyakusosen*. In 1591, a position called *funabugyo* was created to monitor those boats and to manage tax imposition and collection (Shimosaka 1980).

At first, Senshun, a monk of Kannonji Temple and a local governor of Hideyoshi's territory, performed the office of *funabugyo*, whose official residence was located at Kannonji town in Otsu. Subsequent to the death of Senshun, the role was performed by Choken and then Choshun, who were also from Kannonji Temple. After Choshun was removed from office by the Edo Shogunate, the local governor of Otsu served concurrently as the *funabugyo*.

Restructuring of the Water Transport on Lake Biwa

What kind of roles did *Otsu Hyakusosen* and *funabugyo* play?

First of all, the monitoring of the number of boats operating on the lake and their cargo was one role. Secondly, the clarified command system enabled easier control of the boats distributed to different ports. In addition, *Tomoori Hatto* (rules) was stipulated by which the unloading of cargo was allowed from people who pulled over their sterns, bringing order to the ports (Yasuoka and Moritani 1980a). Furthermore, a system of transporting goods from eastern Japan, excluding the Pacific side, via Lake Biwa to Otsu was established. Consequently, *kurayashiki*, buildings combining the function of a storehouse and a residence, were developed in Otsu.

At the end of the sixteenth century, water transportation on Lake Biwa was thus restructured.

Prosperity of Otsu

Kurayashiki in Otsu

Kurayashiki refers to buildings with the functions of a storehouse and a residence that were built during the Edo period, from 1600 to 1867, by *daimyo* (local governors) in order to sell rice collected as tax and local specialties. They were located in major cities such as Osaka, Edo (Tokyo), Tsuruga, Sakai, and Otsu, places that were key junctions of transportation and commerce. In Otsu, rice was accumulated and traded with the price set at auction. Otsu was the only inland city where *kurayashiki* was built, indicating the significance of water transport on Lake Biwa.

It seems that the *kurayashiki* in Otsu was built between 1592 and 1596, located on the east and west sides of Otsu-jo Castle (which later became Otsu magistrate's office), facing Lake Biwa to the north, and the lakeshore road with a string of rice wholesalers to the south (Yausoka and Moritani 1980b). According to *Omiroku* (Records of Omi) written in 1688, there were 19 *kurayashiki* buildings in Otsu, including the Okura owned by the shogunate, the Kaga-kura that belonged to the Kaga Domain ruled by the Maeda clan, and the Hikone-gura that belonged to the Hikone Domain ruled by the Ii clan.

Local governors (*daimyo*) were directly in-charge of maintenance and management of *kurayashiki* and, occasionally, delegated the tasks of *kurayado* (merchants that sold rice for the shogunate) and *kuramoto* (constituent members of *kurayashiki*) to rice wholesalers. Consequently, a large amount of rice was accumulated there, leading to the formation of western Japan's major rice markets in Otsu and Osaka, which served as the index of the national market price of rice in the early seventeenth century.

Meanwhile, in Kyoto, the city with the largest consumption of rice, since the end of the eighth century, there was a rice market called *komeba* dating from the Muromachi Period (1392–1573), but it gradually disappeared along with the emergence and development of the markets in Otsu and Osaka.

Prosperity of Otsu

Around 1602, the town of Otsu became a post station on the Tokaido Road (the main road of Japan in the Edo Period) connecting Edo (Tokyo) with Kyo (Kyoto). Otsu Castle was abandoned after being destroyed in the skirmish that led to the Battle of Sekigahara in 1600. The center of the ruins was turned into the magistrate's office of Otsu and Okura (a *kurayashiki* owned by the shogunate) and the remaining area was developed into a downtown area. Part of the moat began serving as the landing place at the port of Otsu.

The bustling town of Otsu was painted on the *Omi Meisho-zu* of the early seventeenth century (an illustrated map of famous spots in Omi, owned by Suntory Museum). Wooden floats for use in the Otsu Matsuri festival, which continues to be held today, were constructed one after another after the float of Tanukiyama was built in 1635. As a port town, a post station town, and a temple town of Miidera, Otsu had grown into the largest city on the Tokaido Road with a population of 18,774 in the year 1691.

Establishment of the Western Sea Circuit

Drawbacks of Water Transportation on Lake Biwa

For transportation of goods, Lake Biwa functioned as a part of the Sea of Japan route (*Fig. 2*). The cargo from the Northern provinces were shipped down this route, unloaded at Tsuruga or Obama, and then carried by horses across a mountain pass to the ports at northern Lake Biwa such as Shiotsu, where the cargo was transported on water to Otsu. Then, the cargo was unloaded again and transported to Kyoto or Osaka by crossing another pass.

Crossing two mountain passes greatly hindered transporting a large amount of cargo at one time, and the repeated transshipments not only caused damage to the products but also required additional handling fees. Thus, it was disadvantageous for traders (*Fig. 1*).

Kawamura Zuiken's Western Sea Circuit

Kawamura Zuiken, a merchant and civil engineer, succeeded in reducing shipping costs by transporting goods from northeast Japan via the Pacific Ocean to Edo (*higashi-mawari* route, the eastern sea circuit) without any transshipment. In 1672, on orders of the shogunate, he took charge of the transportation of rice from Sakata in Dewa province (the current Yamagata Prefecture) to Edo. This route headed southward from Dewa on the Sea of Japan, passing the Hokuriku and Sanin areas, through the Seto Inland Sea, via the Kammon Straights, went around the Kii peninsula, and then headed north to reach Edo (*nishi-mawari* route, the western sea circuit) (Yausoka and Moritani 1980a) (*Fig. 1*).

In the *Kanbun Zakki* (Random records of the Kanbun Era), written between 1661 and 1673 by the Uda clan, a wealthy merchant family of Tsuruga, a comparison of

Fig. 2
Ports around Lake Biwa.

expenses was made for shipping 15 metric tons of rice with the market price of 60–100 million yen from Echigo Province (the current Niigata Prefecture) through the western sea circuit via the Seto Inland Sea to Osaka, and the alternative of landing the same amount at Tsuruga and transporting it to Otsu via Lake Biwa. According to the trial calculation, the shipping cost to Otsu was cheaper due to the shorter distance, but considering damages to the goods and handling fees that needed to be paid to the wholesalers at transshipment, and the difference in market price between Osaka and Otsu, shipping to Osaka would result in an increase of profit of 584 silver *monme* (about 600 thousand to 1 million yen in today's money).

By developing a sea route, the shipping of goods from the Sea of Japan side to Osaka and Edo without going through Lake Biwa became more advantageous.

Effect of the Western Sea Circuit on Lake Biwa Transportation

Dwindling Number of Boats

The amount of rice and soybeans entering Tsuruga peaked between 1661 and 1673 with an annual average of 33,600 metric t. This had fallen to half during the period from 1688 to 1704, and to one fifth during the period from 1716 to 1735. In short, the number of boats entering Otsu with cargo that went through Tsuruga dropped drastically along with the establishment of the western sea circuit.

Otsu Hyakusosen, a fleet with its role gradually specialized to the transportation of goods from the Sea of Japan region in eastern Japan, owned 102 boats in 1665 and 107 boats in 1693, but the number continued to decline thereafter to 47 in 1725 and 39 in 1766. The rise of Hikone Sanminato (three ports in Hikone) with the backing of the Hikone Domain is also considered to account for this (Yausoka and Moritani 1980a).

Transformation of the Town of Otsu

In the early seventeenth century, Otsu had a significant influence on the market price of rice due to the accumulation of vast amounts of rice collected as land tax. However, the goods that used to come into Otsu from the Sea of Japan area in eastern Japan started to be shipped to Osaka when the western sea circuit was established. As a result, the rice market of Otsu gradually declined while the market of Osaka grew dramatically to become the center of distribution, being called the "Kitchen of the Country." As a result of this, 14 of the 20 rice granaries, called Okura, owned by the shogunate in Otsu were abolished in 1700.

The *Nippon Eitaigura*, published by Ihara Saikaku in 1688, records the conditions in Otsu during that time, and details that one resident had debts amounting to 3,750 kg of silver (equivalent to 1–1.6 billion yen in today's money), which was extremely rare in Otsu. However, in the late seventeenth century when this book was written, there were people who went bankrupt with debts four times as much as this in Kyoto and Osaka, implying that the prosperity of these areas was much greater in contrast to the downfall of Otsu (Yasuoka and Moritani 1980b).

Subsequent Water Transportation on Lake Biwa

Although the whole picture is not clear due to lack of data, the amount of rice that was transported into Otsu was 45,120 metric tons in 1659, 84,000 in 1773, and 47,400 in 1828. This indicates that water transportation on Lake Biwa did not crumble while suffering from the development of the western sea circuit (Kanemaki 2005). The rice collected in the Lake Biwa, Tango, and Wakasa areas continued to be transported on the lake to Otsu, and *kurayashiki* buildings remained in use on a smaller scale. Otsu was still playing the role as one of the leading industrial cities. The first long-distance railroad line in Japan, which was launched between Tokyo and Kyoto (the current Tokaido line), had ferryboats connect the section from Nagahama to Otsu. In fact, ferryboats were in service for several years until the railroads were fully opened. In the proposal for the first railroad, it is written that the interval from Nagahama to Otsu can be left to the water transportation on Lake Biwa, and the building of a railroad between these two points was not indispensable. This indicates that water transportation on Lake Biwa was highly valued (Nakamura 2009).

Lake Biwa had functioned as a canal connecting the east and west, north and south of the Japanese Archipelago, and the ports, including Otsu, attained prosperity until railroads became commonplace.

4.2.4 *Maruko-Bune* and its Role in Lake Transportation

Kumi Makino

Abstract *Maruko-bune*, "*bune*" meaning boat, is a type of traditional wooden sailing boat only found in the Lake Biwa region. This type of boat played a major role in lake transport, especially during the Edo Period, around the seventeenth and eighteenth centuries. More than 1,300 *maruko-bune* boats were in service during that period. They relayed cargo that arrived via the Sea of Japan from various parts of Japan, especially the northern regions, to the ancient capital area on the routes connected by rivers and land around Lake Biwa. The lake was a convenient route for transporting large cargos, and the *maruko-bune* was an inevitable choice for this purpose. This role of the *maruko-bune*, however, changed along with the changing social and economical roles of Lake Biwa.

Keywords *Maruko-bune* [traditional wooden sailing boat] • Water transportation • Cultural transformation

Introduction

The Lake Biwa region once played an important role as a route of transportation. This role was, however, reduced after the development of a new marine route through the Sea of Japan and Seto Inland Sea in the late seventeenth century, and it almost came to an end after the development of a railroad system in the nineteenth century. The role of *maruko-bune* as cargo boats was forced to end in this manner. *Maruko-bune*, however, did not disappear right away, and some survived until the mid-twentieth century experiencing a process of functional change (Makino 1999, 2008). The process can be traced in the shape and building techniques of *maruko-bune*, letting us understand the nature of the lake transportation in the Lake Biwa region.

This article is mainly based on the information and materials collected during the *maruko-bune* reconstruction project from 1992 to 1995 (Yoda and Makino 1999). It was a great opportunity for the author, as a research scientist of the Lake Biwa Museum, to be able to participate in this project. *Maruko-bune* had neither been built nor used for already half a century when the project was initiated. Thus, not much was known about these boats at that time. In the project, information concerning the building techniques and the historical background of their use, which were either forgotten or only known by carpenters, was collected and recorded. Oral information provided by boat carpenters, in particular, had a great importance since most of it was never recorded in written documents.

What Is a Maruko-Bune?

A *maruko-bune* is a type of wooden sailing boat found only in the Lake Biwa region, the origin of which is still unknown. As *maru* means "round," it is probably named after the curved shape of the boat in distinction from other wooden sailing boats used in fishing, and farming in wetlands which disappeared between the 1930s and 1980s.

A *maruko-bune* consists of six main structures: *shiki* (the bottom), *shin* (the bow), *heita*, *furikake*, *omogi* (the side planks), and *hobashira* (the mast) (› *Fig. 1*. *Shiki*, referring to the bottom of the boat, was constructed with several cedar planks joined together by sewing nails (*nui-kugi*), a type of nail used in almost every part of the boat. *Omogi* are the halves of a cedar log attached to both sides of the boat that contribute to the stability and the round shape of *maruko-bune*. Since the bow piece (*shin*) is the most important part of the boat, before it is attached, carpenters would choose an auspicious day and pour *sake* on the surface of bow, praying to gods for the success of the construction. *Heita* are planks made of *Podocarpus* trees (a type of conifer) and form the front part of the boat.

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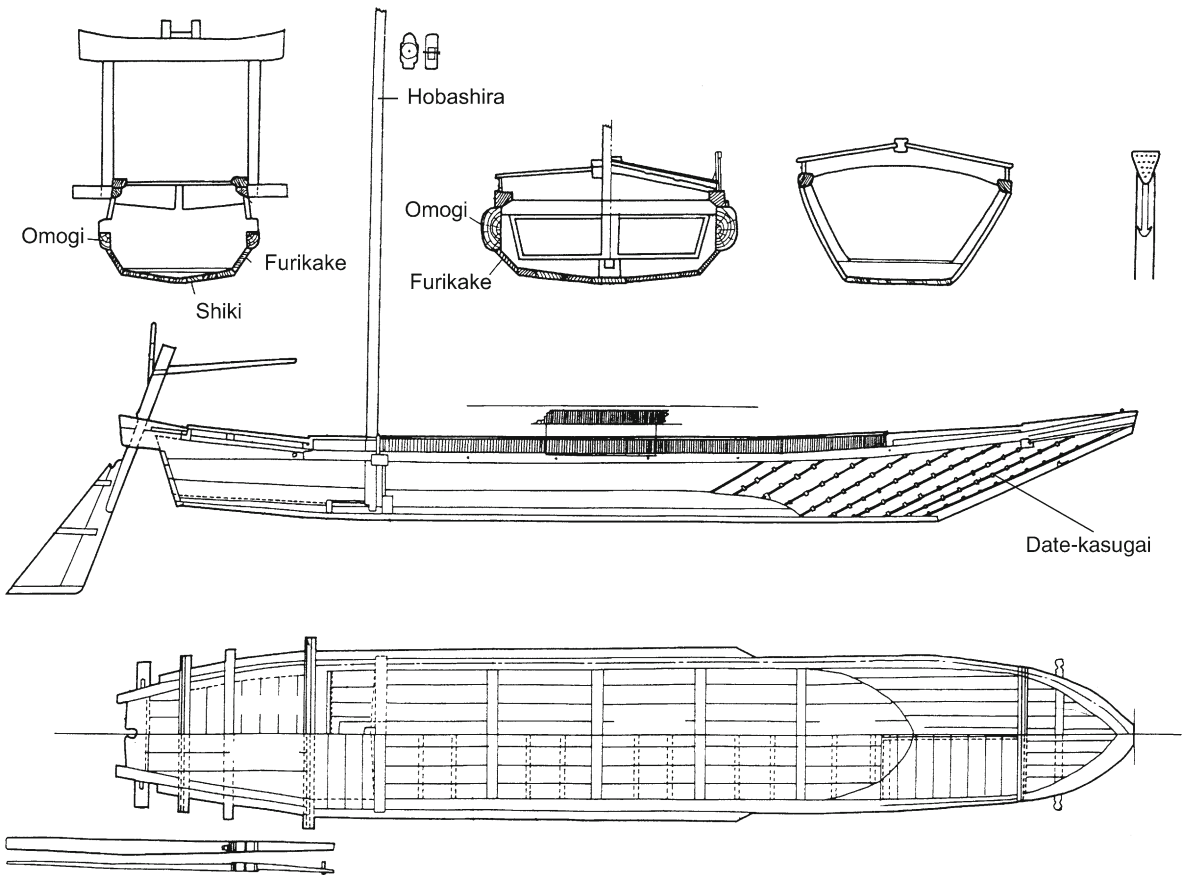

Fig. 1
Plan and sections of *maruko-bune* boat. Names of the characteristic wooden parts mentioned in the text.

Podocarpus is also used for the *shin* and *furikake* (between the *omogi* and *shiki*), since it contains a lot of oil that will protect the boat by repelling water. The planks are tied together with sewing nails so as to fill the space between the *shin* and *omogi*.

The boat is decorated with copper plates that are colored black with a mixture of charcoal and rapeseed oil. These plates were originally used for covering the gaps between planks, but later they were used mainly for the decoration of the boat. The front part of the boat called the *date-kasugai* (black patches shown in *Fig. 1*) is a common trait of boats in the Lake Biwa region, and it can be seen even on modern fiber glass boats.

Though there were three main different sizes of *maruko-bune*, medium-sized boats with an interior volume of 80 to 100 *koku* (1 *koku* is about 180 l) were most likely to be used on Lake Biwa as well as other water routes in this region. These water routes were sometimes shallow and narrow, so were not suitable for the operation of large-sized boats, a crucial weakness for cargo transport using boats. To compensate for the limitation of size, the round body was specially adopted; the round shape of *maruko-bune* is established by *omogi* and *heita*, and it allows greater interior volume without deepening the boat. The *maruko-bune* reconstructed in the project is also a medium-sized boat with a length of 19 m including the helm, 2.4 m in width, 1 m in depth, and 12 m in height including the mast (*Fig. 2*).

From Prosperity to Decline

In the Edo Period, cargo from various parts of Japan, especially the northern regions, was transported to Wakasa Bay on the Sea of Japan coast, from where it made its way overland to the northern part of Lake Biwa. *Maruko-bune* played the role of relaying the cargo down the length of the lake to Otsu, from where it was transported overland to the ancient capital area of Kyoto. The cargo mainly included

Fig. 2
The completed and exhibited *maruko-bune* boat at the Lake Biwa Museum.

rice collected as land tax and valuables such as preserved marine products, clothes, and dyeing materials. Lake Biwa was a convenient route for the shipping of these large cargos, and *maruko-bune* boats were an inevitable choice for this purpose.

The shift of the economic center from Kyoto to Osaka led to the development of a new marine route, the "*nishi-mawari*," the western sea circuit, after 1672, which connected the ports on the Sea of Japan with Osaka through the Shimonoseki Strait and the Seto Inland Sea (*Fig. 3*). There was an advantage by taking the *nishi-mawari* route since it removed the need for stopping at Tsuruga or Obama on the Sea of Japan coast, and the cargo was directly transferred to Osaka. More than 1,000 *maruko-bune* boats were, however, known to be still in service at any given time from the middle of the seventeenth century to the end of the eighteenth century, based on analyses of historical documents.

The number of *maruko-bune* decreased as their role in lake transportation diminished after the railroad system was completed around Lake Biwa in 1889. They almost disappeared after the Second World War (Miyahata 1978; Hashimoto 1979a, b). Research has shown that the number began to decrease together with the collapse of the supply chain of raw materials for boat carpenters due to the loss of traditional forestry-related occupations in the early 1930s (Makino 1999). Thus, freight transportation on Lake Biwa ceased, while the boats started serving the interest of leisure and tourism.

Struggle for Survival

While remaining in use, the roles of *maruko-bune* went through changes brought about by nature, political situations, goods to be transported, methods of boat building, and so on.

One interesting phenomenon is the changes made to their shapes over time. While it is commonly assumed that *maruko-bune* had a sharp bow (*shin*), several documents show that this type of bow might have been introduced in the early nineteenth century. The document, "*Wakan-sen-yo-shu*," which provides an introduction to Japanese traditional boats, shows a shape of *maruko-bune* in the mid-eighteenth century that is not the same as the modern examples that we know today. The document explains that these types of boats were built "long and deep, with planks attached from the top to the bottom in a round shape." This method was even applied to the front part. Thus, *maruko-bune*

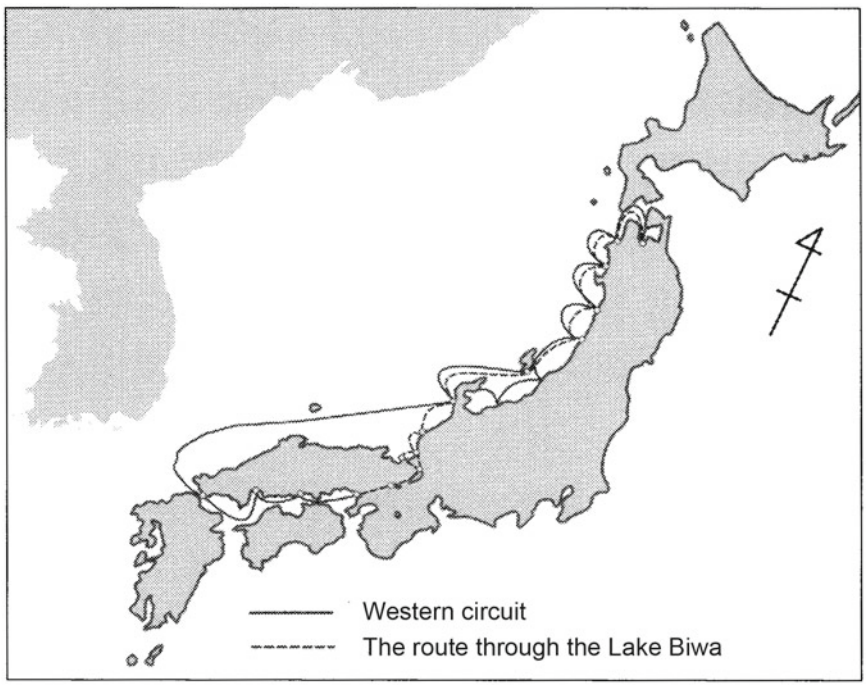

Fig. 3
Map of two sea routes, one through Lake Biwa and the other western circuit.

in the mid-eighteenth century had no bow piece (*shin*), and its whole shape was similar to a bathtub. Another document from the same period, "*Maruko-bune-sunpou-cho*," which documents measurements of *maruko-bune*, shows how to build a boat with the *shin*, saying "if the *shin* has a suitable length, it will support the *heita*." Although there are no remains of boats without a *shin*, these mid-eighteenth century documents show that there were two types of *maruko-bune*, one with and one without the *shin*. The *haya-bune* documents, dating back to the early nineteenth century, indicate that the development of the *shin* might be related to a requirement for an increase in speed in order to utilize *maruko-bune* for tourism. Recent studies also show that the shape of *maruko-bune* was transformed due to the demand for speed rather than stability (Makino 2007, 2009), which implies that people have tried to keep the design of *maruko-bune* up-to-date to cope with their changing roles from cargo transportation to tourism.

Conclusion

Material culture often reflects the relationship between people and nature, as do the traditional boats in the Lake Biwa region. In particular, the shape, construction techniques, and roles of *maruko-bune*, the main tool of lake transport in this region, demonstrate the historical, economical, and social impact of the lake and other related watercourses on local people.

Acknowledgements

I would like to thank the staff of the Lake Biwa Museum for giving me inspiration from various academic fields, and Mr. Sanshiro Matsui and Mr. Mitsuo Matsui, the last *maruko-bune* carpenter and his son, for sharing their precious knowledge and techniques with us.

4.3 Period of Exploitation

Masaharu Yoda

From the end of the Edo Period in the middle of the nineteenth century, when the feudal system was about to collapse, western ideas, technologies, institutions, industries, and culture had been pouring into Japan. During this period, in 1869, modern steamboats went into service on Lake Biwa. They played an important role not only in the Lake Biwa area, but also as a part of the main transportation network of Japan until the late Meiji Period, when railroads were built. From the early twentieth century, the steamboats were used for tourism, an activity that continues to the present day in different forms.

Meanwhile, the abundant water resources gave rise to the textile industry in the Lake Biwa area, which became a key driving force for the modernization of Japan. The Lake Biwa Canal was built in 1890 to supply water and hydroelectricity to the former capital of Kyoto, followed by the Nango Weir in 1905 to control and manage the water flowing out of Lake Biwa as a resource. Although it was a dam intended to prevent floods and droughts, it was built primarily to ensure a steady water supply to Kyoto and Osaka. This was also one of the aims of the Seta River Weir built in the late twentieth century, and the national Lake Biwa Comprehensive Development Plan that started in 1972.

Thus, modern technologies started to be adopted for water resource management and full-scale exploitation of Lake Biwa, which led to the reconsideration of the idea, which has existed as far back as the twelfth century, of a canal connecting the Sea of Japan and the Pacific Ocean via Lake Biwa.

On the other hand, for people living around the lake, the use of boats for daily transport and the utilization of water itself had not changed since the previous era. Traditional festivals and ceremonies associated with the lake had also continued in people's daily lives. Such daily usage of the lake persisted until the late twentieth century, the postwar era of high economic growth that began around 1965, but it went through a radical transformation from then onward. The lake lost its function as a transport route, and boats were thereafter used just for fishing and tourism. The domestic use of water was entirely provided by water supply systems, while water pollution became evident along with the industrialization in the lake area. A sewerage system was eventually built, and the Lake Biwa Comprehensive Development Plan was initiated as a national project for the purpose of sustainable utilization of water resources.

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4.3.1 People's Livelihoods and Utilization of Attached Lakes

Shizuyo Sano

Abstract Attached lakes of Lake Biwa are rich in biological resources, but many of them have been lost through reclamation projects from 1943 onward. They had been important areas of subsistence activities for humans for over 1,000 years, because they can provide environmental resources, such as waterweeds, mud, and reeds, which had been used in various ways in the village communities along the shores until the 1940s. These activities were necessary to maintain an interactive system, which are the local ecosystems involving humans. Just like *satoyama* (landscapes developed through agricultural and forestry use), attached lakes can be recognized as "traditionally managed environments" that were closely tied to people's lives. Traditional utilization management methods should be applicable to the conservation and ecological restoration of attached lakes in the future.

Keywords Attached lake • Reed • Waterweeds as fertilizer • Traditionally managed environments

Introduction

Attached lakes mentioned here are lagoons formed around the shores of Lake Biwa. There used to be over 40 attached lakes around Lake Biwa (*Fig. 1*), but many of them were lost by reclamation projects from 1943 onward: at least 2,521 hectares have been lost (Nishino and Hamabata 2005). The remaining ones no longer retain their original shapes and are lined with concrete revetments.

In recent years, attached lakes have been reevaluated for their ecological function as a spawning ground for fish (Nishino and Hamabata 2005). These lakes, nurturing highly diverse ecosystems, had been "the space with rich biological resources" for humans as well, and had been center stage for human activities, including fishing and gathering, for over 1,000 years until the 1940s. This paper investigates the attached lakes from the perspective of their relationships with humans, as well as examining the influences of human activities on the ecosystem of the attached lakes, along with their role in the history of Shiga Prefecture. This paper also attempts to see how future conservation of attached lakes can be achieved by looking at how they have been managed in the past.

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Landforms and Biological Resources of Attached Lakes

A particular feature of the attached lake is that it is partially connected to Lake Biwa (main lake) by a waterway, while beach ridges block waves from the main lake, thus forming calm waters. Attached lakes are fairly shallow with an average depth of less than 2 m in most cases, while Lake Biwa has a maximum depth of 104 m and an average depth of 44 m.

Such calm waters with muddy sediment, as like as shallow calm bays, are the preferred habitat for waterweeds and reeds that are susceptible to wind and waves. More importantly, waterweeds and reed beds serve as spawning grounds for cyprinid fishes from Lake Biwa, such as crucian carp (Kawanabe 1999; Rossiter 2000). Fishes migrating to attached lakes in early spring for spawning have been an important fishery target, from which the traditional *eri* fish trap, has elaborated and developed in Shiga Prefecture (Sano 2011). Crucian carps caught by *eri* fish traps were often lactate-fermented with rice to produce the famous "funa-zushi" (fermented crucian carp), which is part of the food culture unique to Shiga (Yasumuro 2005). Thus, behind the unique local folk culture associated with crucian carps, the attached lakes play an important role as fishing grounds; and, thus, these lakes are very valuable to people.

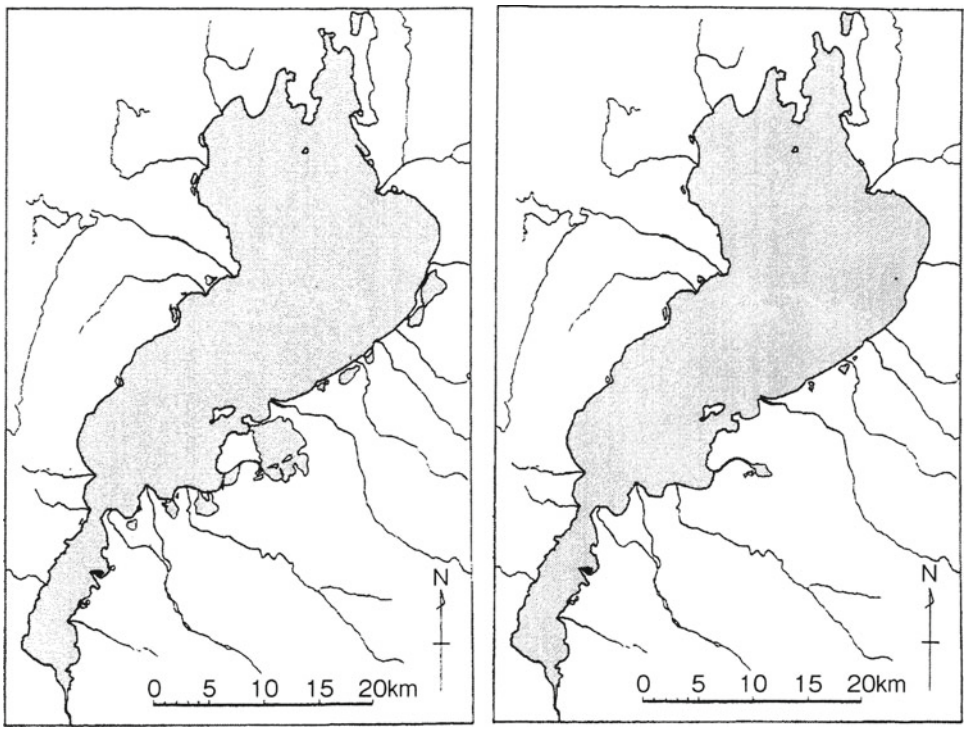

Fig. 1

Decrease in the total area of the major attached lakes around Lake Biwa due to reclamation projects in the Showa Period (left: 1940s; right: 1990s). Each lake is somewhat enlarged to exemplify the location. (Sano, S., 2010:84, Fig. 3–1).

It is not just fishes that inhabit attached lakes. The calm shallow waters are also favored by waterfowls, such as the mallard duck that feeds on waterweeds, as safe feeding locations with abundant food sources. Therefore, for the local people, the attached lake has been an important area not only for fishing but also for hunting waterfowls.

Historical Significance of Attached Lakes

Besides the important function of the attached lakes as fishing grounds, their function as ports must not be overlooked. With beach ridges blocking out the waves, the calm and shallow attached lakes served as natural ports for boats. In the early Showa period, among the major ports of Lake Biwa, there were many taking advantage of attached lakes (e.g., Katata, Maibara, Nagahama).

As early as the Nara (710–794) and Heian (794–1185) Periods, powerful people in the area started to regard attached lakes as key areas around Lake Biwa due to their value as fishing grounds and ports. Territories under the direct control of the imperial court or powerful shrines, *mikuriya*, were placed around attached lakes, within which the residents were organized into *niebito* and *kugonin*, being granted privileges of fishing and transportation on the lake (Sano 2008).

With such privileges, people based at ports around attached lakes grew into organizations strongly influencing the transportation on Lake Biwa, and later became the naval forces in the following era. As a naval force, fishermen of the Katata area were outstanding, and were referred to as *kozoku* (pirates of the lake). Katata communities were formed on the beach ridge of an attached lake. The waterways leading to Lake Biwa could obviously be taken advantage of as ports by the residents.

It was Oda Nobunaga, a powerful feudal ruler of the sixteenth century, who took particular note of the port function and military potential of the attached lakes. Among the four castles around Lake Biwa constructed by Nobunaga, three were intentionally located in the areas of attached lakes (Sano 2008).

Thus, since ancient times, attached lakes had been valued as key junctions for commodity distribution and military affairs, serving as the center stage of history in Shiga Prefecture.

Utilization of Attached Lakes in Everyday Life

While the above is mainly focused on the history regarding the utilization of attached lakes, it is also necessary to analyze people's daily activities associated with these lakes. The lives of people on the shores of attached lakes before reclamation is investigated below based on interviews.

Communities were located on the beach ridges facing both Lake Biwa and the attached lakes, while utilization of the two water bodies was clearly separated. Local residents had their mind set that "the dirty water" should be drained into the attached lake. Domestic wastewater from washing, etc. was all consciously drained into the attached lake. On the other hand, it was often heard that people were strictly taught by their mothers that, "the wastewater cannot be drained toward Lake Biwa." Likewise, the drainage from the surrounding paddy fields was also discharged first into the attached lake.

Nutrients in wastewater were gradually deposited at the bottom of the attached lake, and the relatively clean surface water flowed out into Lake Biwa. In other words, the attached lake had functioned as "a precipitation purification tank." Such a use of the attached lakes was widely acknowledged in Shiga Prefecture.

While conserving the water quality of Lake Biwa, this mechanism would accumulate sludge in the attached lake, potentially accelerating eutrophication. However, the bottom mud and flourishing waterweeds were dredged up on regular basis by local residents. This effort was not intended to clean up the lake, but to use the sludge and waterweeds as fertilizer.

The paddy fields around attached lakes were located in swampy areas, thus it was difficult to use farm animals for plowing. Animal manure was hence not easily accessible. Rice straw was the most common source of compost, but it was more often used as fuel since people were not able to obtain sufficient fuel wood on the lakeshore due to sparsely distributed forests. Therefore, the waterweeds and sludge, which absorbed phosphorus and nitrogen from the water, were valuable fertilizers free of cost for farmers at that time (Shiga Prefectural Agricultural Experiment Station 1939).

At many attached lakes, waterweeds were gathered for fertilizer during an allotted time period every year. In a village, for example, waterweeds were gathered from May 15th to 31st for wet paddies, and from August 1st to September 30th for dry fields. The gathering of waterweeds was banned between June and July when cyprinid fishes swam into the attached lakes from Lake Biwa for spawning.

Although reeds have been growing gregariously since long ago on the shores of attached lakes, it is only recently that their water purifying function by absorbing nutrients has attracted much attention. Reed beds presumably contribute to the improvement of water quality, but they die in winter and if left uncut, the absorbed nutrients may dissolve back into the water. In the past, however, reeds were gathered by local communities every January and utilized as roofing material. This traditional practice unintentionally prevented the release of nutrients back into the lake, which had an important role.

If reed beds are left untouched in areas with active sediment deposition, it is known that as aggradation and desiccation proceed, they gradually change, for example, into stands of willow trees. On the other hand, in the areas where reeds are gathered regularly by people, the removal of the dead reeds functions as an artificial disturbance, resulting in a temporal halt of this process. It is important to acknowledge the fact that such human activities have helped to maintain the landscape of reed beds.

Waterside Ecosystems Involving Human Activities

As stated above, activities such as utilizing the attached lake as "a precipitation purification tank," and gathering waterweeds, sludge, and reeds for fertilizer were correlated with each other (*Fig. 2*). Such utilization by local residents had created diverse interactions between humans and attached lakes. However, more importantly, all these relationships were linked together to form one large, interactive system. The use of attached lakes by humans helped to maintain a particular type of environment, and thus humans played a central role in this ecosystem.

The idea of nature conservation in the past was that humans were bad for the environment; hence, there was a strong preconceived idea that nature should be left untouched. However, as seen in the recent reevaluation of *satoyama*, the value of "traditionally managed environments," which have been maintained by subsistence of the local people, is being reconsidered (Washitani and Yahara 1996). Attached lakes are also considered as "traditionally managed environments," and their presence has been connected with human life as closely as *satoyama*.

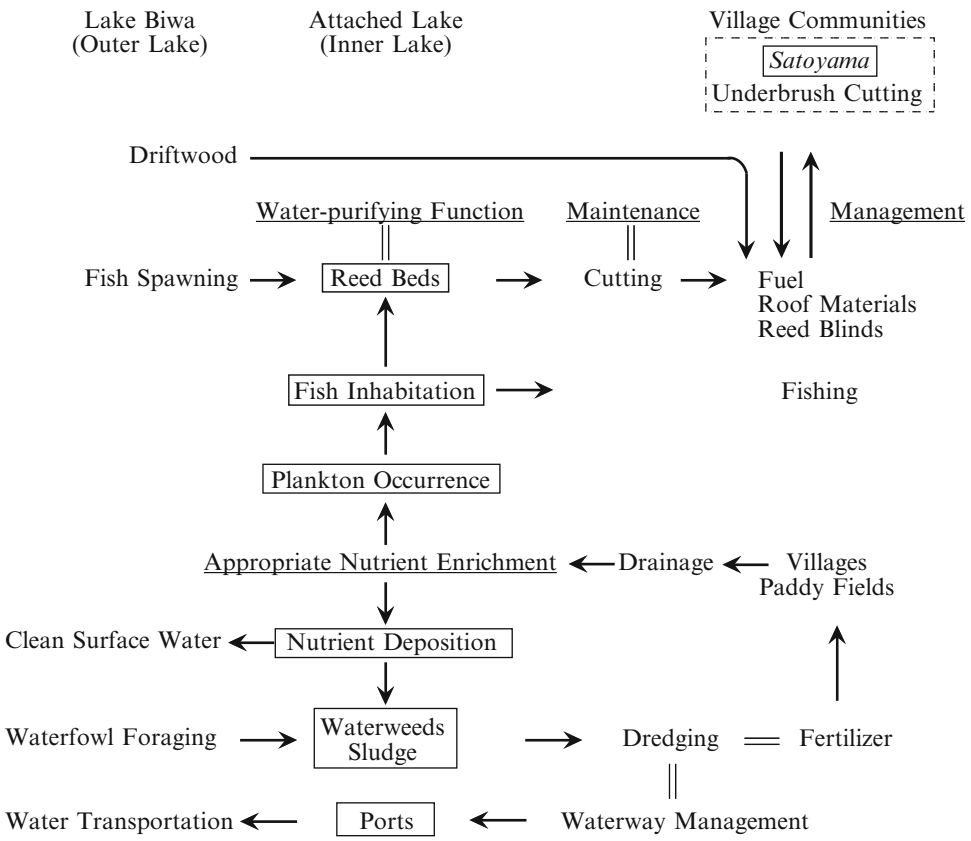

Fig. 2
The interactive system of the use and conservation of attached lakes.

It is noteworthy that village communities around attached lakes had social rules established to support the interactive system of such "traditionally managed environments." The valuable resources of attached lakes, including waterweeds, reeds, and crucian carps, were comanaged as joint property of the village communities, and personal, arbitrary use of these resources were barred.

The diverse interaction between humans and attached lakes indicated above lasted until the beginning of the Showa Era (1926–1989), when it faced a major turning point. First of all, attached lakes experienced a severe lowering of water levels due to that of Lake Biwa in 1926–1930, the lowest water level in the Spring spawning season (Kinki Regional Development Bureau 1956), The inflow of organisms from Lake Biwa was disturbed, resulting in a record decline of biological resources and plants, such as waterweeds, in attached lakes (Agricultural *Junior College* of *Shiga Prefecture* 1950).

Around the same time, a major change was about to occur in people's lifestyles in the attached lake areas. Instead of individuals simultaneously farming and fishing, people made a transition to either farming or fishing. This livelihood specialization took place in conjunction with a separation of working space. Full-time fishermen moved their fishing grounds to Lake Biwa seeking more resources. Meanwhile, attached lakes became increasingly important as auxiliary farming spaces.

Due to changes in both natural and social environments, the diverse relationships between local inhabitants and attached lakes were gradually lost. While valued as fishing and gathering grounds until the beginning of the Showa era, attached lakes eventually became uniformly viewed as space efficiently "convertible to farmland." This is considered as the main cause for the promotion of reclamation after the middle Showa era (Sano 2008).

Conclusion

As indicated above, attached lakes had a significant role both ecologically and culturally. The shallow lakes with mild wind and wave were desirable habitats for waterweeds and reeds, which became home to a rich fauna of fishes and waterfowls, and were also easily accessible fishing and gathering grounds for the local people. Utilization of the rich fauna allowed people to form a diverse folk culture. In other words, the biodiversity and folk culture of the Lake Biwa area were fostered in the entire lake area, including the surrounding attached lakes that functioned as land/inland-water ecotones.

The importance of attached lakes should be reevaluated from the above perspective. However, the understanding of the function played by attached lakes is not sufficient at present. This is reflected by the fact that although Lake Biwa was registered with the Ramsar Convention for the "conservation and appropriate usage" of wetlands in 1993, (see Topic 23), none of the surrounding attached lakes are included, except Nishino-ko, which was only added to the list in 2008.

Attached lakes are "traditionally managed environments" connected with human life just like *satoyama*, and they would be subject to silting up if left untouched. Therefore, "appropriate maintenance" is needed for conserving these types of environment, rather than leaving them natural. To properly manage the attached lakes, the appropriate level of human intervention should be studied first from traditional practices.

In the case of *satoyama*, research has been carried out to establish the best ways to restore its ecology. There are even manuals providing instructions on when and how much to cut the underbrush, which are all based on the traditional lifestyles of local residents that were inseparable from *satoyama*. Likewise, it is essential to examine in detail what kinds of waterweeds were gathered, and when and how much was taken from attached lakes in order to learn the appropriate methods of vegetation management and biotechnical restoration suitable to the area.

Traditionally managed environments that come in balance with human intervention are liable to change. Its ecosystem, fauna, and flora vary across the ages. Since there is no clear goal for "nature restoration" at attached lakes, historical verification of the overall environmental change is indispensable. Detailed examination of the attached lakes before reclamation and the lifestyles of local communities, while these are still remembered by the residents, should be the first step in constructing a suitable and sustainable relationship between humans and attached lakes.

Acknowledgments

I am grateful to A. Hattori and M. Horikawa for their valuable advice on the manuscript.

4.3.2 The Long-held Idea of a Lake Biwa Canal

Masaharu Yoda

Abstract A series of attempts were made throughout history to construct a large-scale canal connecting Lake Biwa either to the Sea of Japan or to the Pacific Ocean. This is because Lake Biwa is located approximately at the center of the main island of Japan, between Wakasa Bay on the Sea of Japan side and Ise Bay on the Pacific side. Most of the canal projects planned to connect Lake Biwa to the Sea of Japan, and the idea to connect the lake to Osaka or to Ise Bay was brought up later. These attempts were mostly for the sake of the economy, while other purposes, such as flood control, were also included.

Keywords Canal • Ise Bay • Wakasa Bay • Pacific Ocean • Sea of Japan

Since Lake Biwa is located approximately in the center of the main island of Japan, with Wakasa Bay on the Sea of Japan side and Ise Bay on the Pacific side, a series of attempts were made throughout history to build a large-scale canal connecting Lake Biwa to the Sea of Japan or the Pacific Ocean.

At the end of the Heian Period (794–1185 AD), Taira-no Kiyomori, head of the most powerful warrior clan in Kyoto at that time, ordered his son Shigemori, who was a local governor (*shugo*) of Echizen Province, to build a 25-km long canal starting from Shiotsu in the north of Lake Biwa toward Tsuruga, facing the Sea of Japan. The work, however, came to a halt at a point about 12 km from the port of Shiotsu, where it was obstructed by the huge rocks of Mt. Fukasaka. It was said that at the end of the canal Shigemori erected a statue of Jizo (Ksitigarbha) called "horidome-no-jiizoson," literally meaning "a canal stopping statue." In the Azuchi-Momoyama Period (1568–1600), Toyotomi Hideyoshi, the person at the helm, ordered Otani Yoshitsugu, the owner of Tsuruga Castle, to build a canal from Oura toward Tsuruga, but this attempt also failed due to encountering a rocky hill. This incomplete canal was named "Taiko no ketsuwari-bori," meaning Hideyoshi's abandoned moat.

In the Edo Period (1603–1868), in order to rebuild Lake Biwa transportation, which was on the decline after goods from northern provinces started to be shipped via the *nishi-mawari* route (western sea circuit) to Kyoto and Osaka, the idea of connecting Lake Biwa to the Sea of Japan by a canal was brought up many times, mainly by merchants, including Suminokura Ryoi and Kawamura Zuiken. Later, flood control and development of new fields on the lakeshores were added as reasons to build a canal, but the attempts faltered every time in the face of counter-views from local, lakeside villages, and the shogunate. At the end of the Edo Period, Hikone Domain drew up a canal project to connect Lake Biwa to Ise Bay, which once again did not come to realization.

In 1923, the army captain Yoshida Kozaburo took over his father's, Gennosuke, proposal for connecting the Sea of Japan and the Pacific Ocean by a canal, and he announced a grand plan called the Great Hanton Canal (a canal connecting Osaka to Tsuruga) that could have enabled a 3,000-t class steam ship and a 4,000-t class warship to pass through. Then, in 1935, Tanabe Sakuro, the chief engineer of the Lake Biwa Canal project (a waterway intended to supply water to Kyoto), drew up a plan for the Great Lake Biwa Canal that could be passable by a 10,000-t class ship. Both of these plans were to connect the Sea of Japan to Osaka through Lake Biwa and its outlet, the Seta River, called the Uji and Yodo rivers further downstream.

Yoshida's plan was to lower the water surface of Lake Biwa by 43m to make it about 41m above sea level. The surface area of the lake would be reduced by half, and the rest would be subjected to reclamation. This was to reduce the number of locks needed to resolve the difference in water levels, as well as to increase farmland.

The last plan was drawn up in 1961 by the political baron Ono Tomochika and the mayor of Yokkaichi, for building a canal cutting across Japan to connect Ise Bay,

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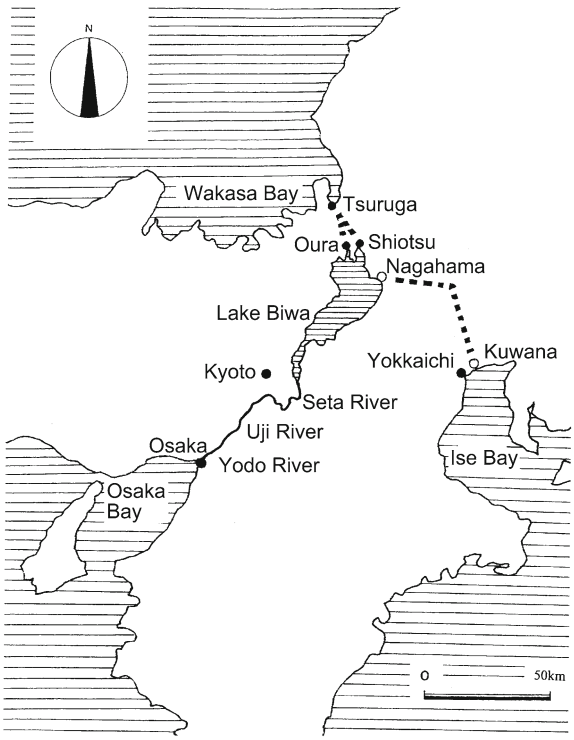

Fig. 1
Some plans of canals.

Lake Biwa, and Tsuruga that would allow the passage of a 30,000-t class ship, while serving a flood control purpose and providing water to the industrial areas in Yokkaichi City. Even though a budget for the surveying of the route was approved by the Ministry of Construction, the project was again abandoned due to the huge competing demand for national expenses for constructing the Meishin Expressway, connecting Nagoya and Kobe (Takebayashi 1999).

Thus, in most cases, the canal projects were intended to connect Lake Biwa to the Sea of Japan, while plans were brought up later to connect the lake to Osaka or to Ise Bay. These attempts were made primarily to meet economical needs; and other purposes, including flood control, were only secondary considerations.

In 1722, merchants in Kyoto made a request to the shogunate for building a canal connecting Lake Biwa to Tsuruga. Once the canal is completed, it would lower the water level of the lake by about 60 cm, resulting in the emergence of some lands, and greatly shorten the route for transportation of goods from the Northern provinces. The purposes of the merchants were to take advantage of the newly emerged lands and the transportation convenience. This is a good example of what has been behind the idea of building a Lake Biwa Canal (*Fig. 1*).

4.3.3 The Recent Shift in the Role of Lake Biwa from Transportation to Tourism

Masaharu Yoda

Abstract In the late seventeenth century, during the Edo Period, as a result of the establishment of the western sea circuit (*nishi-mawari* route) that allowed goods from the Hokkoku region (Northern provinces on the Sea of Japan side) to be shipped to Osaka through the Seto Inland Sea via Shimonoseki, the traffic volume on Lake Biwa decreased at the national level. However, the largest impact to lake transportation was the discontinuation of the railway-ferry service in 1889 when the Tokaido Railway Line connecting Shimbashi and Kobe was fully opened, bypassing the lake. The transportation function of the lake declined from then onward, and was gradually replaced by tourism. Lake transportation, however, was still in use in limited areas until around the 1960s. Lake Biwa tourism was at the end of its heyday just around this time.

Keywords Modern era • Steamboat • Lake Biwa tourism

Transportation

In the history of Japan, the period subsequent to the Meiji Restoration in 1868 is commonly referred to as the modern era. Regarding Lake Biwa, the new Meiji government released a Dajo-kan (the then Department of State) Proclamation in 1871, by which the control institutions for transportation on the lake established by the Edo Shogunate were concentrated in the province of Otsu, and the preexisting transportation privileges, such as that of the *Otsu Hyakusosen* (a fleet of 100 boats of Otsu), were all dissolved. In other words, Lake Biwa became a public route and national property. Two years prior to this, in 1869, the first steamboat, the *Ichiban-maru*, went into service, connecting Kaizu (the current Takashima City) to Otsu, a distance of approximately 64 km. A total of 14 steamboats were launched one after another on Lake Biwa during 1872–1874.

The *Ichiban-maru* was a 12-horsepower, five-t capacity boat, while the *Konki-maru*, connecting Maibara with Otsu (approximately 50 km), was 27 m long, 3.6 m wide, and with an 18-t capacity, which was equivalent to a *maru-kobune* (a traditional wooden boat unique to Lake Biwa) with a capacity of 300 straw bags of rice. Thus, there was no significant size difference between the modern steamboats and traditional wooden boats (*Fig. 1*).

In 1883, the first steel-hulled boat built in Japan, named the *Taiko-maru* and with a 516-t weight went into service on Lake Biwa. This is considered to be the first railway-ferry in Japan, taking rail passengers from Nagahama in the north of the lake to Otsu in the south, a distance of approximately 55 km. The *Taiko-maru*, however, went out of service in 1889 when a railroad line opened between Otsu and Nagahama, bypassing the lake.

According to statistics from 1906, the steamboat passengers of two companies, Taiko and Konan, totaled 774,000, which was equivalent to 52% of the total number of railroad passengers traveling around the lake in the same year. This had grown to 1,208,000 by 1922, but this was only equivalent to 26% of the rail passengers of the same year (Kobayashi 1984). The number of passengers and volume of shipments handled on the lake peaked in 1931, and it turned downward thereafter.

The ferry service connecting Otsu to Anamura (in Kusatsu City) was discontinued in 1965, the Sakamoto-Hamaotsu-Ishiyama-Nango route in 1967, and the Otsu-Yamada (in Kusatsu City) route in 1968. The only surviving ferry service is to Okishima, the only inhabited island in Lake Biwa.

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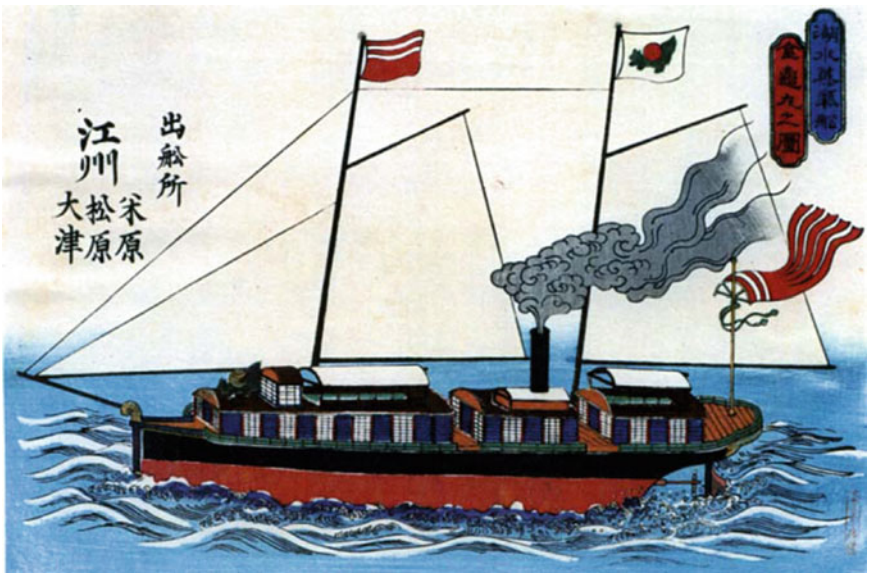

Fig. 1
Steamboat *Konki-maru*.

Tourism

In 1894, the Konan Steamboat Company started advertising for excursion cruises on Lake Biwa. The Taiko Steamboat Company launched the excursion boat *Hakkei-maru* in 1907, and in 1920 they invited the Prince of Wales for the first cruise of their new excursion boat *Midori-maru*. The Konan Steamboat Company constructed a new excursion boat, *Hakkei*, in 1924.

In 1934, the Makino ski resort opened in the current Takashima City, and in the following year, the boats *Keihan-maru* and *Hakucho-maru* were launched to transport passengers to the resort.

Excursions on Lake Biwa peaked in 1960, attracting 835,000 passengers. The end of the ski ferry service in 1962, and the completion of the Great Bridge of Lake Biwa in 1964 might have contributed to the decline in passenger numbers from then onward. By 1975, excursion numbers had fallen to 50% of the peak.

Thus, a shift in the role of Lake Biwa from transportation to tourism during the period after the Tokaido Railway was completed in 1889, and the heyday of tourism in 1960, can be considered as major turning points in recent times from the perspective of tourism.

Characteristics and Epoch-Making Events in the History of Lake Transportation

The establishment of the western sea circuit during the late seventeenth century under the rule of the Edo Shogunate, enabled the shipment of goods from the Hokkoku region to Osaka through the Seto Inland Sea via Shimonoseki, and caused a decline in traffic volume on Lake Biwa. However, what really brought a change to lake water transportation was the abandonment of the railway-ferry service when the Tokaido Railway Line was fully opened in 1889.

Since then, the role of Lake Biwa in transportation gradually declined, and it was superseded by tourism. Limited lake transportation routes remained in service in some areas until around 1960, when Lake Biwa tourism was at its peak.

Throughout the long history of lake transportation, the most important period occurred when Omi (present day Shiga Prefecture) was under the rule of the famous warlord Oda Nobunaga. Seen from a social perspective, it was the construction of castles around the lake starting in 1576 that led to the restoration of centralized control over lake transportation, which was once achieved in the process of ancient state formation. This system was later taken over by the Edo Shogunate and then the Meiji government, before reaching the present state. Centralized control was socially and economically essential for the modernization of Japan.

The most symbolic event of this period was the immediate dismantling of a large warship after its completion in 1573 by the order of Oda Nobunaga. This over 50-m long warship was dismantled and the wood was used to construct about 10 small, faster boats. Nobunaga realized that a large warship could not function in shallow areas and would be less buoyant on the freshwaters of Lake Biwa. This was a very defining event in the history of transportation and shipbuilding in the Lake Biwa area.

Conclusion

In the period from the beginning of the Showa Period (1926) to the 1960s, transportation on Lake Biwa was not yet part of the national system of passenger transportation and commodity distribution, but was closely linked with the daily lives and livelihoods of local people. Especially in the transportation of large and heavy items, boats rather played a major role.

The uniqueness of the history of transportation on Lake Biwa was derived from the continuous movement of people and transportation of goods among small to mid-sized communities around the lake since the establishment of the royal authority centering on the Kinai area in the third century, or at least from the formation of the ancient state in the seventh century, through to the 1960s.

Topic 11 Mysteries of Underwater Remains in Lake Biwa

Osamu Hama

Off the headland of Tsuzuraozaki at a depth ranging from 10 to 70 m, pottery with little damage was discovered that has been dated to the early Jomon Period, about 8,000 years ago, through to the end of the Heian Period, about 800 years ago, which remains a mystery of the underwater remains in Lake Biwa. There are more than 100 sites of underwater remains in Lake Biwa, which are categorized into three main groups: sites located deeper than 10 m underwater, such as Tsuzuraozaki, sites located at the shoreline to the depth of about 2 m, and sites located in attached lakes or drained attached lakes. A characteristic of the Lake Biwa sites is that major remains are mostly located in the littoral zone, more notable along the east shore of the southern basin of Lake Biwa.

Lake Biwa remains can be classified based on notable traces of community, industry, commerce, and ceremony. Hariehama at Shin-asahi in Takashima City, Karasumazaki in Kusatsu City, and Akanoihama and Ozuhama in Moriyama City are among the community sites within which the traces of ancient homes (from the early and middle Yayoi Period, from the tenth century BC to the first century BC) have been found. In the surrounding areas, remains of rice paddies and square tombs surrounded by ditches have also been discovered. At the Akanoi Bay site in Moriyama City, stone-filled holes dating back to some 6,400 years ago, corresponding to the end of the early Jomon Period, were discovered at a water depth of 4 m. These were used to steam roast small animals with heated stones, and in which plenty of fish bones of carp species, including the pharyngeal teeth (throat teeth) of an extinct species, have been excavated. The Awazu underwater remains in Otsu City are Japan's largest freshwater shell mound, which dates back to about 5,000 years ago to the middle Jomon Period. Within the deposits of the shell mound, primarily consisting of Seta-shijimi clams that are a specialty of Lake Biwa, remains of carp species, catfishes and Chinese soft-shelled turtles were found besides acorns, water caltrops and bones of mammals such as wild boars and deer. It is assumed that people started living around the lake since the Jomon Period.

Lake Biwa has also been essential for transportation and commerce since ancient times. For transportation, dugout canoes (*maruki-bune*) were used in the Jomon Period. Thirty dugout canoes have been discovered mainly at attached lake sites, including Irienaiko, Matsubaranaiko, and Motosuikei. Attached lakes were utilized as ports due to their calm waters throughout the year and easy access to residential areas. On the shore of Akanoi Bay in Moriyama City, a total of 80 unused roof tiles dating back to the seventh century were excavated. These tiles were abandoned due to some accident during their shipment to somewhere. At the Azuchi Dainakanoko-minami site, remains of three ancient, stone-lined piers constructed from the beach toward the lake were found. It is considered they were part of a dock utilizing the attached lake.

The shore of the Onoe area in the northern lake has a stunning view during sunsets. For ancient people it was a special place for prayer, with a mystic view of the water surface tinged with gold on which Chikubushima Island floats. From the Onoe site, wood effigies of humans and horses have been excavated, which might have been used to resolve disasters, sins or diseases, or to pray for rain.

Many remains of lake dwellings are found in Lake Zurich, Switzerland, which would give an explanation to the formation of underwater remains. However, there are no signs of such structures in Lake Biwa. There are various opinions about the formation of the underwater remains in Lake Biwa; settlement remains might have become submerged due to rising water levels or crustal movements, and potteries could have been immersed to repose departed souls. However, their presence in the lake still remains a mystery.

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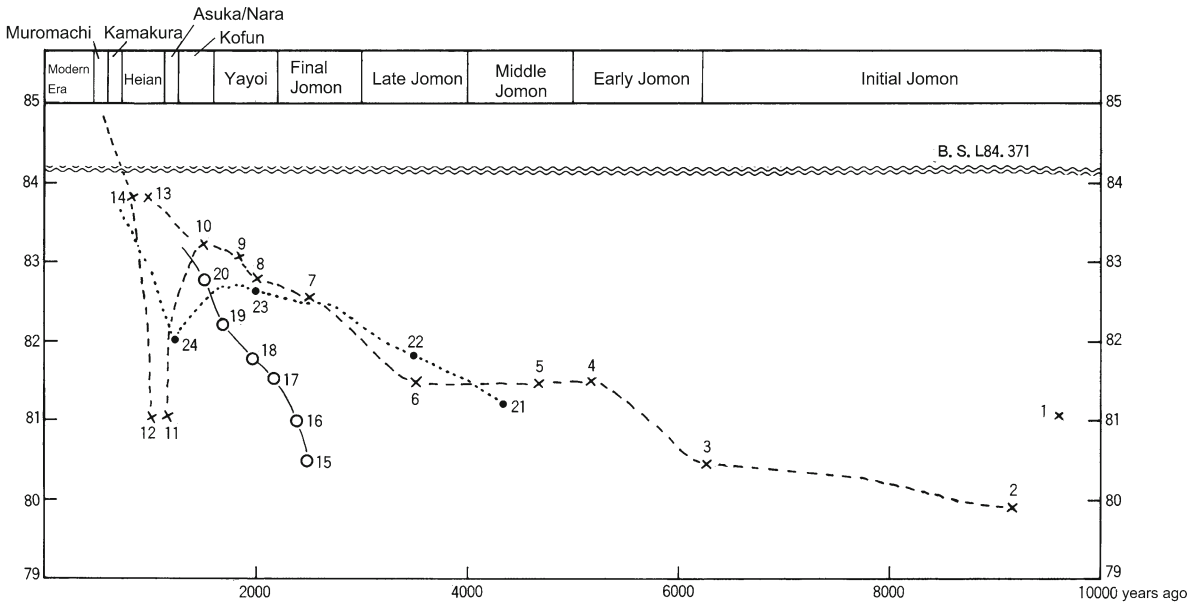

Southern Lake Group

1. Awazu Lake Site Chestnut Mound
2. Hotarudani Site Relic-bearing Formation
3. Akanoi Bay Site Fire Pit Remains
4. Tsudae Lake Site Burial Pit
5. Awazu Lake Site the Third Shell Mound
6. Akanoi Bay Site Relic-bearing Formation
7. Shina Lake Site Jar Burial
8. Akanoi Bay Site Ditch Remains
9. Akanoi Bay Site Ditch Remains
10. Akanoi Bay Site Burial Pit
11. Karahashi Site Bridge Footing
12. Hotarudani Site Relic-bearing Formation
13. Akanoi Bay Site Burial Pit
14. Akanoi Bay Site Burial Pit

North of Western Lake Group

15. Omizo Lake Site Submerged Forest
16. Hariehama Relic-bearing Formation
17. Hariehama Site Dwelling Remains
18. Hariehama Site Dwelling Remains
19. Morihama Site Ditch Remains
20. Morihama Site Relic-bearing Formation

Northern Lake Group

21. Enshoji Lake Site Relic-bearing Formation
22. Enshoji Lake Site Relic-bearing Formation
23. Enshoji Lake Site Ditch Remains
24. Onoe Site Fire Pit and Tile Remains

Fig. 1

Distribution of archaeological sites in relation to elevation.

Topic 12 Otsu-Kyo: The Lakeshore Capital

Hiromichi Hayashi

The ancient capital Otsu-kyo was established on the lakeshore of the southwestern part of Lake Biwa, the present location of Otsu City. For 5 years and 5 months, from March 667 until July 672, Otsu-kyo flourished as the capital of Japan in all aspects, such as politics, economics, culture, and military affairs.

This transfer of the capital from Asuka (today's Nara Prefecture) to Omi (today's Shiga Prefecture) occurred during a tense international situation in East Asia back then. Around that time, the Tang Dynasty of China wielded great power, and it was looking for an opportunity to invade its surrounding countries. Meanwhile, the Korean Peninsula was the stage of a war involving three countries: Goguryeo, Paekche, and Silla. The intervention by the Tang Dynasty in this war caused a dramatic shift in the situation. The Tang Dynasty and Silla formed an alliance on the continent, while Goguryeo allied with Paekche, resulting in an all-out war. In 660, Paekche fell, and with the intention of staging a comeback, requested assistance from Japan, relying on the close ties between the two countries since ancient times. Japan granted the request and sent a relief column, but it lost decisively to the Tang Navy in the battle of Baekgang, Paekche, in 663. Despite the continued presence of Goguryeo, Japan lost an important foothold on the continent, and was forced in a precarious position, fearing invasion by its powerful enemy, the Tang Dynasty, at any moment. The transfer of the capital to Otsu happened under this tense situation.

The purpose of the transfer of the capital to Otsu-kyo was to form a strong alliance with Gokuryeo in order to counterbalance the tie up of the Tang Dynasty and Silla. The new capital was located on the diplomatic corridor with Gokuryeo, connecting Hokuriku, the coastal area of the Sea of Japan, and Yamato, the center of Japan, which was developed in the late sixth century. With the vast extent of plains, prosperous agriculture, and rich iron production in the Lake Biwa area, the new capital had potential to become a solid footing of the government in times of emergencies. Moreover, being located at a crossroads of routes connecting the east and west, north and south, Otsu-kyo was a favorable location for enlisting soldiers and gathering goods for emergencies. Furthermore, foreign immigrants had been concentrated in the area since the end of the fifth century, establishing advanced cultures, technologies, and a solid economic foundation. It was possible to rely on these capable people for the capital-building.

By implementing strong national defense policies, such as the construction of Korean-style fortresses around the coastal areas of the Seto Inland Sea in preparation for the Tang Dynasty invasion, the Imperial Court of Omi made steady headway toward a centralized government, adopting the Ritsuryo system (a centralized political system based on law) from China. It laid the foundations of a nation administered by Ritsuryo, which was later achieved at the end of the seventh century. Cultural enrichment was also notable during this period, such as the composition of Chinese and Japanese *Manyo* style poems.

Eventually, Goguryeo was defeated, but the Tang Dynasty's attention was drawn away from Japan due to the rebellion of Silla.

Many facts about Otsu-kyo remained unknown for a long time until recent excavations and research revealed that the central palace had been located in the Nishikori area. Also revealed was the existence of four temples within the capital, namely the temple ruins of Sufukuji, Minami-Shiga, Ano, and the predecessor of Onjoji. The investigation is still ongoing.

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1 Ano Temple Ruins 2 Sufukuji Temple Ruins
3 Minami-Shiga Temple Ruins 4 Otsu Place (the main area)
5 Predecessor of Onjoji Temple

Fig. 1
The Location of Otsu Palace and Temples within the Capital of Otsu-Kyo.

Topic 13 Castles built on the Shores of Lake Biwa; from Nobunaga's Era through to Hideyoshi's Era

Masayuki Kido

Oda Nobunaga, a warlord based at Gifu Castle, after taking over Owari and Mino provinces (today's western part of Aichi Prefecture and southern part of Gifu Prefecture) in 1567, succeeded in entering Kyoto, the capital of Japan, with shogun Ashikaga Yoshiaki. However, they were still surrounded by numerous enemies. Soon after their entrance to Kyoto, the Miyoshi clan, who held the helm of the Muromachi Shogunate, raided Honkokuji Temple, the temporary residence of Yoshiaki. The retainers of Nobunaga bravely fought against the Miyoshi force before their lord (Oda Nobunaga), who received word of this incident back in Gifu, arrived on the scene with his relief army. Gifu was too far away from Kyoto, which was a fatal disadvantage to Nobunaga. Therefore, he wanted to move his residence to Omi Province, today's Shiga Prefecture, located between Gifu and Kyoto.

In order to achieve this goal, Omi had to be conquered. Under the orders of Nobunaga, in September 1571, Akechi Mitsuhide set fire to Enryakuji Temple on Mt. Hiei and its town of Katata, aiming to destroy the force, which had monopolized the local transportation rights on Lake Biwa and had made huge profits out of it, and built Sakamoto Castle the next year at the southern end of the lake, a location that served as a gateway to Kyoto. Likewise, Hashiba Hideyoshi (also a retainer of Nobunaga) crushed the Azai clan, the ruler of the northern areas of Lake Biwa, in the battle of Anegawa and the siege of Odani Castle, and built Nagahama Castle in 1574 so as to keep a watchful eye over the area. This secured Nobunaga a waterway, connecting the north to the south of the lake. Then, in 1576, Azuchi Castle was constructed on the western shore of Lake Biwa as his residence as well as a front-line base and a governing center. The castle was built on a 198-meter-high, 90-hectare, calabash-shaped hill by the lake. On two sides, the hill was flanked by attached lakes, while on another side was a moat, giving an impression that the hill and castle were a ship floating on the ocean. Stonewalls were built as foundations of the castle along with security facilities such as gates and watchtowers. The roofs of the buildings were covered with gilded tiles. In the keep of the castle on the hilltop, called the "Honmaru," where Nobunaga resided, a palace was built to serve as the lodgings of Emperor Ogimachi. Also the very first high-rise building in Japan, called "Tenshu," was built here, consisting of a seven-story building with six levels above ground and one below, but when viewed from the outside it appeared to be only five stories. Being lavishly decorated, dazzlingly bright, gorgeous, and majestic all at once, a comparable building could not be found anywhere else in the country. In 1578, Tsuda Nobuzumi, Nobunaga's nephew, built Omizo Castle on the opposite shore of Lake Biwa from Azuchi Castle, completing Nobunaga's castle construction project around the lake. Those castles standing symbolically in the north, south, east, and west of Lake Biwa represented Nobunaga's power and served as landmarks.

After the death of Nobunaga, Hideyoshi, now with the surname of Toyotomi, given to him by the Emperor, took over Nobunaga's leadership and continued his strategies. In 1585, Hideyoshi made Yamanouchi Kazutoyo the lord of Nagahama Castle, and he let Azuchi Castle become sacred ruins in honor of Nobunaga. He built Omihachiman-yama Castle right next to Azuchi Castle, and gave it to his nephew, Hidetsugu. Hideyoshi had his subordinate, Niwa Nagahide, reconstruct Sakamoto Castle and assigned Sugihara Ietsugu and then Asano Nagamasa as its lord, but he abandoned it in 1590 and built Otsu Castle by the lake shore, to the south of Sakamoto Castle.

Thus, Hideyoshi built on Nobunaga's castle building project that used Lake Biwa as a natural defense barrier and laid the groundwork toward the unification of Japan. After all, Nobunaga and Hideyoshi were, while creating history, well aware that Lake Biwa's merit was more than just a rich water resource.

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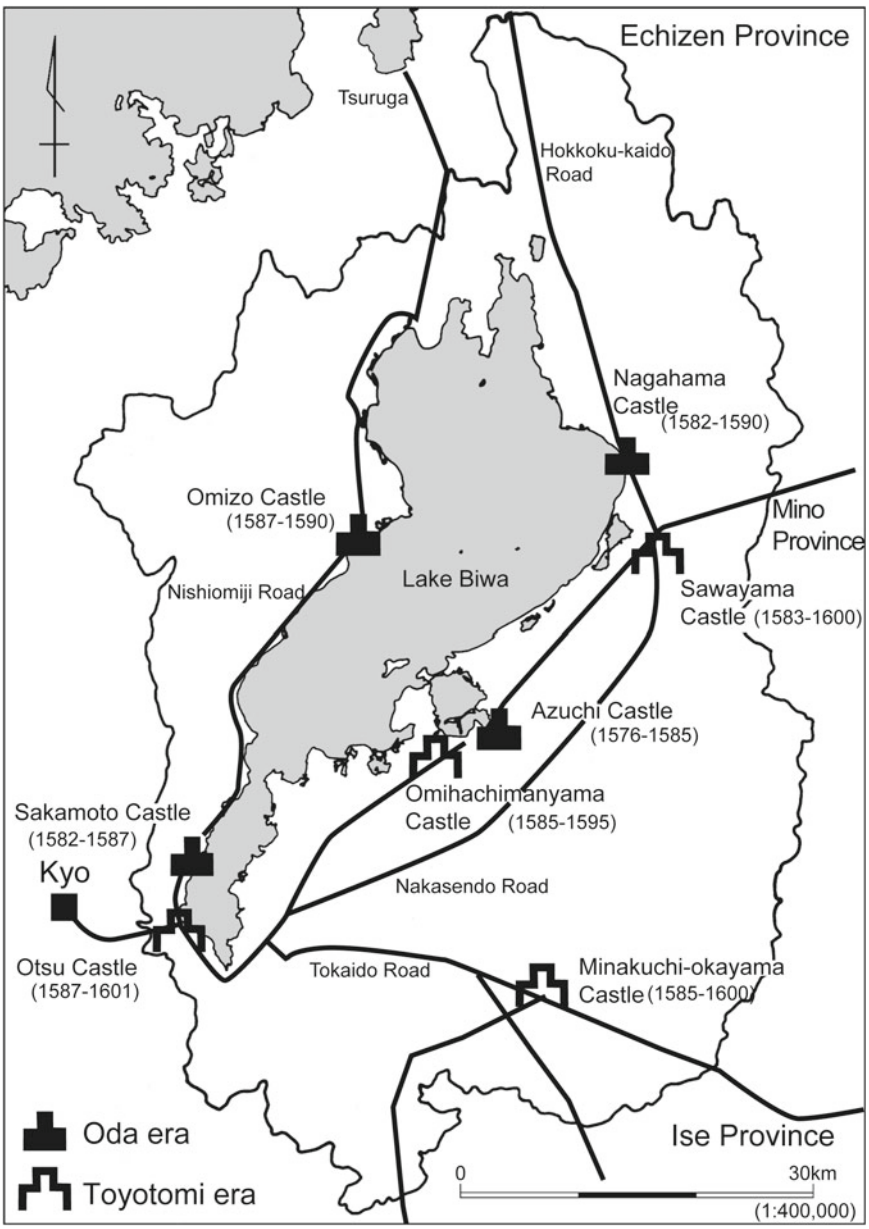

Fig. 1
The connection of castles around Lake Biwa.

Topic 14 Festivity and Folklore of Lake Biwa

Yoshikazu Hasegawa

In Lake Biwa there is a small rocky island, 2 km in circumference, called Chikubushima. Since ancient times it has been regarded as an island where gods reside. The largest festival related to the island is called Renge-e; people sculpture a new statue of Benzaiten, the goddess of Lake Biwa, and dedicate it to the island, while many people visit the island by boats. The festival scenes from around the sixteenth century are depicted on the painting called Chibushima-Saireiezu, the Painting of Chikubu-shima Festival. Due to its expensive operating cost, the festival has been gradually simplified over the years, but it still continues today. Benzaiten was originally a river god of India, Saraswati, and was introduced into Japan as the goddess of treasure, wisdom, and music.

Located between Lake Biwa and Kyoto is Mt. Hiei, a religiously important mountain of national significance. Mt. Hiei is located in the northeast of Kyoto, which was the capital of Japan for approximately 1,000 years since the end of the eighth century. On top of the mountain, there is an old Buddhist temple, Enryakuji, which protects the capital, and which is the headquarters of Tendai Buddhist sect. At the foot of the mountain is the Hiyoshi-Taisha Shrine, regarded as the protector of Mt. Hiei, and which is the location for the spring festival of Hiyoshi-Sannosai. The festival has been modified over time, but it is still held today. During the festival it is said that the gods sail out on the lake to celebrate the arrival of spring.

The Hiyoshi-Taisha Shrine is dedicated to two main gods. One is the "god of the mountain," honored at the Higashi Hongu (eastern main shrine) and which takes the main role in the first half of the festival. The other is Miwa-Myojin of Nara; according to legend, this is the god of Mt. Miwa who was brought here. This deity is honored at the Nishi-Hongu (western main shrine). In the second half of the festival, after holding a ceremony at Nishi Hongu with the attendance of the leading monk of Enryakuji Temple, people carry the gods on *mikoshi* (god's ride) and sail out on the lake (See color page 9).

The festival begins on the first of March (now the first Sunday of March) when participants go up to the mountaintop carring *mikoshi* to meet with the gods. In Japanese farm villages, they believe that the gods of the mountain wake up in spring and come down to the plains to help them with agricultural work.

The *mikoshi* that arrived on top of the mountain are carried down to the plains on April 12th, and the marriage of the gods takes place that night. On the next day, the 13th, a series of events, such as the dedication of newly harvested tea to the gods and Hanawatari, the dedication of flowers by child warriors, continue until the night, symbolically describing the birth of Wakamiya, the child of the gods. This is a prayer for the fertility of all beings.

Within the Hiyoshi-Taisha Shrine, there are seven shrines of Sanno honoring seven gods, including the two main gods. On April 14th, the *mikoshi* of each god leaves the shore and sails out on the lake, each being carried on two small boats that are connected together. Afterward, a boat departs Awazu to deliver offerings to the gods on the lake. This event is based on a myth that a fisherman from Awazu encountered the lake god while fishing and made him an offering of food. Awazu used to be a *mikuriya* in ancient times, serving a role of offering fishery products from Lake Biwa to the Imperial Court. The place is presumed to have been established by maritime people. The offerings are thrown into the water after the ceremony since the gods do not actually eat. This is not meant to waste the offerings but to dedicate them to the gods of the lake, praying for a bumper catch. After the boats return, the *mikoshi* of each god comes ashore to be placed back into its original shrine.

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5 The Use of Lake Biwa and People's Lifestyle

Masayoshi Maehata

People have been living around Lake Biwa since ancient times, using various resources including fishes, reeds, waterweeds, bottom mud, and the lake water itself for their daily life and industrial activities. Earlier, people unknowingly kept their use of these resources below a certain threshold, thereby neither draining nor exceeding the natural purification capacity of Lake Biwa. However, after World War II, when Japan entered a period of high economic growth, great changes occurred with respect to industrial infrastructure as well as people's lifestyle, and this greatly altered the traditional use of resources. In this chapter, the changes that occurred in traditional fishery, water use, and waterside living and the other changes in traditional lifestyle are introduced.

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5.1 Fisheries in and around Lake Biwa

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Ever since people settled in the Lake Biwa area, various implements and methods have been developed and improved over the ages to increase the efficiency of fishing. A number of fishing implements and methods used today in the Lake Biwa area are the fruit of our predecessors' inventiveness. Recently, however, some of them are falling into disuse due to the decrease of fishing the lake and changes in social circumstances surrounding the lake's fisheries and fishermen. In this chapter, various kinds of fishing implements and methods designed for each season, including those no longer in use, are introduced. Recent changes are also discussed.

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5.1.1 Recent Changes in the Lake Biwa Fisheries

Yasuhiro Fujioka · Masayoshi Maehata

Abstract The fisheries of the Lake Biwa area have a long history from the time when people first settled around the lake and began to fish. Since then, people have invented many kinds of fishing equipment and methods based on their experience. However, some of these traditional fishing equipment and methods are gradually becoming obsolete with the decrease in fish resources and the ageing of fishermen. As a result, the annual total catch has decreased dramatically in the past several decades.

Keywords Fishery • Traditional fishing equipment • Aquatic products • Fishery management

Introduction

Many kinds of fish and shellfish inhabit Lake Biwa and its watershed. In order to obtain these fish resources as food, people have invented a variety of fishing equipment and methods over the ages (Maehata et al. 1984). However, in recent years, fisheries have dramatically changed due to the decrease in abundance of aquatic species (fish, shellfish, shrimps), developments in fishing methods, and changes in social conditions. Here we briefly give an outline of these changes to provide a view of the future of the lake's fisheries.

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Changes in Aquatic Products and Catch

Until around 30 years ago, more than 20 species of fish, shellfish and shrimps were caught in Lake Biwa, while only 10 of them (seven fish species, one shell species, and two shrimp species) remain as fishery targets today (*Table 1*; Fujioka 2003) after the sudden decrease in these resources (see Chaps. 2–5). The total catch, including fish, shellfish and shrimps, was over 10,000 tons per year in the 1950s, 80% of which was a certain type of shellfish (the 'Seta-shijimi' bivalve, *Corbicula sandai*) (Shiga Statistics and Information Offices 2010). Thereafter, the total catch fell to below 4,000 tons tons per year in the 1990s mainly due to a decrease in the *Seta-shijimi*, and it is about 2,000 tons per year now (*Fig. 1*). In the 1950s, the total catch of fish was about 2,000 tons per year, but it increased gradually through the 1960s, reaching 3,000–3,500 tons from the 1970s to the 1980s. This increase was mainly due to larger catches of the Biwa ayu (*Plecoglossus altivelis* subsp.) (*Fig. 2*), In addition to being a food resource, young fish are caught and transported live to stock river fisheries throughout Japan. Since 1992, the total catch has decreased considerably, remaining at about 1,500 tons over the last 10 years, because the native fishery targets have all dramatically decreased, including the Biwa ayu (Shiga Statistics and Information Offices 2010).

Changes in the Number of Fishermen and Fishing Boats

There have been many different kinds of fisheries in Lake Biwa, as mentioned in detail in the following section. Traditionally, many fishermen of the lake area were also part-time farmers. In the Lake Biwa area, fishing boats are commonly crewed by a man and his wife, or parent(s), and his son; a single person without family members is

Table 1

Fishing methods and devices, and their targets species in and around Lake Biwa

Field for fishery	Fishing methods or devices	Main target animals	Main Seasons
Offshore	Naga koito-ami (long length gill net) Koito-ami (short length gill net) Okisukui-ami (Off-shore scoop net) Cyubiki-ami (Off-shore sein net)	Biwa salmon willow minnows, Biwa ayu Biwa ayu Biwa goby, willow minnows, Suji-ebi (lake prawn)	May–September March–July June–July October–April
Lakeshore and attached lakes	Eri (Set net) Kaibiki-ami Oisade-ami Jibiki-ami Tatsube Ebi-tatsube Mondori (Ue) Haenawa Takezutsu	crucian carps, Biwa ayu Seta-sijimi (freshwater clam) Biwa ayu willow minnows common carp, crucian carps Suji-ebi (lake prawn), Tenaga-ebi (freshwater prawn) crucian carps Japanese eel Japanese eel	February–July November–May March–June May–November February–May June–September March–June April–October April–October
Mouth of rivers	Kattori-yana Masu-yana Yotsude-ami Kawa-eri Gara-biki	Biwa ayu Biwa salmon Biwa ayu crucian carps Biwa yellow-gill	March–June October–November April–July March–June June–August

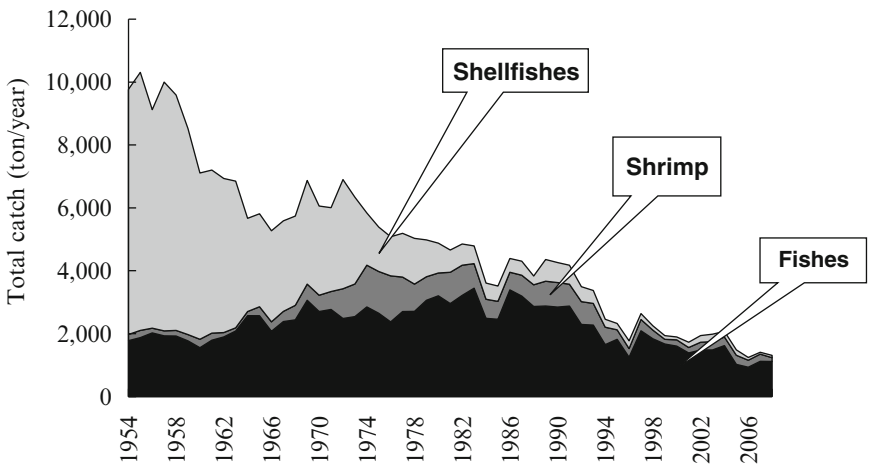


Fig. 1

Changes in the total catch of Lake Biwa's fisheries.

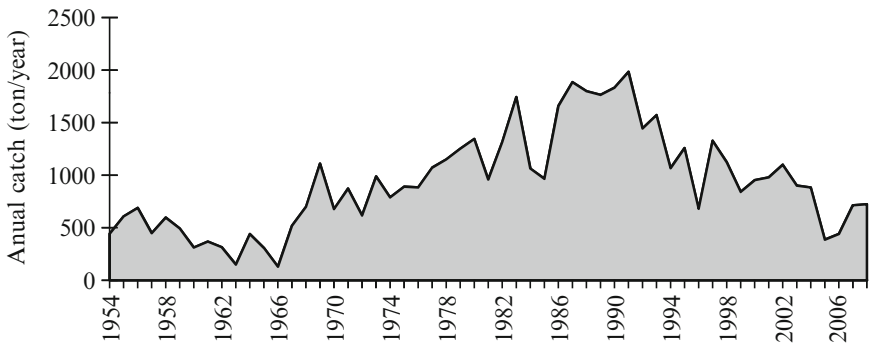


Fig. 2

Changes in the annual catch of Biwa ayu in Lake Biwa.

Fig. 3
Changes in the number of fishermen in the Lake Biwa area.

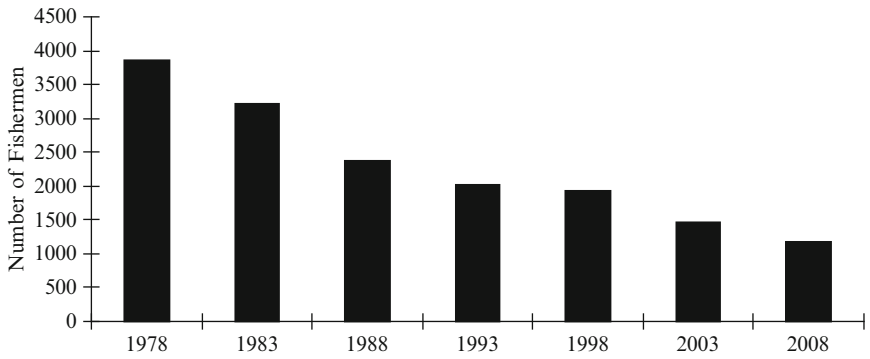


Fig. 4
Changes in the number of fishery management organizations.

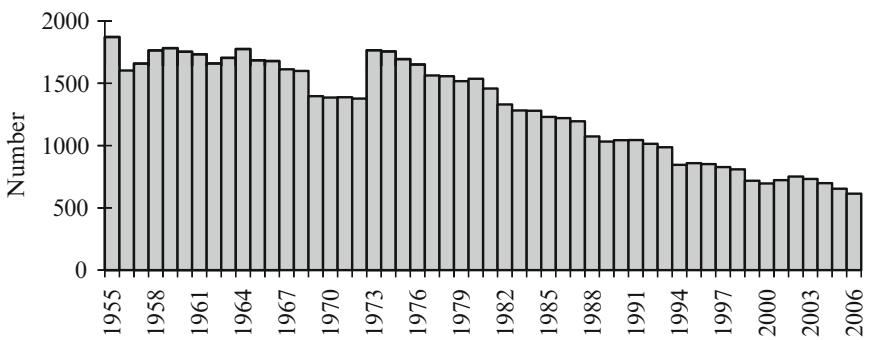
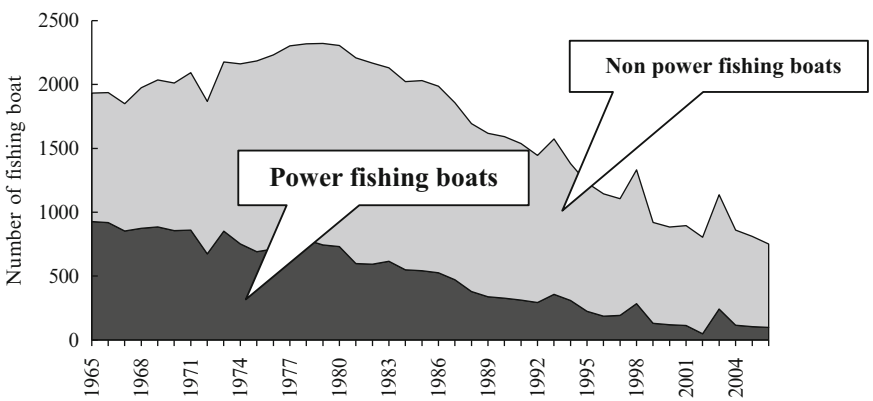


Fig. 5
Changes in the number of fishing boats in the Lake Biwa area.



rarely employed in the fisheries (Kurata 1983). The number of fishermen has decreased significantly in recent years (*Fig. 3*) (Shiga Statistics and Information Offices 2010).

The number of fishery management organizations was 1,800 in the 1950s, but it decreased greatly in the 1980s, and is only around 700 at present (*Fig. 4*) (Shiga Statistics and Information Offices 2010).

The fishing boats in Lake Biwa are mostly smaller than 5 tons because of the limitation under a Shiga Prefectural ordinance (Shiga Prefectural Government 2010a). Although the number of fishing boats was 2,300 in the 1980s, it has decreased since then and is only 1,000 today (*Fig. 5*) (Shiga Prefectural Government 2006). Fishing boats without engines, which used to be the main type, have largely fallen out of use in recent times.

Changes in Fishing Equipment and Fishing Methods

In the Lake Biwa area, there are various habitats, including deep offshore areas, shallow sandy shores, rocky shores, shallow attached lakes connected with the lake, and rivers flowing into the lake, all of which have different physical characteristics (e.g. see Lake Biwa Environmental Research Institute 1991). These environments have been inhabited by a variety of fauna, including endemic species, throughout the long history of the lake (e.g. see Tomoda 1978; Kawanabe 1996).

In order to obtain such fish resources from different environments, people have developed numerous kinds of fishing equipment and methods based on their experience and knowledge of the habitat of each target fish (i.e. fish, shellfish, shrimps etc.) and of the changes in water flow, water temperature, direction of wind, water depth, and weather conditions each day and/or season. Some of these fishing methods and equipment are considered to have been invented locally (Maehata et al. 1984), while some might have originated from ancient China (Kurata 1983). In *Table 1*, some fishing methods unique to each area of the lake are shown. More information is given in the following chapters.

Conclusion

The Lake Biwa fisheries have declined over the past several decades. The first cause of the decline is considered to be the decrease in target species such as fish, shellfish, and shrimps, accompanied by the ageing of fishermen (Shiga Statistics and Information Offices 2010). The reasons for the decrease in fish stocks, which include the devastation of nursery environments, increase in nonindigenous fish species, and overharvesting, all of which have occurred during the past several decades, are detailed in Chaps. 2–5.

The decline of fisheries does not only mean the decline of fishing itself but also the decline of the unique local culture which has been cultivated in the lake area over a long period of time. Firm guidelines to achieve recovery of the species in the lake, beginning with fishes, have already been prepared by the Biwa-ko Sogo Hozen Gakujutsu I'inkai (Academic Committee for Comprehensive Conservation of Lake Biwa) (2010). In order to prevent the devastation to the local culture, the issues covered above should be urgently overcome by acting in accordance with the guidelines.

5.1.2 Various Fishing Methods Developed in and around Lake Biwa

Yasuhiro Fujioka · Masayoshi Maehata

Abstract There are various fishing implements and methods used in the littoral zone, attached lakes, offshore areas, and inflowing rivers of Lake Biwa. In the littoral zone and attached lakes, fish traps called eri and tatsube-traps, mainly target crucian carp (*Carassius* spp.), common carp (*Cyprinus carpio*), and willow minnow (*Gnathopogon caerulescens*), which migrate to shallow waters to spawn. Net fishing by devices called Jibiki-ami (seine), haenawa (longline), oisade-ami etc. are mainly operated during the period from spring to early summer. Offshore, the fishing method oki-sukui, which targets Biwa ayu (*Plecoglossus altivelis* subsp.) and others such as chu-biki-ami and koito-ami (gill-net), is used. In the rivers, yana-trap fishing mainly targets those fishes that ascend rivers, e.g. Biwa ayu from spring to early summer, and Biwa salmon (*Onchorhynchus masou* subsp.) in the late autumn. This chapter introduces some of the major fishing implements and methods of the Lake Biwa area, including some that are no longer in use.

Keywords Fishing implements and methods • Littoral zone • Attached lakes • Offing • Rivers

Lakeshore and Attached Lakes Fisheries

In the littoral zone and attached lakes of Lake Biwa, people have been using many different fishing implements and methods for many years. Some of the characteristic and distinctive ones are introduced below.

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Eri-Trap Fishing

Eri is a traditional fish-trapping device used in Lake Biwa, consisting of a set of large nets that are fixed near the lakeshore. Large ones can be about 200–300 m in length, and small ones are about 50 m in length, and they are built from the lakeshore toward the offing (*Fig. 1*). Until the 1960s, this device was made of bamboo, reed fencing, and bamboo stakes, but these materials were later replaced with artificial fibre fencing. The history of eri-trap fishing dates back 1,500 years to the Kofun Period (250–538CE) (Kurata 1983). The installment of an eri in the lake requires in-depth knowledge of factors such as water currents, topographical information of the lake bottom, and fish behaviour, so until recently, there was an occupation 'eri-shi' (eri expert). The experts lived mainly in the areas of Moriyama and Omihachiman City on the eastern shore of Lake Biwa, and they set up many eri-traps around the lake. The total number of eri in Lake Biwa is currently about 120. In the past, there were large numbers of arame-eri (large mesh eri) mainly targeting large fishes such as common carp (*Cyprinus carpio*) and crucian carps (three species/subspecies of the genus *Carassius*: *C. auratus grandculis*, *C. cuvieri*, and *Carassius* sp.) (Maehta et al. 1984). The number of arame-eri, however, decreased significantly, and hosome-eri (fine mesh eri) is the most common type today, which mainly targets Biwa ayu (*Plecoglossus altivelis* subsp). Many kinds of fish, including common carp and crucian carp, are also captured by hosome-eri in addition to Biwa ayu, although in small numbers. Hosome-eri are built in some lakes attached with Lake Biwa as well. Both arame-eri and hosome-eri are also set up at the mouth of the inflowing rivers and small streams of the lake (*Fig. 2*; see *Fig. 3*). At present, almost all of these fishing devices are made of polyvinyl chloride (PVC) pipes.

Tatsube-Trap Fishing

Tatsube (also called 'mondori' or 'ue') is a small trapping cage made of bamboo for catching fishes or shrimps, and its size varies from about 30 to 100 cm in length (*Fig. 3*). In order

Fig. 1
Eri-trap fishing.

Fig. 2
Eri-trap set at the mouth of the small stream.

to attract the targets, bait is usually put in the trap. There are many types of traps: traps for fishes are usually installed in the reed zone along the lakeshore and attached lakes (*Fig. 4*), targeting common carp and crucian carp, and traps for shrimps are usually installed alongside open lakeshores, targeting both small (sujiebi, *Palaemon paucidens*) and large (tenagaebi, *Macrobrachium nipponensis*) species.

Oisade-Ami Fishing

Oisade-ami is one of the early fishing devices developed in the Lake Biwa area (Maehata et al. 1984). It targets young Biwa ayu, which form schools alongside the lakeshore in spring. The fishermen drive Biwa ayu schools into a large square-shaped net called 'sade-ami', which has crow feathers attached to the top of a bamboo rod (*Fig. 5*). The fish caught by this method are usually kept alive and used to stock rivers throughout Japan, or fish farms in Shiga Prefecture (see *Topic 16*).

Jibiki-Ami Fishing

Earlier, there were several cooperative associations for jibiki-ami (seine) fisheries. Two types of seines were used according to the size of the target fishes: large mesh net (o-ami) and fine mesh net (ko-ami). O-ami was used in the period from April to mid-August, especially

Fig. 3
Tatsube-trap fishing.

Fig. 4
Tatsube-traps are set in the reed zone.

from May to June, mainly targeting common carp and crucian carp. Ko-ami was used in different periods of the year depending on the targets. When the target was Biwa ayu, the fishing season in the 1930s was from the beginning of November to mid-March (Kawabata 1931), and in the 1950s it was from mid-January to the end of September (Kondo 1982). When the target was willow minnow (*Gnathopogon caerulescens*), the fishing season during the 1980s was from May to the beginning of November (Maehata et al. 1984; *Fig. 6*). However, as a result of the decrease in fishery resources, o-ami fell out of use in the mid-1980s. At about the same time, ko-ami stopped being used for Biwa ayu, and in the 1990s fell out of use for catching willow minnow as well. Jibiki-ami fishing is now operated only to entertain tourists, several times a year.

Fig. 5
Oisade-ami fishing.

Fig. 6
Jibiki-ami fishing.

Haenawa Fishing

This method uses a long line, called the main line, with many baited hooks attached at intervals by means of branch lines (*Fig. 7*). The longest main line was more than 18 km in length. Target fish include Japanese eel (*Anguilla japonica*), forktail bullhead (*Pseudobuglus nudiceps*), rock catfish (*Silurus lithophilus*), Biwa culter (*Ischikauia steenacheri*), Biwa minnow (*Sarcocheilichthys variegatus microoculus*), common carp living in the littoral zone and/or attached lakes and/or rocky shores, and Biwa salmon (*Oncorhynchus masou* subsp.) in deep offshore areas (Maehata et al. 1984). In the case of Japanese eel, the fishing season was from the beginning of April to the end of September, and that of the forktail bullhead was mainly in summer. Most of the fisheries targeting those fishes mentioned here disappeared many decades ago; for example, this fishing method targeting Biwa salmon disappeared before the 1940s (Matsuda et al. 1980). Today, only the eel fishery still exists.

Fig. 7
Basket with hook rigs used for Haenawa fishing. (Photo by Lake Biwa Museum)

Fig. 8
Kaibiki-ami fishing.

Kaibiki-Ami Fishing

This fishing method is used in the shallow areas that have a sandy or muddy bottom to collect bivalves such as Seta-shijimi bivalve (*Corbicula sandai*), tateboshi-gai (*Unio biwae*), dobu-gai (*Anodonta woodiana*), menkarasu-gai (*Cristaria spatiosa*), ikecho-gai (*Hyriopsis schlegeli*), etc. (*Fig. 8*). In the 1950s, it was a prosperous operation, and the annual catch was more than 7,000 t. However, it has gradually declined as the bivalves, especially Seta-shijimi and ikecho-gai, which are endemic to Lake Biwa, decreased significantly. Nowadays, the annual catch of kaibiki-ami is less than 200 t, and ikecho-gai is endangered due to over-harvesting (Matsuda 2006).

The fishing season is usually in winter, from November to April (Maehata et al. 1984). Fishing implements called 'manguwa' or 'tama' are pulled along the bottom in a circular pattern by a powered boat. Before powered boats were introduced in the 1960s, people used to catch shellfish by hand with tools such as hoes (Nishimori 2000).

Offshore Fisheries

Until the early Showa Period (ca. 1940s), fishing implements, including nets and ropes, were mainly made of natural materials, such as silk and straw, which are not durable. In addition, the engine power of fishing boats was very low, limiting fishing activities to near the shore of Lake Biwa. Later, natural materials were gradually replaced by synthetic ones, such as nylon, vinylon, and polyethylene fiber, and this was also accompanied by a significant increase in the horsepower of boats. As a result, the area used for fishing was greatly expanded, and offshore fishing became active in the lake only 40–50 years ago. Several methods used in offshore fisheries are described below.

Okisukui Fishing

In the rainy season (from June to July), Biwa ayu form large, dense assemblages called 'maki' at the surface of the lake. Okisukui fishing is a method where the fishermen approach the assemblage at high speed by boat, and then scoop it up by lowering a large, square-shaped net mounted on the bow (*Fig. 9*). It is thought to have been developed ca. 1925 in Sugaura, which is located at the north end of the lake (Maehata et al. 1984). Early okisukui fishing was operated by hand with a scooping net about 60 cm in diameter. Later in the early 1970s, it was replaced by the modern version, which increased the efficiency of catching ayu fish. However, the high efficiency of the modern fishing method led to the establishment of catch limits to prevent overfishing.

Koito-Ami Fishing

Koito-ami is a type of gill net. In Lake Biwa, several different mesh sizes and length of nets have been used depending on the target fishes. Long gill nets (naga-koito-ami), about 6 m in length, are used for catching Biwa salmon and Biwa ayu, which live offshore. Short gill nets, about 1.5 m in length, are usually used for catching crucian carp (funa-rui), Biwa ayu, and willow minnow (honmoroko), which come alongside the shore (*Fig. 10*). These nets are called funa-koito, ayu-koito, and moroko-koito, respectively, depending on the target fish.

Chubikiami Fishing

Bottom trawling in deep offshore areas of Lake Biwa (50–90 m in depth) used to be conducted in winter, when several types of fish, such as willow minnow, round crucian carp (*Carassius auratus grandoculis*), and lake prawn (Sujiebi, *Palaemon paucidens*) migrate to the offshore areas. The drag rope of the net was about 600 m in length (*Fig. 11*). The impact of this type of fishing is higher than other fishing methods, and so the Fishery

Fig. 9
Okisukui fishing.

Fig. 10
Koito-ami fishing.

Fig. 11
Chubikiami fishing.

Adjustment Rule of Shiga Prefectural Government prohibited it in order to prevent overfishing (Shiga Prefectural Government 1965).

River Fisheries

Typical examples of fishing operations conducted in the inflowing rivers of Lake Biwa are kawa-eri, yotsude-ami, and yana fishing. In particular, there are different types of yana, for example, kattori-yana (yana with kattori-guchi), yotsude-yana (yana with yotsude-ami), and chiritori-yana (yana with chiritori), etc. Some of these are described here.

Kawa-Eri Fishing

The arame-eri and hosome-eri mentioned in (1) above are also used in the inflowing rivers (in which case they are both called 'kawa-eri' instead, which means river eri).

Fig. 12
Biwa-ayu.

The targets are those fishes that ascend rivers and/or streams for spawning or migrating, e.g. crucian carp, common carp, and Biwa ayu, from spring to early summer, and Biwa salmon in late autumn. Today, it seems that this is mainly operated for fun by elderly men who enjoy fishing as a hobby.

Kattori-Yana Fishing

Yana is a kind of fish trap that is fixed in the river for catching the ascending or descending fishes. Among many kinds of yana, the ones for catching the ascending fishes are generally called 'nobori-yana', and those for catching the descending fishes are generally called 'kudari-yana'. The yana-traps used in the Lake Biwa area are all nobori-yana, which are always set near the mouth of inflowing rivers. The main target is now Biwa ayu, which migrates upstream from March to July (*Fig. 12*) or Biwa salmon in autumn (see masu-yana fishing below). Different types of yana and/or combinations of yana and other fishing methods are used to target Biwa ayu in each river. The most famous one is 'kattori-yana' used in the Ado River, which flows into the lake from the western shore (*Fig. 13*). This yana, made of bamboo fencing and sandbags, is set across the river. Various kinds of yana fishing, including kattori-yana and masu-yana, used to be operated in many rivers until about 50–60 years ago, but they are no longer seen except in three rivers: the Ado River, Ane River, and Ishida River.

Masu-Yana Fishing

This is a kind of 'nobori-yana', mentioned above, made of bamboo and fish nets set across a river (*Fig. 14*). It is used to catch adult Biwa salmon (*Oncorhynchus masou* subsp.) when they are migrating from Lake Biwa to rivers to spawn from October to November. Every year, the adult fish caught by this fishing method are used for artificial fertilization, after which they are usually cooked with rice as a traditional dish called 'masu-meshi'. It is currently operated in a few inlet rivers for a limited period every year under special permission of Shiga Prefecture.

Yotsude-Ami Fishing

This is usually operated at a river mouth, targeting fishes that ascend the river for spawning and/or feeding from spring to early summer, e.g. Biwa ayu, and piscivorous chub (*Opsariichthys uncirostris uncirostris*). The fishermen

Fig. 13
Kattori-yana fishing.

Fig. 14
Masu-yana fishing.

lower a small, four-arm scoop net (yotsude-ami) to the bottom of the river and after several minutes quickly lift it up to catch the fishes (*Fig. 15*). Today, this fishing method is only conducted in the Ane River and Ado River. In the Ane River, it is operated in combination with yana-fishery.

Conclusion

In Lake Biwa, there are various implements and methods for fishing in the littoral zone, attached lakes, offshore areas, and inflowing rivers throughout the fishing seasons. The use of some of these implements have, however,

Fig. 15
Yotsude-ami fishing. (Photo by Lake Biwa Museum)

disappeared during the past several decades. It is generally accepted that old fishing implements and methods will be replaced with newly developed and more efficient ones. However, even those that are refined enough, such as jibiki-ami (seine net) and some kinds of yana, have in fact disappeared or declined due to lack of use. The first reason for the decline in the lake's fishing industry is the decrease in the number of target fishes; the second is the increase in the average age of the fisherman, which is the result of not only the decrease of the lake's fishes, which reduces the opportunities for younger people to take up fishing for a living, but also other social changes; however, the first reason appears to be the most significant. Thus, in order to preserve the traditional fishing implements and methods of this lake, restoring the fishery resources of Lake Biwa is most essential. (see Chaps. 2–5).

5.1.3 Propagation and Conservation of Fishery Resources

Yasuhiro Fujioka · Masayoshi Maehata

Abstract In Lake Biwa, various measures have been undertaken to maintain and increase fish and shellfish resources since the Meiji Period. These include propagation and/or release of target species of fish and shellfish, including Biwa salmon (*Oncorhynchus masou* subsp.), Biwa ayu (*Plecoglossus altivelis* subsp.), nigoro-buna (round crucian carp, *Crassius auratus grandoculis)*, and so on, and development of spawning grounds for fishes. This article introduces specific measures employed for each fish and shellfish species.

Keywords Resources • Propagation • Conservation • Release • Spawning ground

The first trial for conservation of fishery resources (fishes, shellfishes and shrimps) in Lake Biwa began in the Meiji Period (1868–1912). At that time, the construction of the Nango-araizeki Weir, the predecessor of the current Seta River Weir, was planned on the Seta River for regulating water levels of the lake. As the Seta River is Lake Biwa's only natural outlet, the lake became isolated from the sea after the weir's construction. As a result, new supplies of fishery resources from the sea through the Seta River were blocked (Kawabata 1931). Since that time, various trials for conserving and/or maintaining fishery resources have been carried out. Some examples in each of the fishery resources are shown below.

1. *Biwa-masu* (Biwa salmon, *Oncorhynchus masou* subsp.): Artificial hatching and release of Biwa salmon has been conducted since 1878, and the first hatchery was constructed in 1883 at the mouth of Chinai River (Kawabata 1931). In 1907, five million fry of Biwa salmon were released into Lake Biwa (Fujioka 2009). At present, rivers are stocked every spring by the Fisheries Co-operative Association with approximately 700,000 juveniles of about 7 cm total length (TL), to enhance resources (*Fig. 1*) (Fujioka 2009). In the Biwa salmon fishery, it is prohibited by the Fishery Adjustment Rule of Shiga Prefecture to catch fish which are less than 25 cm in TL, and during the spawning period from October to November (Shiga Prefectural Government 2010a).
2. *Biwa ayu* (ayu fish, *Plecoglossus altivelis* subsp.): In order to develop and maintain the ayu fish resource in Lake Biwa, people have adopted various efforts. Ayu fish spawn on pebbles at the mouth of rivers from late August to November, and riverbeds of spawning sites have been cultivated prior to the spawning season to improve their environments. Furthermore, matured ayu fish raised in ponds have been used to stock rivers just before the spawning season. These two methods have served the purpose of maintaining the stock of ayu (Shiga Prefectural Government 2000). In order to conserve this fish resource, ayu catches are prohibited between August 21 and November 20 every year, coinciding with its spawning season. The catch of other aquatic species is also prohibited by the Fishery Adjustment Rule of Shiga Prefecture in some areas of river mouths, where the spawning grounds for ayu are located (Shiga Prefectural Government 2010a).
3. *Nigoro-buna* (round crucian carp, *Crassius auratus grandoculis*): Among the three species of crucian carp inhabiting Lake Biwa, the nigoro-buna is preferred the most for food, and is made into the traditional fermented product, 'funa-zushi' (see section 'Traditional culinary culture of Shiga Prefecture'). Therefore, nigoro-buna juveniles have been released into Lake Biwa for a long time. So far, about ten million juveniles (about 3 cm in TL) naturally grown in paddy fields and one million young fish (about 12 cm in TL) raised in ponds have been released into the lake (Fisheries Management

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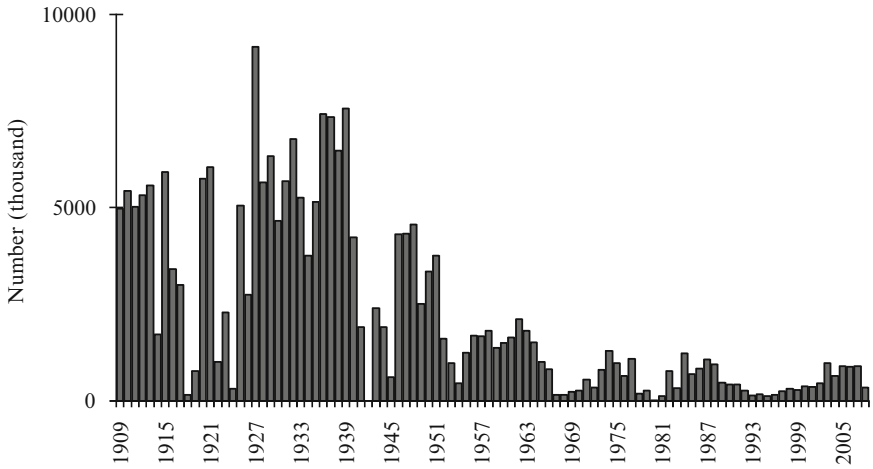

Fig. 1
Changes in the number of Biwa salmon. (*Oncorhynchus masou* subsp.)

Office, Shiga Prefectural Government 2008). Reed beds have also been artificially restored along the shore to serve as breeding sites for nigoro-buna.

4. *Hommoroko* (willow minnow, *Gnathopogon caerulescens*): This fish is an important fishery target, and is known for its good taste (see section 'Traditional culinary culture of Shiga Prefecture'). Its annual catch, however, dropped sharply from 200–300 tons to about 10 tons in the 1990s. Thus, the Shiga Prefecture Fishermen's Cooperative Association has been making efforts to maintain the resource of hommoroko by releasing its fry into the lake (Fisheries Management Office, Shiga Prefectural Government 2008). Annually, from 2008, the lake is stocked with 2–3 million juveniles, 2 cm in TL, which are reared in ponds, and 100 million eggs.
5. *Unagi* (Japanese eel, *Anguilla japonica*): Japanese eel is one of the most important fish resources in the lake. A large number of juveniles used to migrate from Osaka Bay (central Japan) to the lake through the outlet river of Lake Biwa, the Seta River (known as the Uji River in Kyoto, and the Yodo River in Osaka), before the Nango Weir was constructed in 1905 (Kawabata 1931). After that, the 70 m high Amagase dam was constructed on the Uji River in 1964, resulting in the total cessation of fish migration from Osaka Bay, including migration by Japanese eels. Therefore, in order to maintain this resource, juvenile eels have been released into the lake since 1905.
6. *Koi* (common carp, *Cyprinus carpio*): Although the demand for carp today has considerably decreased compared with the past, it is important to maintain carp resources in the lake so that they can still be used as a traditional cooking ingredient. On account of this, 10,000–100,000 carp fry were released into the lake every year until 2003. At present, the release of the fry has stopped due to an outbreak of KHV (Koi Herpes Virus) disease that occurred in Lake Biwa for the first time in 2004 (Suzuki et al. 2008).
7. *Seta-shijimi bivalve* (*Corbicula sandai*): The Seta-shijimi bivalve has shown the most significant decrease among the fishery resources in Lake Biwa. This bivalve has been utilized as a food resource by people living around the lake since ancient times (more than 5,000 years ago, during the Jomon Period). In order to restore its population, larvae production methods have been developed through a long-term investigation by Shiga Prefectural Fishery Experiment Station, and a 1,000 million larvae of the bivalve have been released so far along the sandy shores of the lake (Fisheries Management Office, Shiga Prefectural Government 2008).
8. *Other countermeasures*: The reed beds along the shores of Lake Biwa and attached lakes play an important role as egg-laying sites for fishes such as common carp, crucian carps and hommoroko. However, the reed beds have dramatically decreased as a result of the intensive development implemented around the lake during and after World War II. Partially submerged reed beds serve as spawning grounds for fishes from March to around July, while the water level of the lake is artificially kept low in this period to prevent flooding. There were 99.2 ha of reed beds in 1975 but this had decreased to 80.4 ha by 1992 (Kaneko 2005). The Shiga Prefectural Government has been planting reed seedlings along the lakeshore for the purpose of developing spawning grounds for fishes since 1996

(Shiga Prefectural Government 2008). In addition, since 2009, the Shiga Prefecture Fishermen's Cooperative Association has been dredging the bottom of the lake in order to restore the habitat for shellfish.

Conclusion

In Lake Biwa, various efforts to restore fishery resources have been carried out over the past several decades, but in spite of these efforts annual catches have not been increasing as expected (see Chaps. 2–5). The reason is not clear yet, but the effects of invasive fish species and/or devastation of the nursery grounds for the fishes and shellfishes are inferred to be far stronger than expected. Although some think that the efforts are too late, there are still many native species in the lake. These efforts should be continued in full strength in order to restore and recover the lake's fisheries. Meanwhile, extermination of invasive species, prevention of invasion by new alien species, and restoring nursery grounds for the native species should be enforced (see Topic 15).

5.2 Rural Daily Lives and Water Use Cultures in the Lake Biwa Area

Atsushi Makino

This chapter focuses on the interactions between rural daily lives and the living environment in the Lake Biwa area. Especially, adequate attention is paid to the modernization of rural lifestyles and water use cultures in the Lake Biwa area after World War II. Some of these changes in traditional rural lives are closely related to the recent environmental problems of Lake Biwa.

In the following discussion, several aspects of village lives around Lake Biwa are examined, including various subsistence activities, traditional water use and its changes, relationship between people's daily lives and rivers, and traditional food culture. In addition, traditional baths, female farmers, and waterside living and landscape are mentioned.

Through these discussions, the significance of rural daily lives and water use cultures for environmental sustainability in the Lake Biwa area is indicated.

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5.2.1 People's Subsistence Activities in the Lake Biwa Basin

Atsushi Makino

Abstract In the Lake Biwa basin, people's lifestyles used to be very closely connected with the lake and the associated rivers. Traditional ways of living have been brought to the public's attention lately along with increasing environmental awareness. The characteristics of traditional water-related subsistence activities of the residents of the (1) mountain areas, (2) midstream areas of rivers, and (3) lakeshores are described. Also, some examples are given on how such traditional practices have been applied to recent environmental conservation activities.

Keywords Subsistence activities • The production of timber and forestry products • Rice • Farming • Irrigation ponds • Farmers' fishing activities

Purpose

'Subsistence activities' can refer to a variety of work we do to maintain ourselves, including agriculture, fishing, and forestry, as well as nonfarming jobs. However, the 'subsistence activities' discussed here will be limited to those deeply associated with water: rice farming, fishing, and forestry. Small-scale fishing activities carried out by farmers, such as paddy field fishing, will be introduced in contrast to the highly professional fishing operations described in the previous chapters.

Firstly, traditional subsistence livelihood activities in the three different residential areas, the (1) mountains, (2) midstream areas of rivers, and (3) lakeshores will be reviewed. Then, the current trends of environmental activities based on such traditional living around Lake Biwa will be introduced.

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Subsistence Activities in the Lake Biwa Basin

Subsistence Activities in the Mountain Areas

Half the catchment area of Lake Biwa is covered with forests, which therefore form a major component of the entire lake ecosystem. Large forests are found in the areas of Ibuki and Suzuka Mountains in the east, and the Hira Mountains and Mount Hiei in the west. Besides that, many of the inflowing rivers of Lake Biwa originate in these mountains, and the wide range of forests in the area has been beneficial to local residents in various ways. For example, the production of timber and forestry products, such as charcoal, were important subsistence activities for the residents, although the production scale was not very large compared with the wood processing industries in other parts of Japan (*Fig. 1*).

It is also noteworthy that rivers played a significant role in relation to wood production. In the Bulletin of the Shiga Industries, published in 1913, several routes used for transporting wood by river, including the Ado River, Takatoki River, and Yasu River, were reported. In addition, small rivers and waterways were used as transportation routes too (Shiga Prefectural Government 1913).

Subsistence Activities in the Midstream Areas of Rivers

About 13% of the entire catchment area of Lake Biwa is occupied by farmland, mainly paddy fields. While rice farming has been one of the major livelihood activities around Lake Biwa, farmers of local villages suffered from chronic water shortages in the past as the rivers, the primary water source for agriculture, did not always carry abundant water. For example, in the Gamo area (now part

Fig. 1
Yamakado waterhead forest. Charcoal was made in this forest. (Nagahama City)

Fig. 2
The festival of 'Minazuki-sai' in the 'Benten-dame' irrigation pond. (Higashi-omi City) (Photo by P. Yang)

of Higashi-Omi City), located in the middle part of the Hino River, residents were often faced with water shortage problems. Although the Hino River is one of the major inflowing rivers of Lake Biwa, it has low water levels and even dries up in the summer. However, under such environmental conditions, people have developed various strategies to use the valuable water wisely (Gamo Town Government 1999).

In Otsuka Village, a farming village in the Gamo area, many irrigation ponds were built to save water for daily use, rice farming, and fish breeding. In recent years, the role of these irrigation ponds in supplying water has been taken over by agricultural dams. Hence, subsistence activities, such as fish breeding, have been lost. However, irrigation ponds are still part of people's lives (Yang 2008). *Fig. 2* is the scene of 'Minazuki-sai', the annual festival of

the small shrine on the small island in an irrigation pond. In this village, an irrigation pond gives residents enjoyment and a place to hold festivals.

Subsistence Activities of Lakeshore Villages

A long time ago, the shores of Lake Biwa were not habitable. First, the residents had to deal with the risk of flooding due to fluctuations in water level of the lake. Secondly, the lakeshore was mostly covered with lowland swamps, which was inconvenient for farming. In fact, people utilized small boats to travel between their homes and paddy fields until the implementation of land improvement projects in the 1970s. However, this indicates that people have been living on the lakeshores since early times, while adjusting to the difficult environmental conditions.

There are several informative studies regarding the subsistence activities of lakeshore villages. Otsuki (1984), who studied people's subsistence activities during the period from 1912 (the Taisho Period) to the 1970s, described the fishing activities by farmers of a village on the west shore of Lake Biwa. In this village, the village board held a controlling interest of an eri (a type of stationary fishing trap, see section 'Various fishing methods developed in and around Lake Biwa'), and often took measures to preferentially let the poor in the village use it. Thus, the fishing system served as a kind of social security for the village residents.

Yasumuro (1998), who studied the subsistence activities of rice farmers in the south basin area of Lake Biwa, pointed out that the farmers' fishing activities not only served as minor subsistence activity to obtain food, but also as part of the enjoyment of rice farming. According to Yasumuro, paddy field fishing unique to rice farming in lowland swamps was an integral part of life for the rice farmers.

As described above, there have been a variety of major and minor subsistence activities associated with water (*Fig. 3*). The residents of the Lake Biwa basin used to combine such major and minor subsistence activities to make a living. This is called a 'composite livelihood' by ethnologists in Japan.

Models for Modern Environmental Conservation Activities

In recent times, people's lifestyles have changed greatly around Lake Biwa. Subsistence activities such as charcoal production have been lost, and fishing activities by farmers have been decreasing as well. However, a growing interest in nature conservation has given rise to environmentally friendly activities. The '*satoyama*' restoration movement,

Fig. 3
Fishery in a lagoon. (Higashi-omi City)

for example, is well-known in Japan, and is also carried out by various groups of people around Lake Biwa (Matsumura and Kosaka 2010). Moreover, the restoration of reed beds along the lakeshore, and paddy fields as nursery grounds for fishes (see sections 'The Shiga prefectural governmental measure for conservation and restoration of common reed marshes: The ordinance on conservation of the Reed Beds around Lake Biwa' and 'Loss and re-establishment of water networks among rice fields, waterways and Lake Biwa') are noteworthy.

Since people no longer use reeds as roofing material, the restoration movement today is purely for the purpose of conserving biodiversity and improving water quality. Likewise, the restoration efforts of paddy fields as nursery grounds for fishes are mainly made by rice farmers to increase the population of endemic fishes, as they no longer need to count on paddy field fishing for food. Thus, the traditional subsistence living activities have been brought back for different purposes. Although not all of the traditional practices are environmentally friendly, the decades of accumulated experience and knowledge of people from everyday life in the Lake Biwa area provide useful models for today's environmental conservation activities.

Conclusion

Because of the recent environmental problems in the Lake Biwa basin, people have become increasingly aware of the importance of traditional subsistence activities. As a result, these types of activities have been brought back for nature conservation purposes.

Not all of such activities have a solid scientific foundation; for example, the effectiveness of several conservations activities, like harvesting reeds, remains a matter of debate (Makino 2009). However, we can use some traditional subsistence activities as the basis of environmental conservation efforts in populous areas like the Lake Biwa basin.

Acknowledgement

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5.2.2 People's Use of River Water around Lake Biwa

Miki Kawata

Abstract The aim of this section is to examine the relationship between people and water in the Lake Biwa area through daily water use by analysing first the situation before the introduction of a modern water system, and then by analysing the present-day situation using three categories of 'distance' between people and water: geographical distance, social distance, and psychological distance.

Keywords Water supply system • River water • Waterway • Local rule • Visibility of water usage

Relationship Between Water and Its Users

In the 1950s, a modern water supply system was widely introduced in Japan. The Lake Biwa area was no exception, and this introduction changed the relationship between people and water. Yukiko Kada investigated the everyday use of water around Lake Biwa and found that the relationship between people and water used to be 'close' but has become 'distanced' after the modern water system was introduced. Three key elements were involved in this change: geographical distance, social distance, and psychological distance (Kada 2002, 2003).

According to Kada (2003), for example, geographical distance expands by bringing water for people's daily lives far from their living environment, such as not from a local river but from a dam. Social distance expands by shifting the management system of water from local people to either the national government or prefectural authorities, by which the systematic participation of local people becomes difficult. Finally, psychological distance expands when individuals' consciousness towards the water environment is diminished.

The aim of this section is to examine how people made these three categories of 'distance' close in the Lake Biwa area through daily water use. To achieve this, we first analysed daily water use before the introduction of a modern water system, and also their present-day circumstances around Lake Biwa. A river that flows into Lake Biwa, the Takatoki River, and two villages through which the river flows were selected for this study. One village is Nakanokawachi, located in a mountainous area, and the other is Amenomori, located on the plains. People in these villages still use the water from the river in their daily lives (*Fig. 1*).

With the permission of research partners, the following data from Kawata's field work surveying people's consciousness towards the water environment around Lake Kasumigaura (in Ibaraki Prefecture, the Kanto District) (Kawata et al. 2007) are used to compare people's water use between the Lake Kasumigaura and the Lake Biwa areas.

Outline of the Takatoki River Area

The Takatoki River is situated in the far north of Shiga Prefecture, and its source is located next to the border with the neighboring prefecture of Fukui. It has a total length of 41.4 km and a total catchment area of 208.7 km^2. It flows southwards from the mountains to the plains, joining the Ane River just before flowing into Lake Biwa. There used to be several other villages in the mountainous area but the villagers moved out because of hardships and dam planning. On the plains, there are many rice fields that take the water from the Takatoki River.

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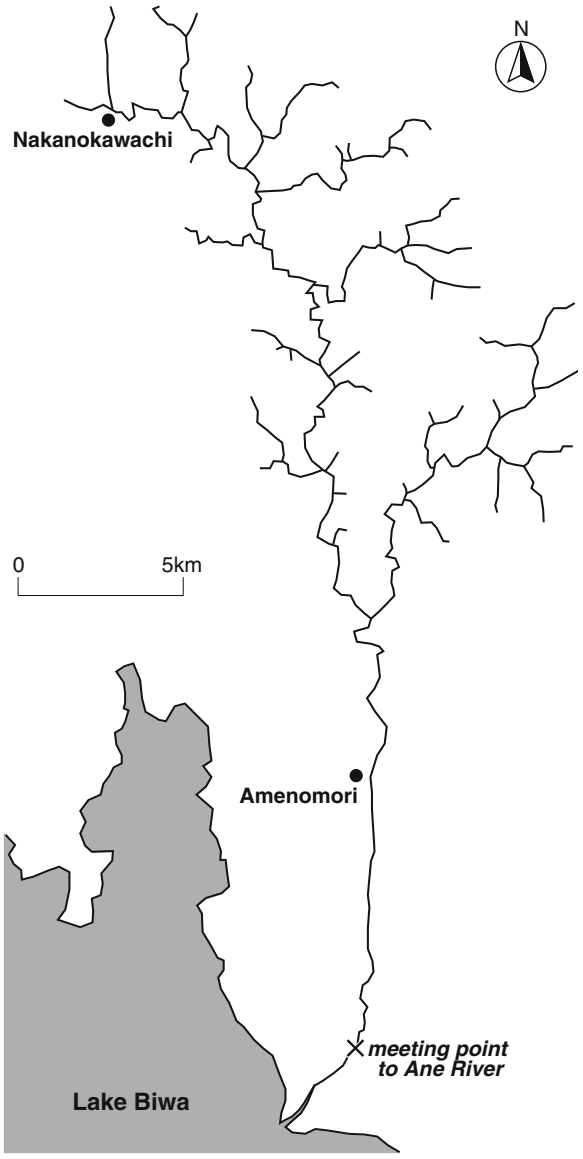

Fig. 1
The basin of the Takatoki River.

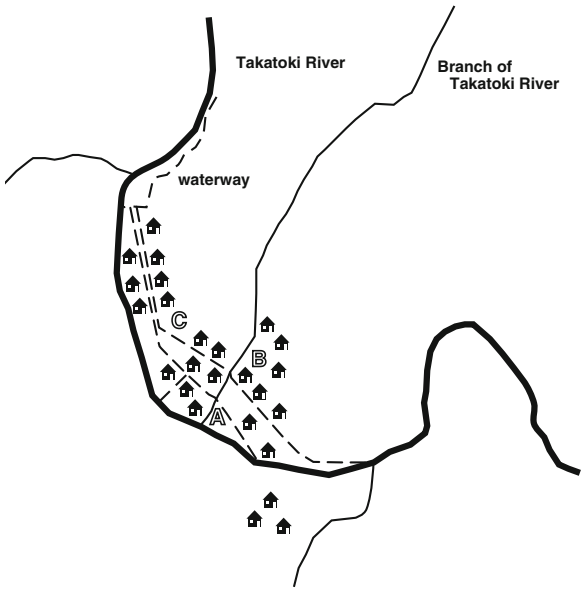

Fig. 2
Waterflow in Nakanokawachi Village.

Water Usage in a Mountain Village: Nakanokawachi

Nakanokawachi is the first village that the Takatoki River meets, and is located approximately 4 km away from the river's source. The village has an old highway nearby, the 'Hokkoku Kaido', which offers a convenience for many tourists.

As indicated in *Fig. 2*, most of the houses in Nakanokawachi were built right next to the Takatoki River and its branch.

A lady, born in 1928 and who has lived by the river (*Fig. 2A*) mentions that when she was a child, there were about ten houses around the source of the river, and several just above hers. She said that she drank the water from the river at that time but never thought it was unhygienic.

In those days, people who lived along the river had private steps to the water, and roofed paths extended from their houses to the river, so that they could use the water even during the rains without getting wet.

Likewise, people who lived by the branch of the Takatoki River (*Fig. 2B*; *Fig. 3*) used water from the branch. The water was used for drinking and washing rice, but nowadays it is only used for cleaning vegetables and breeding fish.

A lady who lived near the branch of the Takatoki River said that there was a local rule that dirty objects, like nappies, must be washed at a designated place located at the lower part of the river. She actually washed her baby's nappies there back in 1964.

From her narrative, we can appreciate that in the past it was possible for people to use the river water, even the lower part of the river within a village, by applying such local rules.

However, the lady said that she chose to go down to the designated place not only because it was the local rule but because she was 'uncomfortable' washing dirty things

such as nappies at the river water facility in her own house. Although the residents no longer use the river water like in the past since the modern water supply system was introduced, she still has this feeling, and does not wash dirty things at home.

In the old days in Nakanokawachi, it seems that well water was used in addition to the river water in people's everyday lives. A man, who was born in 1932, said that in Nakanokawachi, up until the modern water system became accessible to the residents, most of them made use of their private wells. In his house, when he was a child, the well water was for drinking and the river water for washing clothes. Today, he still drinks water from the well but uses tap water for bathing (*Fig. 2C*).

Water Usage in a Plains Village: Amenomori

The Takatoki River passes through Nakanokawachi and several other villages in the mountainous area, and finally arrives on the plains. This area in Shiga Prefecture is known for the conflicts over water usage among several villages. A lot of sluice gates were built on the Takatoki River and many people depended on water supplied through them.

When there was little rain, the rice fields which drew water from the upper sluice took most of the water. This provoked the farmers who drew water from the lower sluice. They marched to the upper sluice and carried out protests calling 'yuotoshi', which roughly means 'break the well'.

Meanwhile, this area sometimes suffered from floods. As shown in *Fig. 4*, Amenomori is situated a little distance away from the Takatoki River. We can see that Amenomori residents, for fear of floods, did not build their houses close to the main river like in Nakanokawachi.

Although Amenomori is situated a short distance from the Takatoki River, there is a waterway for everyday life and for irrigation. It draws water from a point further up the Takatoki River and branches into several courses within the village. Along this waterway, there are many houses and water facilities.

These facilities are roughly divided into two types: those through which people can access the water indoors (locally called 'mizuya' or 'water house') (*Fig. 5*), and others where people go down special steps to reach the water from their yards (*Fig. 6*).

Local people said that they used to have indoor water facilities, but when they rebuilt their houses, many people decided to set up the step-type facilities instead.

Fig. 3
Houses facing the branch waterway.

When there were many indoor water facilities, people felt ashamed for not using any of the water in the river. Hence, they used the water from the waterway mostly for washing and bathing. But recently, people only use the river water for cleaning, gardening, and rinsing vegetables. It seems that the opportunities for using water from the waterway have decreased compared to the past.

A resident explained that people no longer frequently used water from the river due to concerns over pollution. In fact, he has seen colored water flowing down the waterway, which could have been bath salts.

In general, Amenomori residents do not rely on the river water as in the past, but still use it for those tasks which do not require much water purity. Moreover, this change can be interpreted that the form of facility changes in response to how the water is used.

In terms of drinking water, three communal wells were used before the modern water system was introduced into their village. However, when children swam in the Takatoki River, they sometimes accidentally drank its water. It seems that the river water was not necessarily undrinkable, although the well water was considered to be better for drinking.

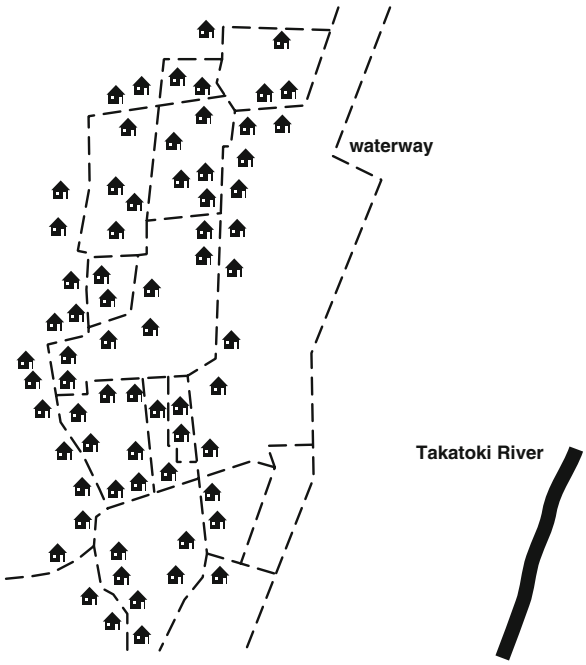

Fig. 4
Waterflow in Amenomori Village.

Closeness of Water

In the village located in a mountainous area, Nakanokawachi, people built their houses along the river. Each house used to have a path covered with a roof extending to the river, which provided people with easy access to the river. This shows that Nakanokawachi residents decreased their

Fig. 5
An indoor facility for water use.

Fig. 6
A step-type facility for water use.

geographical distance to the water by adapting themselves to the surrounding natural environment.

On the other hand, in the plains village, Amenomori, people established a waterway to draw water from the Takatoki River, which branched into several courses in the village. Therefore, many houses faced the waterway and people had easy access to the river water. In this case, people decreased their geographical distance to the water by bringing it to close proximity to where they lived.

One similarity between the two villages is that there were facilities for river water usage at each house along the watercourse. This means that the facilities were connected with each other by the watercourse. This is the background for the rules such as 'wash nappies at the lowest point of the river in the village'. It is thought that such rules made it possible for many people in the village to get access to clean water.

An interesting thing to note here is how such local rules have been kept by individuals. It has been pointed out that social control tends to work strongly in connection with surface water usage, even when people can see what other water users are doing at the water's edge (Kada 1991). This is to say, by enhancing the visibility of water use, rules tend to be kept better. The data of the two villages reveal two different kinds of visibility of water usage. The first is the place where water is used. In both villages, people had their water facilities constructed facing public spaces. This probably raises the potential that someone else will notice what is going on along the water's edge. The second is the condition of the water that was used. In Amenomori, though their water facilities were established at the boundary between private and public space, they used to be placed indoors, so that it was difficult to see how water was being used from the outside. However, people could tell how the water was being used by looking at its condition, just like the man mentioned previously, who could tell something like bath salts were flowing down the waterway. In villages like Amenomori, houses are built close to each other; hence the visibility of water usage would be higher.

In short, water usage has been monitored in two ways among the residents: how people use water and the resulting water quality. These are considered to have drawn the social distance between people and water closer, resulting in managed water use in local communities.

Finally, let us look at the psychological distance. This matter can be considered based on the statements made by the residents of the two villages, who express their attitudes towards the river water as follows: In Nakanokawachi, people feel 'uncomfortable' to wash dirty things at the same place where they wash relatively clean things. In Amenomori, people feel 'uncomfortable' not to use the river water. In both cases, such 'uncomfortable' feelings may come from people's attitude towards nature. Being blessed with natural resources, the residents might have developed a sense of gratitude and closeness to the water.

5.2.3(1) Traditional Culinary Culture of Shiga Prefecture

Masako Horikoshi

Abstract Lake Biwa, located in Shiga Prefecture, is inhabited by a multitude of indigenous species of fish and shellfish that are useful food resources. They are processed to make traditional dishes, such as fermented fish ('funa-zushi'), cooked sweet fish, and soup of the Seta shijimi clam (*Corbicula sandai*). The combination of farming and fishing is a typical lifestyle around Lake Biwa. People have developed the special culinary culture in the Shiga area from the traditional foods, relying on rice and fish in addition to beans, vegetables and potatoes, providing a well-balanced and nutritious diet.

Keywords Traditional culinary culture • Food culture • Rice • Fish • Fermented fish • Funa-zushi • Nare-zushi

The Traditional Culinary Culture of Shiga Prefecture Centered on Fish and Rice

Shiga Prefecture has an Asian monsoonal climate that has high precipitation, and therefore the area is abundant in a variety of foods. Rice and fish in particular are bountiful in many parts of the monsoon region, and they are staple foods in the Asian diet, including that of Japan.

People in Shiga have eaten rice and fish from ancient times, and they have developed a distinctive culinary culture based on Omi rice, which is produced in Shiga Prefecture, and the plentiful fish and shellfish from Lake Biwa. It is characterized by various fermented foods such as nare-zushi and vegetable pickles. People enjoy a well-balanced diet consisting of rice, beans, vegetables, and potatoes from the Lake Biwa basin.

People enjoy various fish dishes, such as grilled fish with miso paste, simmered fish with Japanese pepper, and fish seasoned with vinegar, or soy sauce. There are many types of fermented fish dishes, called 'nare-zushi', made from lake fishes such as funa (crucian carp, *Carassius* spp.), ugui (Japanese dace, *Tribolodon hakonensis*), hasu (piscivorous chub, *Opsariichthys uncirostris uncirostris*), Biwa ayu (*Plecoglossus altivelis* subsp.), wataka (Biwa culter, *Ischikauia steenacheri*), oikawa (pale chub, *Zacco platypus*), Biwa masu (Biwa salmon, *Oncorhynchus masou* subsp.), and dojo (weatherfish, *Misgurunus anguillicaudatus*) (see Appendix 2). The most popular fermented fish dish is funa-zushi.

Rice as a Staple Food in Japan

Shiga has been a famed rice-producing region in the Kansai area from ancient times, and rice is the top agricultural crop of Shiga Prefecture. There are various methods to cook rice, such as boiled rice, 'mochi' (rice cake), and rice dumplings (Shiga no Shokuji Bunka Kenkyukai 2000). Rice is also used for fermentation to make Japanese wine (sake) and 'nare-zushi'. People enjoy a special soup, 'zoni', made of rice cakes and vegetables on New Year's Day. During Okonai, a kind of festival, and spring festivals, farmers pray for good crops by offering big rice cakes, sake, and special nare-zushi to their god of agriculture. There are various cooked rice dishes, including chirashi-zushi, oshi-zushi, sekihan (red bean rice), and takikomi-gohan (cooked rice with vegetable or fish). People also make a variety of rice dumplings (dango), such as oae-dango (with vegetable and tofu), yomogi-dango, yama-gobo-dango, and mitarashi-dango. Rice is an important ingredient for Japanese sake brewing, and there are many sake breweries in the Shiga area.

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Combined Lifestyle of Farming and Fishing

In addition to rice farming, many people in Shiga have also participated in fishing in and around Lake Biwa, a lifestyle that could be called 'farmer's fishing'. The scale of fishing has been very small, conducted with small boats and traps. Accordingly, the fish resources of the lake have been protected from overfishing. This farmer's fishing style is a characteristic feature of Shiga Prefecture and also of the Asian monsoonal area. The famous fishing ports of Lake Biwa are Katata, Okishima, Yamada, Moriyama, Azuchi, Minamihama, Onoe, Siotsu, Sugaura, Chinai, Imazu, Funaki, and Takashima. Fish and shellfish were landed from these fishing ports, sold and consumed widely, not only at the lakeside but also in farming villages within about 10 km of the lake. The fish from the lake have supported people's lives as a good source of protein, calcium, and fat.

Funazushi, the Symbolic Food of Shiga

Sushi is a famous dish of Japan, and there are two major kinds of sushi: 'nigiri-zushi' and 'oshi-zushi'. However, there is another unique type of sushi called 'nare-zushi', which is made from fish and rice fermented with lactic bacteria. When people first taste nare-zushi, they notice its very strong and pungent smell, similar to pickles. People in Shiga, however, appreciate this smell and even say it is one of their favourites.

'Funazushi', a type of 'nare-zushi', is made from round crucian carp and rice (Kojima et al. 1995). It used to be a food for special occasions, such as New Year's Day and festivals. The Shimoni'ikawa shrine in Moriyama City is famous for the funa-zushi cutting festival, 'Sushikiri Jinji', conducted in front of the God of Agriculture (*Fig. 1*).

For nare-zushi, any fish of any size are used, usually funa, koi (common carp, *Cyprinus carpio*), ugui, hasu, oikawa, wataka, moroko (willow minnow, *Gnathopogon caerulescens*), Biwa ayu, Biwa salmon, and dojo. In fact most of the fish species in Lake Biwa can be processed into nare-zushi.

Fig. 2 shows 'hasu-zushi' made in Chinai, Makino, located in the western area of Shiga Prefecture. It is made for the summer festival of Karasaki Shrine, located by the lakeside. There are many kinds of nare-zushi that are made as 'shinsen', an offering for gods, such as 'dojo-zushi' in Ohashi in Ritto City, and 'ugui-zushi' at Kamikaide in Takashima City. After offering to their god, the nare-zushi is eaten at a naorai party.

How to Make 'Nare-zushi', Fermented Fish with Rice

Nare-zushi originated in the monsoonal area of southeastern Asia, namely Thailand, Laos, Vietnam, and Southern China. Rice farmers here have developed fermentation

Fig. 1
The funa-zushi cutting festival conducted in front of the god at the Shimoni'ikawa shrine in Moriyama City is called 'Sushikiri Jinji'. Funa-zushi is cut on the large chopping board by young men.

Fig. 2
People enjoy the summer festival with hasu-zushi in Chinai, Takashima City.

Fig. 3
Amenoio-gohan, cooked rice with Biwa salmon.

techniques for the preservation of raw fish, and have improved their techniques to make delicious nare-zushi.

Although tropical Asian people do not use much rice to ferment the raw fish, people in Shiga usually use a lot of cooked rice to do so. They have developed their own technique to make nare-zushi, by controlling the volume of rice, temperature of fermentation, salt concentration, and fermentation period. Their techniques have some points in common, including the use of fish, rice, and salt as ingredients, and fermentation in anaerobic conditions.

To make nare-zushi (Horikoshi 2005; Shiga no Shokuji Bunka Kenkyukai 2009), first the fish are scaled, and their intestines and gills removed in a process called 'tsubonuki'. Then, they are packed with salt for over 2 months until the summer. Next, during the hottest summer days, the salted fish are washed and dried outside. Then they are pickled with cooked rice and fermented for over 6 months in a pot with heavy stones weighing down the lid to create pressure. As rice promotes fermentation, about an equal volume of rice to fish is required for the fermentation of nare-zushi, which is a lot more rice compared with elsewhere, because the average temperature of Japan is lower than that of tropical Asia.

Lactic bacteria favour both the starch in cooked rice and the anaerobic conditions. Rapidly multiplying lactic bacteria in the pot ferments the salted fish, turning them into pungent nare-zushi. During the fermentation period, many organic compounds are produced, including lactic acid, acetic acid, flavorful alcohols, esters and carbonyl compounds (Kubo et al. 2007). The fermentation process preserves fish for a few years. The product, when it is ready to eat, has an acidity of around pH4, and it tastes sour and smells like cheese. Its distinct aroma, strange taste and strong smell, is due to the many kinds of volatiles and acidic compounds formed in the pot. Many people in Shiga, however, like it very much, and they use special nare-zushi during festivals. They also eat it when they have a bellyache or a cold because they believe it cures those sicknesses.

We found that the fermentation process increased the amount of soluble protein, amino acids, and more soluble types of calcium in funa-zushi, and it also produced many kinds of organic acids, alcohol, ester, aldehyde and ketone (Kubo et al. 2008). The concentration of lactic acid reached a peak at around 1.5–2%. In funa-zushi, 22 kinds of volatile compounds were detected, including acetic acid, 1-butylic acid, ethanol, 2-phenylethanol, ethyl lactate, and propylene glycol.

Other Local Fish Dishes from Lake Biwa

There are various other dishes made with fish and shellfish in Shiga Prefecture, such as 'tsukudani' (fish cooked with soy sauce), fish cooked with soybeans, 'sashimi' and 'namasu' (raw fish with sour miso), 'junjun' (fish sukiyaki), miso soup, roasted dishes, and well-simmered dishes (Shiga no Shokuji Bunka Kenkyukai 2003). The famous dishes are 'amenoio-gohan' (cooked rice with Biwa salmon) as shown in *Fig. 3*, 'ebimame' (cooked shrimp with soybeans), 'ayu-tsukudani' (cooked Biwa ayu with soy sauce and Japanese peppers), 'isaza mame' (cooked Biwa goby with soybeans), 'shijimi-jiru' (Seta shijimi clam soup), 'koi-tsutsuni' (well-cooked common carp with sugar and soy sauce), 'yaki-moroko no dorozu' (grilled willow minnow with sour miso), 'hommoroko nambanzuke' (fried willow

Fig. 4
Funa-miso, well-cooked crucian carp with miso.

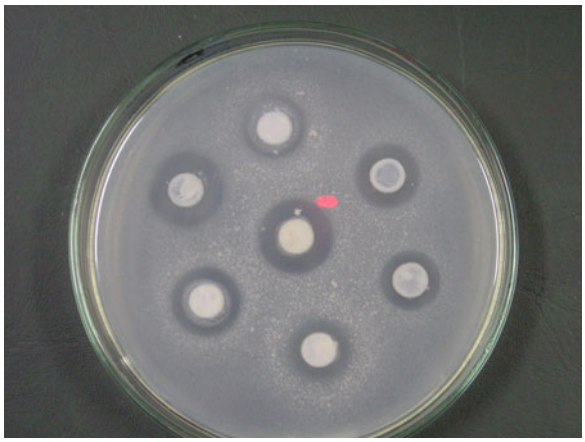

Fig. 5
Antibiotic power of 'funa-zushi' against some microorganisms. Rice from funa-zushi represses multiplication of *Bacillus subtilis* in agar diffusion tests (Kubo et al. 2007).

minnow with vinegar), 'namazu no junjun' (catfish [*Silurus asotus*] sukiyaki with green onions and burdock), and 'funa-miso' (well-cooked crucian carp with miso) as shown in *Fig. 4*. These dishes have been very popular with people in Shiga. Within each area and between households, there are, of course, variations in the taste of the same dish. For example, 'tsukudani' is sweeter in the southern area of Shiga Prefecture than in the northern area.

Good Nutrition for People Around Lake Biwa

Fish is high in protein, fat, and calcium. The calcium salts in nare-zushi are easily dissolved and absorbed into the intestinal cells of the human body, so nare-zushi is a good calcium source for Japanese people, who typically only take 90% of the recommended daily amount of calcium.

Fish oil in round crucian carp forms about 5% of its body weight. We have found by measuring the peroxidized value that nare-zushi keeps the fish oil as fresh as in raw fish. We have also confirmed, with agar diffusion tests, that solutions from funa-zushi have antibiotic powers against some microorganisms, like kinds of *Escherichia coli* and *Bacillus subtilis*, (Kubo et al. 2007), as shown in *Fig. 5*. These transparent circles around the spots of rice taken from funa-zushi show that rice of funa-zushi repressed the multiplication of *Bacillus subtilis*. We also found that acetic acid, one of the volatile components from funa-zushi, inhibited the increase of *E. coli* and *Bacillus subtilis*.

Asian Fermented Fish and High Self-sufficiency of Food

The nare-zushi of Shiga Prefecture originated from the monsoonal area of southeastern Asia, namely southern China, Thailand, Laos, and Vietnam. There are some similarities in the food cultures relating to rice and fish in these areas. Southeastern Asian people have many kinds of fermented fish, such as 'pla ra', 'pla som', and 'nam pla'; pla som is similar to nare-zushi of Shiga Prefecture. We investigated how these fermented foods are used and how often they are eaten in Laos and Thailand. Pla ra and nam pla are used every day for soup, salad, and 'nam phrik'. Pla som is generally eaten, fried or grilled, 2–3 times a week. The home-made ratio of 'pla ra' ('pla duke') was high at 83% in rural villages in Laos. Nam pla was bought and used frequently in Thailand. People who live in the tropical monsoonal areas of Asia consume higher quantities of various fermented fish products for their daily meals than the Japanese. Also, plains people eat a lot of raw vegetables and fermented foods at every meal.

In the Asian monsoonal area, people procure their daily foods mainly from nature, such as paddy fields, gardens, rivers, ponds, forests, and mountains. In Laos, villagers catch wild aquatic resources such as fishes, frogs, shrimps, crabs, and insects, especially crickets; they also harvest various wild greens, young leaves, and fruits. Accordingly, their regional self-sufficiency in food is very high.

In the past, the Japanese were able to obtain most of their food requirements from their fields. However, today most food is imported from foreign countries. Domestic self-sufficiency in food is very low, only 41%, and local food supplies are at threat of being reduced further. We might lose Shiga's unique traditional food culture because of the decrease in fishery resources of Lake Biwa and because of the decline in local agriculture.

Conclusion

Lake Biwa has supported the lives of people living in Shiga Prefecture for a long time. Now, we are facing critical issues, such as decrease in seasonal catches. In ancient days, Lake Biwa was famous for having clean water; it was low in nitrogen, phosphorous, and other pollutants. Nowadays, however, contamination from industry, agriculture, and residential areas has increased the level of pollution in the lake. Some local foods and indigenous fish of Lake Biwa are now on the verge of extinction. The total amount of fish caught has been decreasing gradually for the last four decades, and so Shiga Prefectural Government has been making efforts to reduce the pollution. Fish farms have been built to increase the amount of fish and to help breeding, and large numbers of young fish have been released into the lake and rivers.

As a result of such efforts, pollution levels of Lake Biwa have been reduced, and fish breeding has been marginally improved. Living in harmony with Lake Biwa, it is very important for the older generation to hand down traditional cooking techniques and recipes to the younger generation. This is strongly recommended in view of the urgent need to increase the levels of regional self-sufficiency of food in the future.

Acknowledgement

We would like to thank all who helped us during our surveys and experiments. We appreciate the input of the members of the Study Group for Traditional Food Culture of the Shiga Area.

5.2.3(2) Tap Water, Sewage Systems and the Modern Irrigation System

Atsushi Makino

Abstract For all of the people, water is the most basic resource. However, the way of obtaining water had a variety of forms. In this paper, the traditional water use and its changes around Lake Biwa during modern age will be described. Changes include the adoption of the innovative water and sewer systems, and the modern irrigation system called Gyaku-sui, in the post-war era. These new water systems provided the residents in the catchment area with a constant water supply, but also lead to the emergence of serious water pollution problems in the lake because they undermined the rule on using rivers, streams and waterways. As a result of this analysis, it was pointed out that the residents have to hold appropriate social relationships to manage the water circulation and preserve the water quality in a heavily-populated wetland around Lake Biwa.

Keywords Waterworks and sewage system • Modern irrigation system

Introduction

Located in the East Asian monsoon area, Japan has rich water resources because of plentiful rainfall. In fact, rice, which is a water-intensive crop, is cultivated in the wetlands around rivers and lakes. Moreover, people have been using the existing water resources for drinking, washing, and bathing. Naturally, there is the assumption that people who have access to plentiful water would hardly appreciate it. That, however, is not applicable in Japan. There is enough evidence to show that Japanese people have devoted their attention to the conservation and effective use of valuable water resources (Miyamoto 2010).

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For example, studies of Japanese folklore have detailed the various efforts of people in sustainable daily water usage. The residents around Lake Biwa are no exception. Most rice farmers, who used to comprise the majority of the population in the Lake Biwa area and in most of the lakeshore villages, were also fishermen. Yasumuro, a folklorist in Japan, described people's lifestyles combining rice farming and fishery as unique cultural subsistence composite livelihoods around Lake Biwa (Yasumuro 1998).

The following section introduces one aspect of their livelihood related to the environmental sustainability of Lake Biwa, which is the transformation of water systems during the rapid economic growth era of Japan from the late 1950s to the early 1970s. Since then, most of the Japanese rivers, lakes, and adjacent waters have suffered from serious water pollution caused by eutrophication or red tide, as a result of rapid industrial growth. Traditional water use and its changes around Lake Biwa during modern age will also be described.

The Traditional Water Use Around Lake Biwa

Water Pollution in Lake Biwa

Since the 1970s, water pollution has been causing serious damage to Japan's lakes. In fact, Japanese society went through huge economic and social changes during the period of rapid economic development, which resulted in the concentration of population in big cities and the rise of many industries. Scientists have pointed out that degradation of water quality was the unwanted byproduct of the rapid economic growth. Environmental scientists also focused on problems resulting from drainage water from industries and homes pouring into the catchment area. Lake Biwa was faced with unexpected environmental problems during this period, in particular water pollution, eutrophication, and freshwater red tide.

However, it did not make sense that the lake surrounded by rural areas had to suddenly face serious water pollution, because the local residents had been using water with no problems until then. Furthermore, the sewage system had not yet spread to the rural areas of Japan, including the Lake Biwa Basin area at that time. Now the question arises: what were the causes of such serious wastewater problems in the largest lake in Japan? In order to find answers to this, we need to look at traditional water usage and the changes it underwent after the introduction of waterworks around the lake.

Small Rivers and Wells

There are more than 100 rivers and countless small rivers in the catchment area of Lake Biwa, providing many kinds of resources for people's lives. For example, Furukawa, an environmental sociologist who researched the traditional water use in a village around the lake, reported that such small rivers had provided the residents with ten different types of resources: boat transportation routes, playgrounds for children, drinking water, irrigation water, water for fire prevention, fishery grounds, algae for fertilizer, washing water, water for snow-damage prevention, coolant water, and locations for annual festivals. Residents of the village took good care of these rivers and used them sustainably (Furukawa 1984).

The following section describes the traditional way of using water in Harie Village located on the west bank of the lake. *Fig. 1* shows the arrangement of rooms in a farmer's house in this village, focusing on water use. Today, most of the villagers around Lake Biwa use municipal water. In this village, however, residents have maintained their traditional water use. There is no municipal water available in this house. The family members have been utilizing two kinds of water supply sources for a long time. They obtain water for drinking, cooking, and cleaning from a type of well which they call 'Tsuboike'. In addition, they have also built a small reservoir called 'Hataike' to store water from a mountain stream. They wash vegetables or fish before cooking in this small pond in which they often keep carp.

Small Rivers as Common Property Resources

Turning the attention to people's use of river water, there is another important thing to point out. The wastewater flows from each household into small rivers to be used repeatedly. In this village with such a circulating waterway system, it is important for the residents to be careful, avoiding troubles over the drainage water. That is to say, the residents not only have to take care of the water they use but also their drainage water.

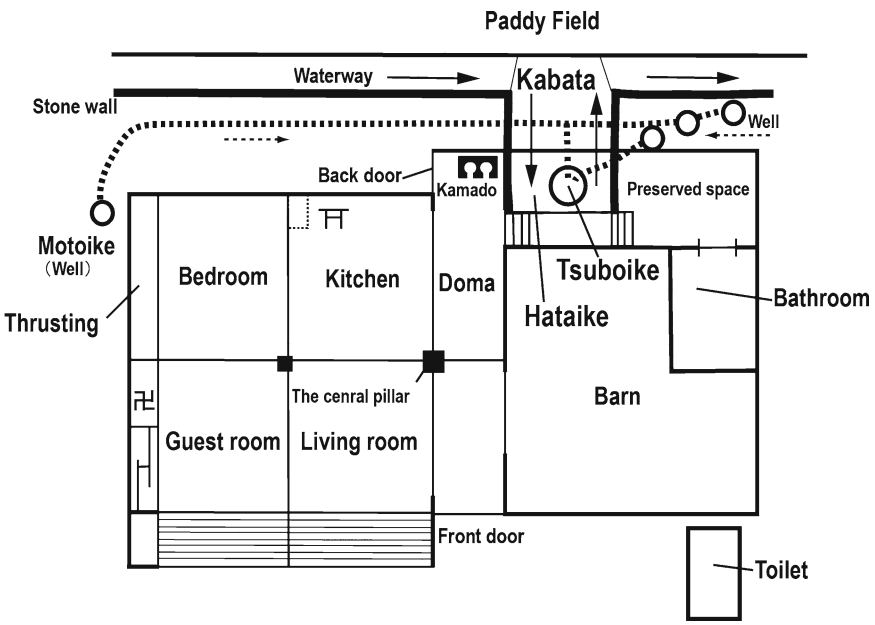

Fig. 1
The arrangement of rooms in a farm house focusing on water use (Harie Village).

As suggested above, the people of the village have made many kinds of unwritten rules regarding the drainage water to sustain their circulating waterway system. For example, in most of the villages, residents had to limit the types of wastewater flowing into the rivers by common consent. The bath water, for example, was percolated into the soil in the garden or farm lands. In such a lifestyle, water of small rivers is one of the common property resources among the residents. Such resources were rather well-maintained because the residents shared responsibility on appropriate use of them (Burger et al., 2001). Thus, it is suggested that water pollutions in the 1970s is characterized by the weakening of the commons institutions concerning small rivers around Lake Biwa.

Fortunately, in this Harie village, water has been maintained clean in the small rivers till now. In recent decades, since about 40 years ago, however, many of the small rivers in the Lake Biwa watershed have been polluted by household wastewater, in spite of the traditional norms of keeping water clean. The following section will examine its cause.

Tap Water and Modern Irrigation System

Waterworks and Sewage System

Around Lake Biwa, municipal waterworks have been expanding rapidly since the 1950s. *Fig. 2* shows the spread of waterworks and sewage systems among the population of the catchment area of the lake. This figure represents two facts. Firstly, municipal waterworks were expanded in the areas around the lake from the 1950s to the 1960s, which coincides with the period of emergence of water pollution problems. Secondly, sewage systems were expanded rapidly from the 1970s, as a result of the environmental policies enacted to conserve the lake's water quality.

Life in rural Japan has been modernized since the end of World War II. The government has implemented various measures of modernization: comprehensive agrarian land reform, democratization of the rural economy system, such as the setting up of farmers' cooperatives, improving the gender gap, reforming the right of fishery, and empowering and encouraging them to participate in the local governments, etc. Postwar modernization in Japan was characterized by political democratization.

Modernization and Life Change

In the 1950s, the emphasis in rural modernization shifted away from political revolution to infrastructure building, and water supply from waterworks was a symbol of modernity during this period. This was welcomed by the farmers, especially women and children who were liberated from the heavy labour of pumping water. Kada, an environmental sociologist, documented the conversation of the women welcoming tap water, 'we felt as if we were in the Heaven' (Kada 2001). Actually, the spread of waterworks brought various advantages. Water from the waterworks was safer and more convenient for people to use compared to the water from wells and small rivers.

However, after the introduction of waterworks, the surrounding water environment began to gradually change, First, people's interest in small rivers was lost, and small rivers which had provided the residents with clean water became the drains for wastewater. Secondly, at the same time, many kinds of water use at the small rivers, such as swimming and fishing, were cut down. Thirdly, small rivers and artificial waterways became the only

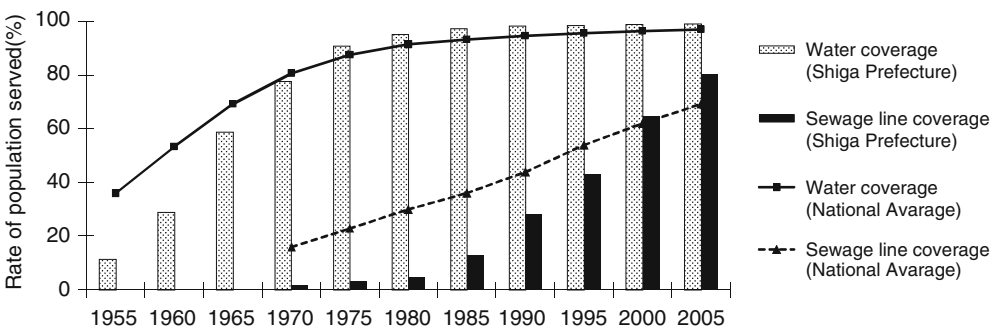

Fig. 2

Spread of tap water and sewage systems around Lake Biwa. (source: Shiga Prefectural Government 2010b, c)

drainage channels in the rural areas after the new irrigation system called Gyaku-sui was built. In this system, irrigation water is pumped directly from Lake Biwa and supplied via a pipeline. Small rivers, including streams and waterways, however, came to be used only as drainage channels. Summing up these changes, the social distance between small rivers and people's lives was extended.

In addition, the residents were liberated from their own rules for sustaining the water use system in their village. Water shortage and the heavy labour of drawing water from streams became memories of the past around Lake Biwa. It was no longer necessary to worry about other people when discharging wastewater. For the reasons mentioned above, the presence of common institutions to ensure sustainable use of water resources such as small rivers was gradually weakened or lost. However, the lifestyle changes based on such liberation brought unintended consequences to the residents' living environment. During the 1970s, Japanese rivers and lakes suffered serious damage from water pollution.

Water Pollution Problems and Its Responses

In Lake Biwa, a freshwater red tide broke out on a large scale in the late 1970s. Experiencing such an unfavourable event, the local residents raised concerns regarding water quality problems in Lake Biwa. Especially, in this period, the Japanese government had ventured into the 'Lake Biwa Comprehensive Development Project' which primarily focused on flood control and water resources development in the Lake Biwa area. The water pollution problems in the upstream area of the Yodo River, which provided water to the Kansai district, became the motive to change policies for conservation of lakes in Japan.

People in the catchment area of the lake started an environmental movement called the 'soap movement' for improving their own drainage water. On the other hand, the prefectural government took various measures for conserving aquatic environments, such as the enforcement of the 'Prefectural Ordinance Concerning the Prevention of Eutrophication of Lake Biwa'. After the establishment of this ordinance, the Japanese Government enacted the 'Act on Special Measures Concerning Conservation of Lake Water Quality', covering the lakes throughout the country.

Since the 1970s, the sewage system expanded rapidly in the watershed of Lake Biwa. As the result of such efforts, Shiga Prefecture has one of the most widespread sewage systems in Japan. And, the construction of the sewage system is an effective measure against the household drainage in the watershed areas of the lake (*Fig. 2*).

Conclusion

The residents around Lake Biwa and Shiga Prefectural Government have tried various methods to maintain the environment of the lake. However, a satisfactory outcome has not yet been obtained, which is to restore the lake to its beautiful state as of 40 years ago. Advanced environmental technologies might provide us with good groundwork for solving environmental issues, but would not be able to increase the residents' motivation for action to achieve sustainable use of water, which is an old common property resource.

Environmental issues, however, have to be resolved by the people themselves. Of course, we would not be able to return to our traditional way of life, but water will continue to be our common property in the future. Therefore, efforts have been made to establish new norms and institutions of water use. In a heavily populated wetland around Lake Biwa, it is important for the residents to keep appropriate social relationships for the use and preservation of water.

At present, the Shiga Prefectural Government and local residents encourage various activities to increase people's recognition of the importance of the water environment, including small rivers and the lake, in daily life. For example, activities to restore reed beds along the lakeshore and to increase biodiversity in paddy fields or forests have been rising strongly in recent years. Especially, the new fun and eco-friendly activities have been brought to public attention lately. Some researchers call such policy and activities 'the restoration of the relationship between water and people's lives'. Such activities may lead to a further indivisibility between the local residents and Lake Biwa in the future (see Topic 19).

Topic 15 Fishery Rights and Management

Yasuhiro Fujioka

Fisheries Regulations

For a long time in the Lake Biwa area there have been many regulations and institutions to preserve fishery resources and protect them from overfishing. By the Meiji Period (1868–1912), a national fishery law had already been established, and the fisheries of Lake Biwa were operated under this law (Kaneda 1991). Also based on the law, the 'Shiga Fishery Adjustment Rule' was established, in which detailed rules were prescribed for the fisheries of Lake Biwa such as the fishing season, location, equipment for some commercially important fishes, etc.

The Lake Biwa fisheries can be broadly divided into two categories: one with fishing rights and the other with licenses issued under a law (Shiga Prefecture 2010a). The former is only given to the fishermen's cooperative associations consisting of fishermen who live in and around a place where 'eri-fisheries' or 'yana-fisheries' etc. are located (see section 'Various fishing methods developed in and around Lake Biwa'). A review is conducted every 10 years for this right, and the right is taken away unless the fishing is the primary occupation. In the other category, licenses are given to each fisherman. For example, the 'koitoami-fishery' and 'kaibikiami fishery' (see section 'Various fishing methods developed in and around Lake Biwa'), categorized as fisheries requiring a license, are managed with a permission system to limit the number of the fishermen who operate these fisheries, in order to protect the resources of the lake. That is to say, the number of fishermen receiving the permission in each fishery is decided.

Since there are limited fishery resources and fisheries operate in restricted areas of the lake, various problems, such as disputes among fishermen, take place. These problems are arbitrated by the 'Lake Biwa Regional Fishery Adjustment Committee' as prescribed by the Fisheries Act. This committee, consisting of fishermen and well-informed people, gives direction for solving the problem, and instructions to the fishermen concerned.

Fishery Organizations

All fishermen of Lake Biwa belong to the local fishermen's cooperative association where they live and conduct fishing. At the present time, there are 36 acting fishermen's cooperative associations in the Lake Biwa area (Fisheries Management Office 2008). Each fisherman pays a fixed fee to the association according to his fishery-based income (usually some percent of his income), and the association is run by the money collected from its members. Furthermore, all the fishermen's cooperative associations form an organization called 'Shiga Prefecture Fishermen's Cooperative Association', and this organization has been managing an increase of fishery resources of the lake in accordance with the prefectural government of Shiga.

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Topic 16 Utilization of Young Ayu Fish

Yasuhiro Fujioka

Biwa ayu (*Plecoglossus altivelis* subsp.) is one of the most utilized fish inhabiting Lake Biwa. The fish caught by the okisukui-fishery (see section 'Various fishing methods developed in and around Lake Biwa') in the lake are usually sold to food processors as fresh fish, and they are processed by boiling in sweetened soy sauce. On the other hand, the young fish caught by yana and eri fisheries (see section 'Various fishing methods developed in and around Lake Biwa') are transported live and released into many rivers all over Japan. The beginning of the release of Biwa ayu is traced back to the Taisho Period (1912–1926) (Azuma 1980), and the practice became popular in about 1960. Because this fish is very delicious, it is one of the most important target fish in river fisheries. It is especially popular with anglers, who usually use an original fishing method called 'tomo-zuri'. This utilizes the fish's behaviour to drive away others of the same species from his territory, i.e. in this type of fishing, ayu fish attached to empty hooks are used as a decoy, and the wild ayu fish are caught with the empty hooks when driving away the decoy fish. River fishermen's associations usually collect a fee from anglers for a managing fund, which is partly used to finance the release of this fish into rivers. Moreover, this practice is also regarded as a duty of conservation and conducted to increase the number of livelihoods that the fisheries can support, as prescribed in the fishery law.

The quantity of the young fish shipped from the lake has been significantly decreasing in recent years, as young fish bred in rivers have been released instead to maintain genetic diversity. Additionally, a bacterial cold-water disease of ayu fish, which has been spreading throughout Japan, has been spurring on this trend, as mentioned in the following topic (Taniguchi and Ikeda 2009) (see Topic 17).

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Topic 17 Invasions of New Fish Diseases to the Lake

Yasuhiro Fujioka

Invasions of new fish diseases from outside regions have frequently become big threats for the fisheries of Lake Biwa. Below are introductions to the representative fish diseases of the lake.

Vibriosis of Biwa Ayu

This disease of Biwa ayu (*Plecoglossus altivelis* subsp.) is caused by a bacterium called *Viblio anguiralum*, and it has been prevalent since the 1970s in and around Lake Biwa until recently. This disease breaks out mainly in summer when water temperatures exceed 15°C (Muroga and Egusa 1988), and many ayu fish died not only in natural environments, but also in fish culture ponds. This disease, however, died out in about the year 2000 after the outbreak of the cold water disease of ayu fish in the lake (see below).

Cold Water Disease of Biwa Ayu

In many rivers throughout Japan where Biwa ayu, including young fish, were released, the populations of ayu suddenly crashed around the year 1985. At the same time, most of the young ayu fish in many fish culture ponds in Shiga Prefecture also died. In 1987, researchers understood that these deaths were the result of a cold water disease, caused by a kind of bacterium (*Flavobacterium psychrophilum*). It is known that this bacterium has a pathogenic character at 15–20°C (Sugahara et al. 2010). Therefore, ayu fish died in large quantities when the fish migrated from the offshore areas of the lake to rivers during springtime, because the water temperature of rivers at that time is usually under 20°C.

KHV of Common Carp

In 2003, cultured common carps (*Cyprinus carpio*, 'koi' in Japanese) died in large quantities in Lake Kasumiga-ura, located in the Kanto area of central Japan (Sano et al. 2004). It was discovered that they died of a disease caused by KHV (Koi Herpes Virus). Since then, this disease has spread throughout Japan. In Lake Biwa, a large number of wild carp (104,072 individuals) died of the disease in 2004 (Iida 2005). The dead fish were collected from various parts of the lake at great effort, and disposed of at incineration sites. Such a large death toll has not occurred since then.

As KHV does not originate from Japan, it is thought that the virus was brought in from foreign countries in recent years (Iida 2005). The reason why the disease has spread throughout Japan is thought to be due to the circulation of edible carp, as Lake Kasumiga-ura is the biggest producer of edible carp in the country (Iida 2005).

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Topic 18 Waterside Living and Landscape

Ping Yang

The word 'delicious' in Japan and the word 'sweet' in China are both used for describing good-quality water. There has been a continuous demand for rich, safe water; so we now take a look at how we interact with water and waterside environments in our daily life. Around Lake Biwa, various traditional folkways involving water have evolved. For example, *kabata*, *kawato*, and *kawaya* (referring to a system for bringing water from rivers and springs to village communities for daily use) are still seen at Harie, Shin-asahi town in Takashima City (*Fig. 1*), and represent the water-related ritual and culture that has been passed down from generation to generation. Similar cultural landscapes have also been developed in the Jiangnan area of China, where a unique waterside culture originated.

Living at Waterside

The TaiHu Lake area in China, which includes the Jiangnan waterside district, has been rich in water since ancient times. Small rivers called 'life-sustaining streamlets' are commonly seen both in the front and the back of houses. Described as 'Small bridge, running stream, few houses', in a poem, traditional living closely linked with water is a notable feature in this area. For example, before the 1980s, at Nanquan in Wuxi City, which is also a waterside district, waterside dwellers built their houses elevated about a meter above the water. People thus devised a lifestyle well-adjusted to the waterside environment. In order to obtain water for daily use, washing places made by piling stones were utilized at the waterside. In the TaiHu Lake watershed area, as another example, many lake dwellers relied on the lake's water and waterside environments for a living. Often, they left their floating homes in a cluster at a particular spot close to the shore, and then sailed out in small boats to fish in order to make a living. These people also traditionally drunk water directly from TaiHu Lake.

Waterside Community and Landscape

Rivers deeply associated with waterside living play an important role as people's water sources as well as living spaces. Waterside dwellers have in Japan and China have developed many ingenious ways to obtain water that is essential for daily use. In short, by utilizing and managing the waterside as a common space, in each waterside region a traditional water-related lifestyle along with unique local cultural folkways has been established. Such a waterscape, not only as an attraction but also as a life space, is a unique feature of waterside environments.

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Fig. 1
'*Kabata*' seen at Harie in Takashima, Shiga Prefecture.

Topic 19 The Traditional Baths used in Houses in Shiga Prefecture

Fumiko Oi

What Is an *Oke-buro*?

Shiga Prefecture is geographically divided into four regions surrounding Lake Biwa, namely the areas north, east, south, and west of the lake, and it has developed a distinctive folk culture in each region. The *oke-buro* (pronounced 'okay-boo-row'), a type of bathtub that held not only hot water but also steam like a sauna, provides one example of such a regionally distinctive cultural feature.

In Shiga Prefecture, various types of oke-buro were used mainly in the regions to the north, east, and south of the lake, and both the shape of the tub and the name used for it differed depending on region. In general, people who lived in the Kohoku region north of the lake called the tub a *goemon-buro* ('go-ay-mon-boo-row'), while people who lived in the Koto region east of the lake called it an *oke-buro*.

In all regions, an oke-buro was a barrel-shaped tub made of two parts. A shallow, round, convex, cast-iron bowl with a brim – called the *hira-gama* – served as the bottom of the bathtub and sat full of water on a wood-burning stove, while a bottomless round barrel served as the bathtub's wall.

To keep the steam inside the tub, some oke-buro used a broad bamboo hat or a wooden board as a lid for the tub. In particular, the type of oke-buro used in the Kohoku and Koto regions was unique on a nationwide scale because a door was built into the side of the barrel. Those used in the Koto region had a different style from those in the Kohoku regions, and they were made of a bulging barrel with a side door and a thin ceiling board (*Fig. 1*).

Before taking a bath, people made a fire in the stove using straw, chaff, or other material as fuel, and heated water in the *hira-gama*. When taking a bath, they floated a thin, round board, called an *uki-ita*, on the warm water, slowly submerged it by stepping onto it (thus also avoiding burnt feet on the hot metal), and soaked themselves in the water. Although the water reached only to about navel height, the upper body got warm enough even in winter because steam was kept inside the tub. (The story in this topic is largely based on the revision made to Oi (2005).)

Fig. 1
An oke-buro from the Koto region with a side door. (Owned by the Hikone City Board of Education)

Oke-buro Seen by a British Traveler

While looking for old records concerning oke-buro, I came across a travel journal, *Gleanings from Japan*, published by the British traveler W. G. Dickson, who journeyed

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around Japan in 1883 and 1884. In this book there is a sketch of an oke-buro that he saw out in the streets of Hikone, Shiga, a town famous as the site of Hikone Castle (Dickson 1889; *Fig. 2*).

In his journal, Dickson introduced this oke-buro by noting that, 'The only novelty we saw was the baths used by the ladies'. He humorously depicted the bathing scene, 'These were for holding one at a time, were out in the street, and were simply large barrels with half of the lid opening, and a door in the side for conversation with gossips in the street.'

Memories of Oke-buro

Until the period between 1945 and 1955 when they largely fell out of use, one could see an oke-buro placed on the earthern floor in the corner immediately inside the entrance of the main building of farm houses anywhere from the Kohoku to Koto regions. It was said to be a dark and scary place for kids. This part of the house was not well lit anyway, and it was even darker inside the oke-buro while taking a bath with the tub door closed.

Ten or more people might use the same bath at night in areas where the custom of 'borrowing a bath' existed, whereby two or three neighbors heated the bath in turn every night. Sometimes, it was said of bathing in an oke-buro that 'It was not clear whether taking a bath meant getting washed or getting dirty', because by the end the bath water would be muddy with the dirt from all the people who had used the bath.

Bathing Without Waste

Although disparaging talk of the negative aspects of an oke-buro, such as 'a dark and dirty bath', might be heard, a change in perspective allows us to appreciate the oke-buro as a highly economical bathing style of low environmental impact, because it took less fuel, water, and labor to heat the water than was true for other forms of traditional baths in Japan. After the bath the remaining hot water was mixed with urine and used as fertilizer, and thus it didn't pollute the river water (Oi 2005; *Fig. 3*). The ashes left after burning straw beneath it to heat the water were saved, and also used as a fertilizer in the fields.

We modern folk might be able to find many hints for 'living sustainably without waste' by recalling the traditional use of the oke-buro (see Topic 20).

Fig. 2
An oke-buro from Hikone drawn in the nineteenth century, from Dickson (1889: Fig. 26), with the original caption, 'Ladies bathing out in the streets of Hikone'.

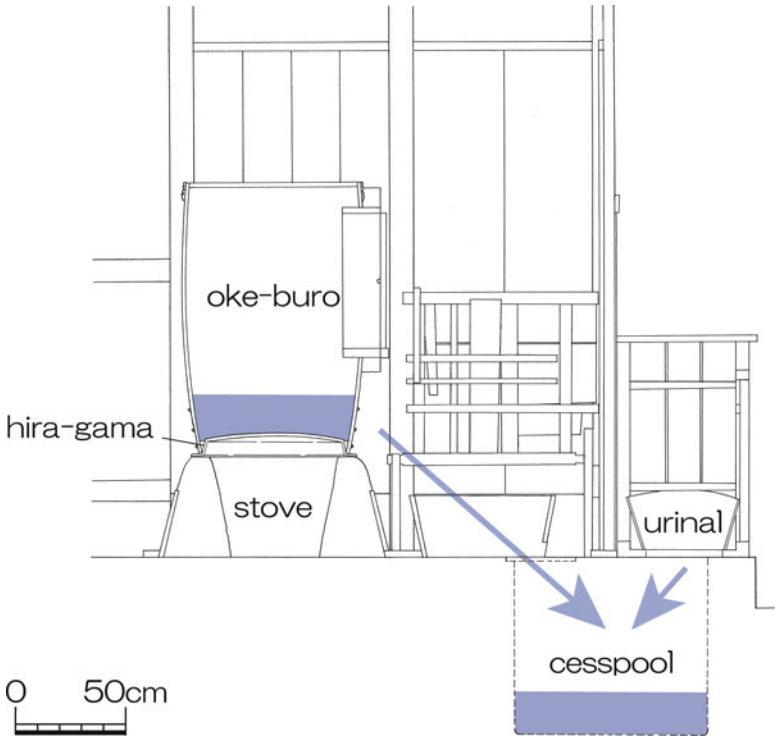

Fig. 3
Cross-sectional view of the Kashima family's oke-buro, Hikone, Shiga. (Owned by the Local History Office of Hikone)

Topic 20 Female Farmers in Shiga Prefecture

Tamaki Kashio

Transformation of Female Farmers in Shiga Prefecture

In general, a farmer's wife in Shiga Prefecture lived with her husband's parents and engaged in their family farm business. In such cases, crop varieties and planting time were determined by the male householder, and the wife engaged in agricultural work under the direction of the husband, while juggling a variety of household chores including taking care of their children and elderly parents.

Since the 1970s, by when the mechanization of rice production had been completed, many farmers have attempted to expand their farm size. Therefore, the farm work of women and elders shifted to tasks that could not be done by machines, such as planting and mowing in narrow spaces inaccessible by machines and being responsible for the daily care of crops. Along with the declining rice price and reduction in rice acreage, it became more common for women to utilize paddy fields to produce vegetables and flowers for the farmers' markets (*Fig. 1*).

Agricultural censuses conducted by the Japanese Government shows a marked decrease in the female population engaged in agriculture and the number of female full-time farmers from 1970 to 2000. In 1970, the female population engaged in agriculture was 91,956, which dropped to one-third to 30,988 by 2000. Meanwhile, the number of female full-time farmers dropped sharply from 27,201 in 1970 to 2,837 in 2000. As for the change in males, the population engaged in agriculture was 43,232 in 1970, which decreased to 21,781 by 2000; the population of full-time farmers has since decreased from 21,924 to 4,199. As indicated in this declining trend, the tendency of women leaving agriculture developed largely during this time period.

However, women occupied 58.7% of the overall population engaged in agriculture and were 40.3% of the full-time farmers in 2000. Although the actual numbers decreased from 1970, women still occupied a large percentage of the overall workers engaged in agriculture. What should further be noted is that earlier, during the 1970s, women used to undertake more supplementary roles under the direction of men in most cases whereas they make independent decisions in various situations today. In the following two case studies, the farming activities of such women farmers and their idea of farm work are introduced.

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The Female Farmer Who Is Processing Local Agricultural Products

A woman living in a village around Lake Biwa has formed a group of farmers' wives to process and sell local agricultural products and fruits. Her village is located on the shores of Lake Biwa, where large-scale rice fields have spread since the modernization of the irrigation system in the early 1970s. Raised in a local farming family, she now produces soybean and vegetables in the fields that are not used for rice production under the set-aside policy of the Japanese Government, while making miso, pickles and jams using local specialties including pears and figs. She has also been involved in developing signature products that have functioned as the catalyst of local revitalization, and hence she is recognized as an expert on local food in the area.

It has been more than 20 years since her food-processing group was formed. They not only sell the processed products, such as miso, at morning markets and farm stands, but also provide these products for school lunches at local elementary schools. In recent years, they also make miso on request from farmers who no longer make their own at home.

It used to be common that farmers made miso and pickles at home. However, there have been changes in people's lifestyles, and as farmers' wives began working non-farming jobs, people have become too busy to spend time and effort to make traditional dishes handed down in each

Fig. 1
Flowers planted in the farmer's paddy field.

family. Moreover, since many local farmers have married women from the city who lack experience of traditional foods, it is becoming increasingly difficult to hand down the family recipes to the next generation. Techniques that have been naturally passed down from generation to generation are no longer able to be carried on without an intention to do so. The woman was alarmed by this fact, and she started to feel that children should know the taste of local food.

Processing safe and secure homemade agricultural products with traditional techniques, she is aiming to hand down to the next generation a lifestyle based on planned consumption through the year. This food-processing group is a fun gathering of people who sympathize with her idea.

In traditional village communities in Shiga, such female groups for food-processing have been established to hand down the processing techniques suitable to local conditions.

A Female Farmer Runs a Vegetable and Flower Farm in Cooperation with a Farmers' Market

We now introduce a woman who runs a vegetable and flower farm in cooperation with a farmers' market. She lives in an inland area where direct sales of signature products, such as melons, grapes and pears, are actively undertaken. This is also an area in which women and elders use paddy fields under the set-aside programme to grow produce for the farmers' market (*Fig. 2*). Thus, a unique farming style has been developed to produce vegetables and flowers for the market and also to create idyllic scenery to entertain tourists.

She used to operate machinery and handle rice-growing as instructed by her husband, when her husband was still engaged in a nonfarming job. She also raised two children while taking care of her mother-in-law. Growing flowers and vegetables was only a relief in her stressful everyday life. She planted her favourite flowers in the garden, and she was encouraged by passersby who enjoyed them. She learned that the beauty of flowers could cheer people up. Since then, she has participated in flower and seedling production subsidized by the prefectural government, and she formed a wholesale cooperative for herbs, which started to be popular at that time. Her activities received recognition from the prefectural government, and she was asked to be an important member of the flower wholesale section when the farmers' market was established. Her work also impressed her husband, which made him decide to retire early in order to support her business. Since then he has taken over the rice-growing work.

She has been enjoying growing flowers and vegetables with her retired husband (*Fig. 3*). In order to offer support to her farm management, her son, who had been

Fig. 2
Farming by a woman who grows a variety of products to ship to the farmers' market.

Fig. 3
Flowers for picking.

engaged in nonagricultural work, started to grow greenhouse strawberries. This female farmer has decorated the area and has created a landscape with flowers through the seasons in her village. Through these two case studies above, it can be seen how some women farmers in Shiga Prefecture are helping to rejuvenate local economies by taking an active and leading role in farming.

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6 Evolving History of Lake Biwa and Yodo River Basin Management

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Abstract The management story of the Lake Biwa-Yodo River Basin may be told in many different ways. It is told here as an intricate but dynamic history of management challenges involving the upstream Lake Biwa region and the downstream Yodo River region, with factual illustrations of associated policies, programs, and specific actions for water resources development, flood control, and environmental and ecosystem concerns. These factual illustrations are also interpreted by the contributing authors with views reflecting their professional backgrounds, as well as their interests and opinions on the conflicting and contested issues.

Keywords Water resources • Flood control • Lake Biwa Comprehensive Development Project • River improvement plan • Basin governance

Introduction

This chapter aims at presenting a general overview of the evolving history of Lake Biwa-Yodo River Basin (hereafter referred to as the Biwa-Yodo Basin) water management, with special focus on flood control, water resources development, environmental, and ecosystem concerns. It reviews the special features of the basin that have required the region to overcome many historical challenges in managing this lake-river basin system.

Although the emphasis was given in this chapter to introduce to the readers a factual review of the evolving courses of events, the interpretive views expressed in different sections of this chapter are not necessarily concerted, because the professional and disciplinary backgrounds, and the thoughts and opinions toward contentious issues, differ significantly among them. Specifically, Section 6.3 and part of Section 6.4 were contributed from a river engineering and planning expert focusing on flood control. He portrayed an official view toward the need for judicious implementation of the project components stipulated in the Management Plan. Section 6.3 and part of Section 6.4 were contributed from an agricultural water policy specialist actively promoting the demand-side water management that he believes has been seriously lacking in the Biwa-Yodo Region. Section 6.5 was contributed by an economic geographer with water management policy expertise on the upstream and downstream dynamics on water and environment. Lastly, the remaining sections, 6.1 and 6.6, and cross infusion of all the section contributions to collectively address the evolving water governance challenges facing the Biwa-Yodo Basin, were synthesized by an environmental policy researcher specializing in lake basin management. Lastly, the making of the Yodo River Improvement Plan was prepared with the help of those involved in either side of the contentious process.

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6.1 Overview of Lake Biwa and Yodo River Basin

6.1.1 Physical and Geographical Features

Lake Biwa had a naturally constricted and shallow river stretch a few kilometers downstream of the southern edge of the lake, restricting the flow out of the lake to cause

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occasional flooding. The distance between this stretch and the northern jurisdictional boundary of the greater Osaka metropolitan region is only a few dozen kilometers. The management history of Lake Biwa water may be characterized by the legacy of flood control conflicts stemming from this inescapable physical reality.

The lake measures 63.5 km in a north-south direction and is divided into two sub-basins. It has a total surface area of 674 km^2, a volume of 27.5 billion m^3, and a shoreline length of 235 km. Its catchment area is nearly five times the area of the lake itself, and its boundary more or less coincides with that of the prefecture, constituting 96% of prefectural land. The catchment area consists of forest-covered hills and mountains (60%), paddy fields and other farmlands (25%), and urban and industrial areas. The prefectural capital, Otsu, located at the southern end of the lake, has an approximate population of 355,000. There are five major rivers flowing into Lake Biwa from the surrounding mountain ranges. There are also more than 100 small coastal streams and irrigation channels draining into the lake, many containing irrigation return flows and urban and agricultural runoff from across the catchment area, measuring 3,848 km^2.

With Lake Biwa and its watershed occupying most of the upper catchment portion, the Yodo River Basin is one of the most extensive river systems in Japan. Encompassing portions of six prefectural jurisdictions (Shiga, Osaka, Kyoto, Hyogo, Nara, and Mie Prefectures), it has a total catchment area of 8,240 km^2 and the main river course length of 75.1 km. The Seta River is the only natural outflowing river from Lake Biwa. The Seta River is called the Uji River along a stretch of some 20 km within the Kyoto Prefectural boundary. It is joined at the Hirakata confluence point with the Kizu River from the east originating in Mie Prefecture, and the Katsura River from the west originating in Kyoto Prefecture. Below this confluence point is the mainstream Yodo River stretching toward the Osaka Bay in the south, for a distance of approximately 20 km. The Ina River joins the mainstream Yodo River approximately 5 km upstream of the Osaka Bay. The Kizu, Katsura, and Uji Rivers contribute 18%, 15%, and 64%, respectively, of the flow to the Yodo River at Hirakata. The Keihanshin (meaning Osaka, Kyoto, and Kobe) metropolitan region as a whole depends almost exclusively on the Yodo River for industrial, municipal, and agricultural waters. Lake Biwa accounts for water supplies totaling about 20 billion m^3 per year, serving as many as 14 million people. In addition, the Seta River water is also used for hydropower generation at Uji, some 15 km downstream of the lake (see *Fig. 1*).

The management history of the Yodo River System may be characterized as that of conflict between the upstream Shiga Prefecture and the downstream *Keihanshin* area. For centuries, the communities immediately surrounding Lake Biwa experienced severe flooding of their agricultural fields, due mainly to the naturally constricted and shallow river stretch a few kilometers downstream of the southern edge of the lake. This natural barrier had been serving well in protecting the downstream population centers from inundation. The downstream and the central governments finally agreed in 1905, after a historic flood in the Lake Biwa region in 1896, to dredge this stretch, and construct a weir structure (this original weir, named the *Nango* Weir, was replaced in 1961 by the Seta River Weir constructed at a short distance downstream). With the construction of the Nango Weir, and the ability to control the lake water level, the frequency of flooding and the associated flood damages along the lake shore and inland were drastically reduced.

6.1.2 Flood Control

The Lake Biwa population always wanted the flood water to be quickly released downstream to save the riparian lands from inundation, while the downstream Osaka population always wanted the flood water to be kept within the lake to save the highly populated metropolitan area. The Lake Biwa lowland farmers, however, had to yield to the downstream political and economic powers over the course history. It was not until the record flooding in 1896, inundating the land around the lake for some 220 days, when the downstream and the central governments finally agreed to the construction of the Nango Weir. The weir served the flow control purpose well for several decades till a new need arose, i.e., to supply water to the rapidly growing urban and industrial centers in the downstream region.

6.1.3 Water Resources Development

The major use of Lake Biwa water had historically been for paddy irrigation, by channelizing and barraging the riparian feeder rivers and the outflowing Yodo River and its tributaries. It was in the late-nineteenth century when the first large-scale water resources development project was implemented. Realizing the potentially serious decline not only of its political status but also its economic status, the then newly appointed Kyoto Governor foresaw the need to develop the Kyoto economy by linking Kyoto with Lake Biwa by a canal to withdraw the lake water. He engaged a

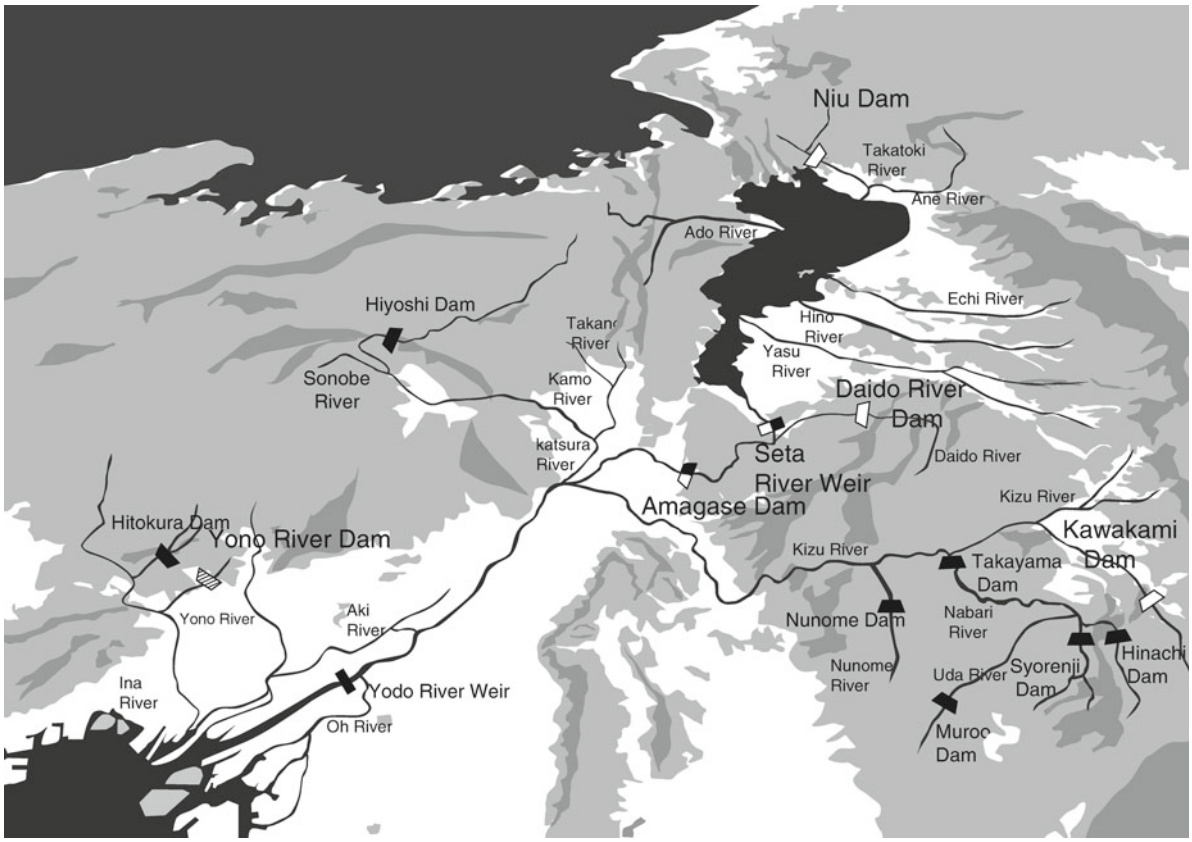


Fig. 1

Bird's eye view of the Lake Biwa and Yodo River Basin (Niu, Daido-River, Kawakami Dams, proposed to have been constructed in an earlier plan, have been subjected to debate whether or not to proceed with the plan. Yono River Dam, also in the earlier plan, was agreed not to be constructed. *Amagase* Dam and the Seta River Weir have been agreed to be renovated. See Section 6.5 for details).

young engineer who succeeded in constructing the canal connecting Lake Biwa to Kyoto in 1890, saving this water-constrained city from a serious economic decline.

The second large-scale water resources development project took shape when Osaka began to regain its industrial strength in the early 1950s after the Second World War devastations. The existing water rights from the Yodo River flow had already been exhausted, however, and by the early 1960s, Osaka was already eyeing the use of the abundant Lake Biwa water.

6.1.4 Lake Biwa Comprehensive Development

Osaka wanted more lake water to be released downstream, particularly during the drought periods, through the existing Nango Weir, which had been constructed more for flood control purposes than for water resource development. It was replaced in 1961 by the Seta River Weir constructed at a short distance downstream both for flood control and water resource development. More than a decade of heated political exchange took place between the downstream local governments (mainly Osaka Prefecture and Osaka City), the National Government, and the Shiga Prefectural Government with regard to the potential gains and losses of this action, in terms of accrued economic benefits, financial burdens, and environmental impacts of transforming Lake Biwa into a sort of man-made reservoir. Increasing the amount of flow through the Seta River channel meant the need for enlargement of the weir capacity, as well as for dredging of the constricting channel. However, reconstruction of the weir to provide a greater water volume in the lake, in preparation for extreme droughts, also meant an increased

probability for flooding damage around the lakeshore lands. Combined with the need to protect the downstream Yodo River from still imminent flooding, the ultimate solution was to construct a levy around the lake to impound more water within the lake in anticipation of possible droughts, and in preparation for protecting both the downstream Yodo River and Lake Biwa coastal areas from flooding.

This agreed scheme of Lake Biwa water resource development is called the *Lake Biwa Comprehensive Development Project* (hereafter referred to as *LBCDP*, see Section 6.4 for details).

6.1.5 Evolving Challenges

The Shiga Prefecture was a reluctant party in LBCDP, insisting the need for totally rehabilitating the coastal infrastructure such as water intake, fishing and navigation facilities, as well as the possible adverse effects on the shoreline ecosystems, particularly, on the habitat environment of fish species, including the indigenous ones. The reluctance of the Shiga Prefecture, however, stemmed more from the psychological rejection of its residents to the notion that the upstream region had to continue to endure a long history of sufferance to occasional flooding of its coastal region for the benefit of the downstream region, and then having the downstream region demanding the release of more water exclusively for its own convenience and economic gain.

While the LBCDP accomplishments have brought about significant overall benefits to the Biwa-Yodo region, there remained unresolved legacies, unfinished businesses, and emerged challenges necessitating such new policy initiatives. The Lake Biwa Comprehensive Conservation Plan, (hereafter referred as LBCCP), is one, and the Yodo River Improvement Plan (hereafter referred to as YRIP), is another. LBCCP is a plan being developed and implemented by Shiga Prefecture and, therefore, touches little on the issues facing the entire Biwa-Yodo Basin, while YRIP is a plan being developed as a river management plan, rather than a river basin management plan, to be implemented as a trans-jurisdictional national government plan. Among the important issues facing LBCCP is financing of the component programs pertaining to, basically, restoration of the lake ecosystem. Among the important issues facing YRIP, on the other hand, is the development of an institutional framework more suitable for basin management than river water management that will be able to meet the emerging governance challenges (see, Section 6.5 for details).

6.2 Brief History of Lake Biwa Flood Control

6.2.1 A Legacy of Lake Biwa Flood Control

Two Major Issues Facing Lake Biwa—Yodo River Flood Control

Within the Yodo River Basin, there are several climatic zones affecting the precipitation patterns of the three major sub-basins, one in the north covering the Lake Biwa watershed, another in the east covering the Kizu River watershed, and still another in the west covering the *Katsura* River in the west. The Yodo River, which originates at the confluence point of the three tributary rivers, however, has one of the most stable flow characteristics among the major rivers in Japan, thanks to Lake Biwa acting as a huge natural regulating pond. Because of this stable flow, the Yodo River had historically been able to serve as a major transportation route of agricultural products from across Lake Biwa and other commercial goods between the upstream eastern Kyoto along the Kizu and Uji Rivers, all the way down to Osaka Bay. It also served as a mode of passenger transportation between Kyoto and Osaka. With Lake Biwa providing ample and stable flow throughout the year, the Yodo River has had an enduring impact on the economic, cultural, and political dynamics of the entire Kinki Region. The evidence remains today in the form of thriving metropolitan regions of Kyoto, Osaka, and Kobe. The water management of the Yodo River System, however, has historically been dictated by two major flood protection concerns, namely:

- Reduction of flooding risks endured by the Lake Biwa shoreline and lowland communities for the upstream's sake; and
- Improvement of river embankments with stronger and higher levies along the Yodo River and its tributaries for the downstream's sake.

These issues have not yet been fully resolved, as discussed later in this chapter.

Constraining Topography of Lake Biwa

There are some 120 or so in-flowing rivers to Lake Biwa originating from the surrounding mountains. These short and steep rivers discharge the collected precipitation from the mountainous terrains almost instantaneously into Lake Biwa, quickly swelling the lake to impede the inflowing river water, eventually causing flooding not only along the coastline, but also along these river channels. A more

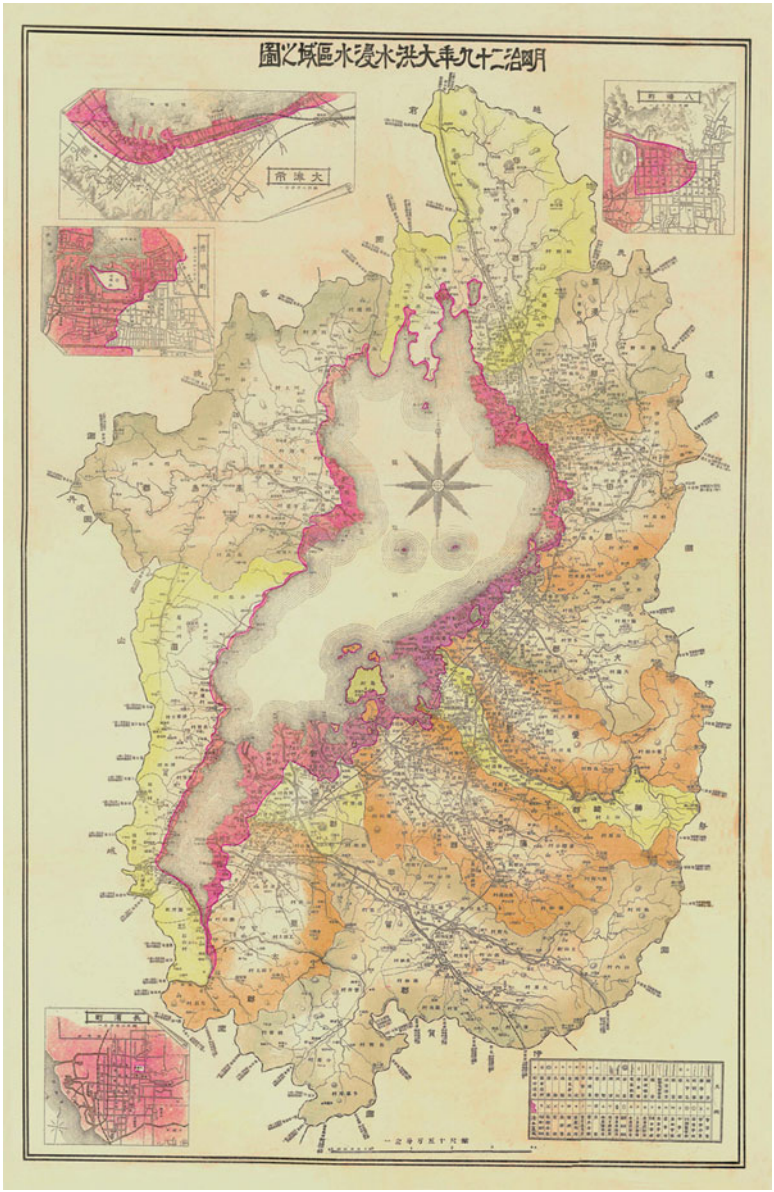


Fig. 2
Inundated areas in red during the Great Lake Biwa flood of 1896 (The land occupied by the prefectural government offices in the center of Otsu City was completely inundated. The surface area of Lake Biwa is estimated to have increased by 30%).

serious concern is that the Seta River, the only outflowing river from the lake, is naturally constricted a few kilometers downstream of the lake outlet, at the protrusion of Mt. Dainichi. This constraining topography causes the lake level to rise rapidly, and inundate the surrounding land during heavy rainfalls periods related to typhoons and other climatic conditions, historically causing hardships to paddy farmers.

A record-breaking flood took place in September 1896. The rainfall over the period of just 10 days from September 3 to 12 was 1,008 mm, or more than half the usual annual average of 1,900 mm, with a dramatic one-day record of 597 mm on September 7 alone. The lake water level rose up to 3.76 m above the normal level (designated as the Biwako Basic Surface Water Level, or B.S.L.), and caused unprecedented flooding around the lake, inundating most of the towns and villages around the lake and along the inflowing water courses. Altogether 14,800 hectares are recorded to have been flooded, with the inundation lasting for as long as 237 days before completely being receded (*Fig. 2*).

Upstream–Downstream Conflicts over Dredging of Seta River

Since the mid-nineteenth century, there have been a number of proposed attempts to dredge the Seta River to increase its discharge capacity for the lake water, particularly to compensate for the above-noted natural topographic flow constriction. These proposed attempts by the upstream farming communities met with severe opposition by the political powers and commercial interests in the downstream population centers. The simple dredging along the shallow and constricting stretch of the Seta River would mean sending flood water downstream, causing damages to population and commercial centers, rather than to upstream farmland and villages. The downstream region wanted the flood water to be kept upstream as long as possible, allowing its gradual release over a prolonged time. The evolving history of events to overcome this extremely complicated and conflicting case of flood management is reviewed in the next sections.

6.2.2 From Premodern to Early Modern Times

Premodern Times (Seventeenth to Nineteenth Centuries)

The first recorded event of Seta River dredging was in 1670. Responding to petitions from people living near the lake, the *shogunal* administration carried out the dredging. Subsequent appeals for dredging were repeatedly refused, one reason being that the dredging destroyed an important strategic point on a military route for the defense of Kyoto. Another was that a reduction in the lake water level also affected the defenses of the then-important military strongholds of Hikone and Zeze (Otsu) Castles. A final major reason was the objections of people living downstream, who feared a greater risk of flooding. During the two centuries before the modern era, 20 formal requests for dredging were made, but it was only allowed five times. It was twice carried out at the cost of the local administration, with private contributors bearing the cost burden for the remaining times. Even when local people were willing to organize and pay for the work themselves, the administration refused permission.

The people living along the lake grew frustrated with the administration for ignoring their heartfelt petitions and took matters into their own hands. Under the guise of harvesting freshwater shellfish, *Corbicula sandai*, they laboriously dug up the river bed and carried away the sediment. The administration at that time did not know what to do about the dissatisfaction of the lakeshore residents. As a kind of response to the long-ignored ardent wishes of the people, the boats were exempted from taxation of the clam harvest until the modernization started. This exemption was practically an acknowledgement that the effect of the clam fishing boats was equivalent to dredging, and was instituted to appease the local people.

Early Modern Period

In the very first year of the Meiji government era (the first modernized government, 1868–1912), there was a major flood that the local government (Otsu Prefecture) took as a cue to undertake the first large-scale dredging since 1831 of the Seta River. While the dredging took place to some extent, the lake remained placid for some years. The lake level rose to 2.71 m above B.S.L. in 1885, however, causing extensive flooding both around the lake and downstream along the Yodo River. During May to September in 1889, the lake level remained at a height between 1.4 m to 2.0 m above B.S.L., a situation that made paddy plantation impossible around the lake. Coincidentally, in the same year, the construction of the Seta River Bridge (length 405 m) was started by the National Railways Tokaido Mainline. Being very concerned that the eighteen pillars of the bridge might interfere with the outflow from Lake Biwa, the Lake Biwa Flood Control Alliance Committee was organized to carry out campaigns to petition the national and local governments for a reduction in the number of bridge pillars. Determined to ensure the issue was resolved once and for all, the slogan was "construct the bridge pillars that do not impede the flow." Joined by the Shiga Governor, this campaign turned into a movement to petition for instituting the Seta River dredging works. A series of petitions was presented to the national government to allow for the dredging, to receive the state subsidies, and to have a project established under direct government control.

At the same time, however, having experienced flood damage in 1885, the downstream residents along the lower reaches of Yodo River also feared that dredging would put them at greater risk. The Yodo River Improvement Action Association was formed, and petitioned for cessation of the Seta River dredging, and for the national government to initiate a large-scale Yodo River improvement project. These opposing interests evolved into a serious political issue.

Facing these circumstances, Mr. Tohru Okoshi, the national government official appointed as governor of Shiga Prefecture, who feverishly believed in the need for the dredging to take place, sent repeated appeals for dredging of the

Seta River to the Home Minister during 1891–1892. It finally resulted in the decision by the Home Ministry to carry out the dredging during the next year (1893) to the extent that it would not increase the flooding danger downstream. Governor Okoshi invited members of the downstream Yodo River improvement action association in Kyoto and Osaka to attend a gathering to celebrate the completion of dredging. In his address to the gathering, he said, "Now, let's join forces and push for a greater Yodo River improvement."

6.2.3 Dawn of Full-Fledged Lake Biwa and Yodo River Flood Control Infrastructure Development

Yodo River Flood Management Works Report: Founding Report of Future Lake Biwa Flood Control Policy

Being catalyzed by the successful dredging undertaken in 1893, the Meiji government urgently formulated a plan for Yodo River improvement. The plan was developed on the basis of the major findings of the Yodo River Flood Defense Works Report compiled mainly by Dr. Tadao Okino, head of the Osaka Construction Field Office of the Home Ministry, in which the Lake Biwa water levels were extensively analyzed. This report also was the foundation for later basic policies to control flooding around Lake Biwa. The main thrusts of the report included the following:

- Reducing Lake Biwa's normal water level by increasing the discharge rate of the Seta River channels during the winter period;
- Constructing a weir across the Seta River to enable adjustment of discharge rates and lake water levels;

In essence, the Report stipulated the following three basic principles that formed the basis of an engineering approach in Lake Biwa flood water management and the related policies; namely:

- To reduce the Lake Biwa water level before flooding occurs, so as to increase the receiving capacity of the lake for the expected influent flood flows.
- To reduce the duration of the Lake Biwa flooding risk by increasing the draining flow of the Seta River, thereby reducing the lake's swelling water volume.
- To reduce the downstream flooding risks by completely closing the weir at times of peak discharges to Yodo River from the Katsura and Kizu Rivers.

For ease of reference, a chronology of Lake Biwa-Yodo River management activities is provided in *Table 1* and discussed in the following sections.

Yodo River Flood Management Works (1896–1909): River Improvement and Weir Installation

Japan's first Rivers Act was passed by the Imperial Diet in March 1896. Following this legal basis, the Yodo River Improvement Scheme was implemented by the national government as outlined in the Yodo River Flood Defense Works Report. Including the whole upstream and downstream river systems from Lake Biwa to the mouth of the Yodo River discharging into the Osaka Bay, this was the first river improvement project in Japan based on a comprehensive river plan. From 1900 to 1908 the project included the thorough dredging of the Seta River and the first construction of a weir in 1905. Still in force after construction of a new replacement weir in 1961, these principles stipulated in the Plan still operate today (*Fig. 4*).

The old weir (the Nango Weir) was opened and closed entirely by manual labor. It took 1 day to completely open the weir, and 2 days to completely close it. Nevertheless, the weir operation decreased the flood damages. Over the period of 30 years prior to the weir installation in 1905, the Lake Biwa flooding occurred 17 times, and twice, the lake water level rose to more than 2.4 m over the normal level. Over the period of 14 years after the weir construction and dredging, relatively small-scale floods occurred twice, with the lake water level rising to only as high as 1.5 m over the normal level, an impressive contribution by the improvement works (see *Fig. 3*).

Yodo River Control Project Phase 1 (1943–1952): Dawn of Lake Biwa Region Comprehensive Development

During the First World War, Japan made great strides in industrial development, particularly with regard to the increased scale of hydroelectric projects. Industrial development was also accompanied by hugely rising demand for water. Along the Yodo River, people also sought for ways to make more effective use of Lake Biwa water. By 1940, the Yodo River Control Project was announced, with the aim to control flooding and promote water supplies. When the Phase 1 of the Project was launched in 1943, the wartime difficulties, including the lack of supplies for construction works, and their steeply rising prices, hindered the needed rapid achievements. Thus, the plan aimed to keep the lake level lower than usual, as follows:

- For flood control purposes, the Lake Biwa water level (measured at the gauging station located at the Torii River confluence point to the Seta River) was to be

Table 1

History of Lake Biwa – Yodo River flood management plans

Name of plan, duration	Objectives and outlines
1. Yodo River Improvement Works (1896–1909)	♦ Seta River Dredging
	• Increase channel width to 110 m and depth to more than 3.0 m
	• Increase discharge capacity from 50 to 200 m^3/s
	• Weir construction (completed in 1905)
	♦ Lake Biwa planned water level
	• Pre-lowering of water level (water level to be reduced by 0.9 m below normal during flood seasons)
2. Yodo River Control Project Phase I (1943–1952)	♦ Seta River Dredging
	• Increase discharge capacity from 200 to 400 m^3/s
	♦ Lake Biwa planned water level
	• Planned high water: Torii River Mark of +0.8 m
	• During receding inundation period: Torii River Mark +0.3 m
	• During flooding: Torii River Mark of ±0.0 m
	• Ensure downstream water supply: Torii River Mark of ±1.0 m (Plan Phase 1)
3. Yodo River Improvement Master Plan (1957–1967)	♦ Seta River Dredging
	• Increase discharge capacity from 400 to 600 m^3/s
	• Construct new weir (completed in 1961)
4. Yodo River System Project Master Plan (1971–2007)	♦ Seta River Dredging
	• Increase discharge capacity from 600 to 800 m^3/s
5. Lake Biwa Comprehensive Development Project (1971–1997)	♦ Seta River Dredging
	• Increase discharge capacity from 600 to 800 m^3/s
	♦ Lake Biwa planned water level
	• Planned high water level: B.S.L. +1.4 m
	• Flood period level: Setat B.S.L. –0.2 m during period between June 16 and August 31, and –0.3 m during period between September 1 and October 15 (lowered from previous ±0.0m)
	• Water supply discharge level: Planned low level B.S.L. –1.5 m, with financial compensation measures to be made for the level lower than B.S.L. 2.0 m
	♦ Lake periphery flood management
	• Construction of levy and pumping stations, etc.
6. Yodo River Infrastructure Master Policy and Yodo River Infrastructure Master Plan (2007 – present)	♦ Seta River Dredging
	• Increase discharge capacity from 600 to 800 m^3/s

maintained at +30 cm, above the normal level of ±0 cm, during the nonflooding period. The water level was allowed to rise up to +80 cm for flood inflows during the flooding period.

- For the water supply purpose, the planned low water level was set at −100 cm. The amount of water to be held within the lake between the low water level of −100 cm and the high water level of +30 cm (during the nonflooding period) would be 920 million m^3 for downstream domestic, industrial, and agricultural uses.

Although carried out under direct government control, many problems worked against completion of the project in 1952. Dredging of the Seta River remained a continuing major challenge.

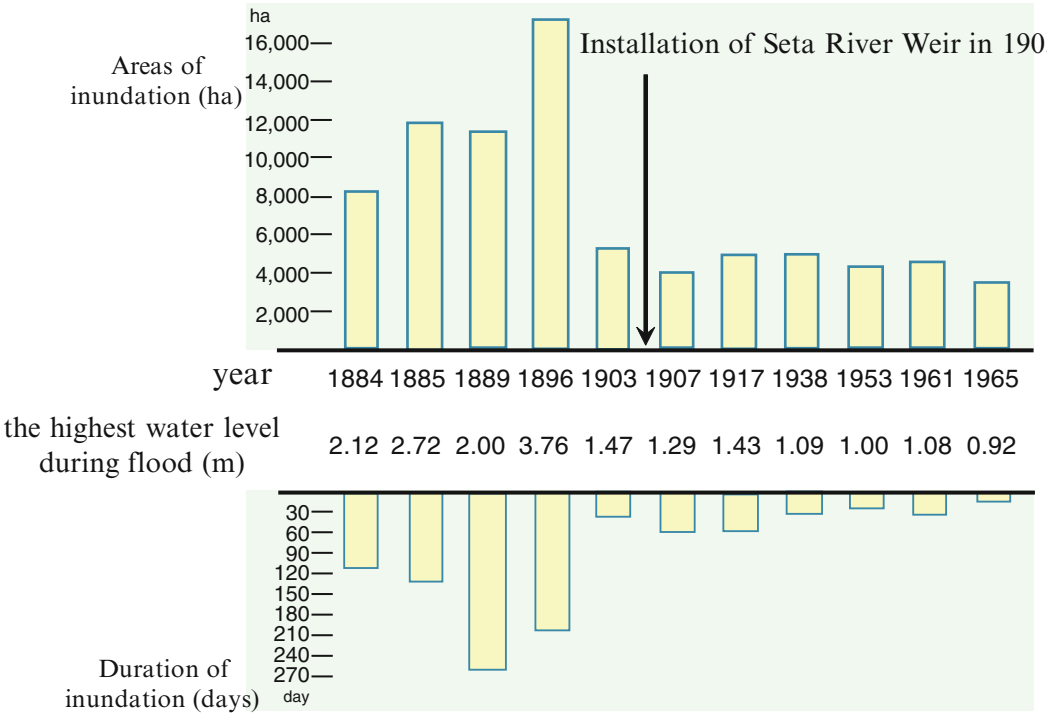


Fig. 3
Extent of inundation before and after the Seta River Weir installation.

Fig. 4
Seta River Weir today (The Seta River Weir was constructed in 1961, replacing the Nango Weir constructed in 1905).

Yodo River Improvement Master Plan (1957–1967) and Installation of New Weir

In September 1953, Typhoon No. 13 inflicted significant damage to the large areas of the Yodo River catchment. This prompted the development of the Yodo River Improvement Master Plan, which included the revision of the discharge capacity targets for the Yodo River System. The plan included even more thorough dredging of the Seta River and the construction of a new weir. The outdated weir, completed

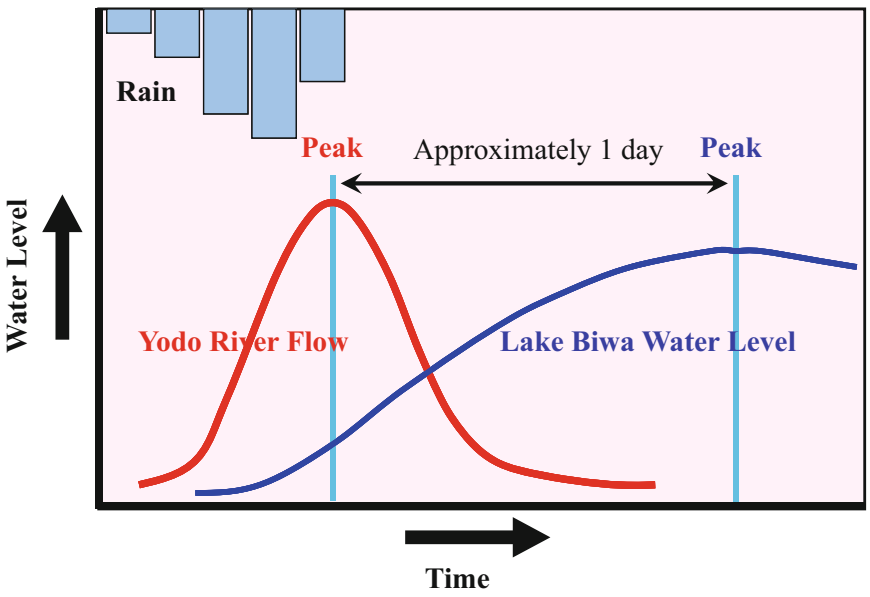


Fig. 5
Time difference between the peaks, respectively, of the Yodo River flow and of the Lake Biwa water level.

in 1905 had to be replaced with a new, mechanically controlled weir in 1961. The new, precision-control weir would now be fully closed and fully opened in just 30 min.

Relationship Between Seta River Dredging and Weir

The dredging of the Seta River and operation of the weir are inextricably linked. The weir controls the Lake Biwa water level in such a way that, under predicted heavy rains, the lake level may be reduced to lower than the normal level and, in turn, the dredged river bottom at the lake outlet would allow flooding water stored in the lake to be quickly released when the downstream flooding risk has been sufficiently reduced. Dredging alone, however, would pose the problem of causing the lake water level to decrease too much at times when there is little rain. The weir prevents this from happening by holding back the water and allowing the lake to function as a reservoir for downstream water uses. The dredged channel, in turn, allows passage of the amount of water required by the downstream, as regulated by the weir.

Synchronizing Weir Operation with Hydraulic Behavior of Yodo River and Lake Biwa

Under conditions of heavy rains, the peak discharge from Lake Biwa can be controlled, whereas the Lake Biwa reaches its peak water level more slowly (approximately one day) than the peak flow in the Yodo River, because of the topographic and hydraulic characteristics of the upstream Biwa Lake and the downstream Yodo River catchment area. This results in a "time lag" between the impacts of heavy rains on Lake Biwa versus the Yodo River (*Fig. 5*). This lag is actually beneficial for managing the Yodo River flooding. When there is heavy rain, the Lake Biwa discharge may be restricted or completely shut off. Once the downstream flow starts to subside, the weir operation may be synchronized to allow discharge of lake water, thereby allowing the lake water level to slowly decrease (*Fig. 6*). Applying this principle, the weir may be operated in such a way that dredging would not increase the risk of downstream flooding. When it rains, the rise in water level can be kept within certain bounds, such that the duration of peak water level may be promptly reduced.

Conflicts over Fully Closing Seta River Weir

Before the Seta River Weir was installed, people living downstream strongly opposed dredging of the outflow channel, arguing that Lake Biwa was a self-regulating natural lake. They believed that increasing the flow capacity would upset the lake's natural equilibrium. Once the weir was installed, however, it became possible to carry out large-scale dredging of the Seta River. The increase in the discharge capacity of the Seta River allowed lowering of the Lake Biwa water level at times of floods, therefore, reducing the flooding damages around the lake. However, the weir would have to be kept fully closed to prevent lake water passing down to the Yodo River at times when it is

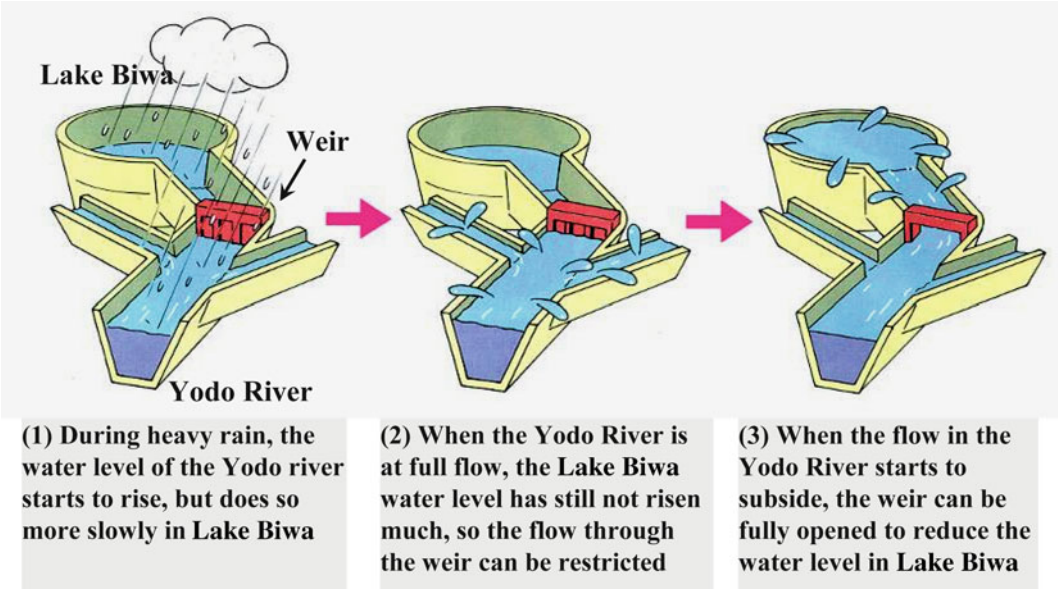


Fig. 6
Synchronized weir operations.

already on the verge of flooding with waters coming from the Katsura River and Kizu River watersheds. Thus, what is beneficial for upstream, that is, opening the weir at times of flooding, is not likely to be beneficial for downstream residents, being the fundamental cause for the upstream–downstream conflict.

For example, in 1917, when a restoration work was being carried out in the wake of flooding cause by a broken embankment downstream at Otsuka (at the western bank of the Yodo River across the city center of Hirakata City today), the citizens of Osaka and Shiga Prefectures submitted a petition against the dredging, and a counter-petition in favor of the dredging, respectively, to the central government. The dispute only subsided when the Emperor visited to inspect the completed work. As another example, in the flood season of 1972, the Shiga Prefecture strongly opposed keeping the weir fully closed, by strongly protesting to the central government. Similarly, in 2006, the Shiga Governor made an urgent request to the central government to, as far as possible, avoid completely closing the weir. To date, the weir operation policy at times of flooding has remained a major issue of contention between upstream and the downstream interests.

6.2.4 From the LBCDP Era to the Present

Having turned out to be a 25-year plan (1972–1997), rather than the originally anticipated 10-year plan (1992–1981), LBCDP has expended 1.9 trillion Japanese Yen. The broader goal of the project was set at developing and managing Lake Biwa in order to contribute to the sound development of the Kinki Region and to the well-being of everyone who relies on the lake. Specifically, the objective of LBCDP was to make proper and effective use of Lake Biwa's resources, while conserving the lake and its surroundings, improving the quality of polluted lake water, and protecting the natural environment.

The policies of the project were guided by three main concerns.

- Management of Lake Biwa water quantity to further reduce flooding around the lake
- Development of the water resources for downstream users, as well as for Shiga Prefecture
- Improvement of Lake Biwa water quality and conservation of the natural environment

Practical targets included development of water resources for the downstream use amounting to a maximum 40 m^3/s at times of droughts, construction of Lakeshore embankment for flood control around the lake, and dredging of the Seta River, together with installation of pumping stations to drain the inundated fields. Under the local development projects, including road construction, sewerage installation, establishment of nature conservation parks, solid waste disposal facilities, water quality monitoring stations, and irrigation return flow pollution treatment facilities were to be implemented by Shiga Prefecture

and the Water Resource Development Corporation, with financial support coming from the national as well as the downstream prefectural and municipal governments, apart from the due payment to be made by the Shiga Prefecture itself.

Planned Management of Lake Biwa Water Level

The purpose of LBCDP was to fulfill the water supply needs of the downstream Keihanshin (the general designation of the greater metropolitan region encompassing Kyoto, Osaka, and Kobe metropolitan regions), based on the arrangement to release the Lake Biwa water down through the Seta River Weir (at a maximum of 40 m^3/s during extreme droughts), as well as coping with the floods of a scale that may occur once in 100 years (a 100-year flood). Consequently, the maximum draw down level of lake water was set at −1.5 m (1.5 m below B.S.L.). In addition, a special arrangement was made for the Shiga Prefectural residents that any damages incurred due to the water level decline between −1.5 m and −2.0 m would be compensated by the national government and downstream local governments. The agreed process is that the contingency plan would be implemented for the domestic, industrial, and agricultural waterworks to continue to function when the lake water level declines toward −2 m, and that the compensatory payments would be made for wells that may run dry. Other provisions include compensation to the fisheries to offset income losses related to reduced fish catches. On matters pertaining to the maximum water level, the planned high water level is set at 1.4 m above B.S.L. to cope with the 100-year floods, in conjunction with other countermeasures carried out around the lake. Thus, the Lake Biwa water level is controlled in the range of −1.5 m and +1.4 m as per B.S.L.

The Lake Biwa Flood Protection Plan was drawn up after considering the flood protection and water supply needs of the Yodo River system as a whole. There are three main strategies, including the following: (a) reducing the water volume in the lake during seasons prone to flood damages; (b) dredging the Seta River; and (c) other works, including embanking around the lake shore, sluice gates, and pumping stations to remove water from the flooded land. These strategies are elaborated as follows:

(a) Reducing flood season lake water levels: During the flood seasons, the lake water level would be reduced in advance to prevent lake overflow and consequent flooding of land near the lake. Depending on the period, the lake would be reduced to –0.20 m or –0.30 m. The lake was previously maintained at B.S.L. ±0;
(b) Seta River dredging: With the greater discharge capacity resulting from dredging of the Seta River, the swollen lake water volume, with the increased water level, could be reduced relatively quickly. The plan calls specifically for dredging to increase the discharge capacity from 600 m^3/s to 800 m^3/s, as measured at B.S.L. ±0 m.
(c) Peripheral flooding countermeasures. To prevent flooding of low-lying lands when the lake level rises, the sluice gates were installed on the feeder river channels:

Construction of lakeshore embankment (*Fig. 8*) and sluices to a crest height B.S.L. +2.6 m, with a planned high water level of B.S.L. +1.4 m.

Pumping stations to remove flood waters, including 14 facilities in six vulnerable areas. There also was an improvement of inflowing channels involving 13 rivers (*Fig. 9*).

Setting Flood Season Lake Water Level Limit

While water in the lake was previously maintained at B.S.L. ±0, the level is now set as B.S.L. –0.20 m from June 16 to August 31 and, from September 1 to October 15 at –0.30 m. This is intended both to reduce the time that the lake water level is higher than normal and to shorten the flooding period.

Seta River Dredging

The Seta River, the only outflow channel from Lake Biwa, was excavated to increase the lake water discharge rate. The increased discharge allows for lowering of the lake level in anticipation of increased rainy season water inflows. This "prelowering" of the water level also would allow the lake to accommodate the 100-year floods, with the lake level reaching its high water mark of B.S.L. +1.4 m. Further, the increased discharge capacity of the lake will enable the prompt reduction of its water level, which would lessen the potential flooding damages around the lake peripheries (*Fig. 8*).

Shoreline Flood Management Measures

Prevention of overflow from the lake, and removal of inundating water, was one of the major goals in the Lake Biwa Comprehensive Development Project. Consequently, the construction of the lakeshore embankment and the river

channel improvements were key elements. To allow for 1.2 m headroom over the B.S.L. +1.4 m planned high water level, the levy embankment was constructed up to the height of B.S.L. +2.6 m around the lake. Channel improvement of inflowing rivers also was carried out, and the pumping stations were installed to remove water that might spill over from flooded rivers to cause lowland inundation around the lake that was blocked by the levy structure.

Formulation of Weir Operating Principles

Even after the weir was installed, regulations for its operation were still undecided because of continuing opposing upstream and downstream interests. As LBCDP neared completion in 1992, however, upstream and downstream agreement had been achieved, and the operating regulations decided. At the same time, downstream water users in Hyogo and Osaka Prefectures were finally able to execute their acquired right to draw up to 40 m^3/s of water from the Yodo River during times of severe droughts. The Seta River Weir has been managed and operated based on these regulations since April 1, 1992.

Under these regulations, the planned peak water level is set at B.S.L. +1.4 m. Seasonally, during the potential flood periods, the level is reduced to B.S.L. –20 cm or –30 cm (between June 16 and October 15), while at other times, when there is a low risk of flooding, the water level may be allowed to reach B.S.L. +30 cm (between October 16 and June 15 the next year). Accordingly, water discharges through the weir are finely controlled to not exceed the regulated values. During times of downstream water shortages, the Weir would be finely controlled. If the Lake Biwa water level decreases to below B.S.L. –1.5 m, however, Ministry of Construction (redesignated as the Ministry of Land, Infrastructure, Transport, and Tourism since 2001) decides the weir operation policy, after consulting with the Governor of Shiga and the other prefectures concerned (*Fig. 7*).

Yodo River Improvement Master Plan (1971–2007): Management of Entire River System

The Rivers Act of 1896 was revised in 1964 to promote the integrated management of both flood control and water supply in the entire drainage systems. Based on the revised Act, the first Yodo River Improvement Master Plan was developed in 1965, covering the entire Yodo River and Lake Biwa. Recognizing the need for security for the increased population and the expanded industrial areas in the Yodo River basin against flooding, this plan had to be completely overhauled. It was eventually implemented in 1971 with the goal of preventing the damages even from the 200-year floods. As of 2010, based on the work carried

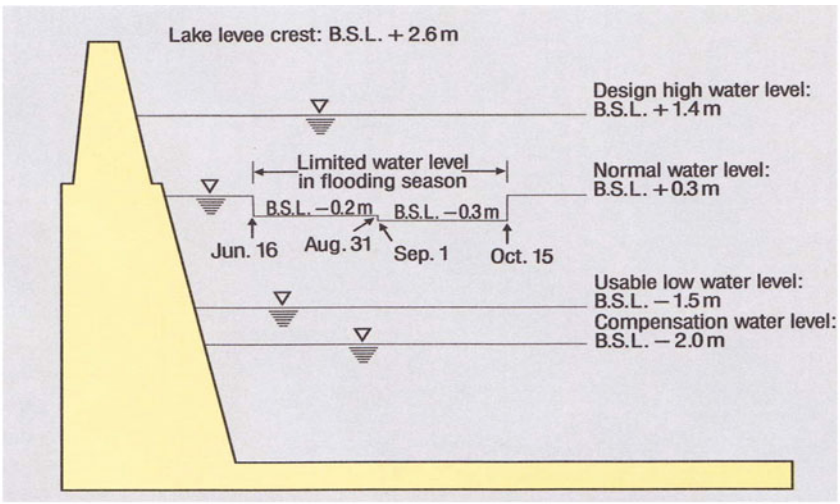


Fig. 7
Water level adjustment in Lake Biwa.

Legend

B.S.L.	Lake Biwa surface level (Tokyo Bay datum+84.371m)
Design high water level	Max. level according to flood control plan
Normal water level	Target level during ordinary conditions
Limited water level in flooding season	Pre-lowered level in anticipation of heavy rain
Supply discharge low level	Level reduced to sustain supply in dry spells
Compensation water level	Low level that triggers compensation measures

Fig. 8
Lakeshore embankment.

out under the plan, the objective of flood control is to prevent the 200-year floods at specific downstream reference points.

Fundamental Yodo River Management Policy and Yodo River Improvement Plan (2007–Present)

In addition to the concern hitherto restricted to flood control and water resource development, the 1964 Rivers Act was further revised in 1997, with the goal of dealing with rehabilitation and protection of the river environment.

In conformity to this revised Act, the Fundamental Yodo River Management Policy was formulated in August 2007, from which the Yodo River Improvement Plan was developed in 2009. The spirit of the Policy was, "rather than sacrificing one area of a region to protect another, the intention is to improve security from flooding in the entire river basin; and after the downstream flood control infrastructure development has been completed and as long as there would be no threat of flooding downstream, the Weir would not be completely closed."

Since the end of the nineteenth century, the fundamental concept of the Yodo River flood control was to lower the normal Lake Biwa water level in advance to offset flood season high water levels. The integrated flood management policy has consistently combined this prelowering before the seasonal inflow of water with dredging of the Seta River to increase the lake outflow capacity, and closing of the Seta River Weir to reduce downstream flood risks.

6.3 Water Resource Development in Lake Biwa Region

6.3.1 Overview

As was typically the case throughout Japan, the early motivation for water resource development in the Biwa-Yodo Basin was the water need for paddy irrigation. The lake region remained poor, sustaining their livelihood more or less exclusively on the basis of a rural agricultural economy. Despite its large quantity and close proximity, Lake Biwa water was not a viable water resource option for the riparian communities in the days when electricity was still not widely available for pumping water upland. Rather, the lake watershed communities had to resort to the diversion of the unstable feeder river waters for paddy irrigation and for meeting their daily needs. During the droughts, the upstream farmers would divert almost all of the river water, leaving little for the downstream users. While the upstream water users usually have the power to control the water, they also have to ensure the water use conflict with the riparian communities would eventually

Inae Pumping Station

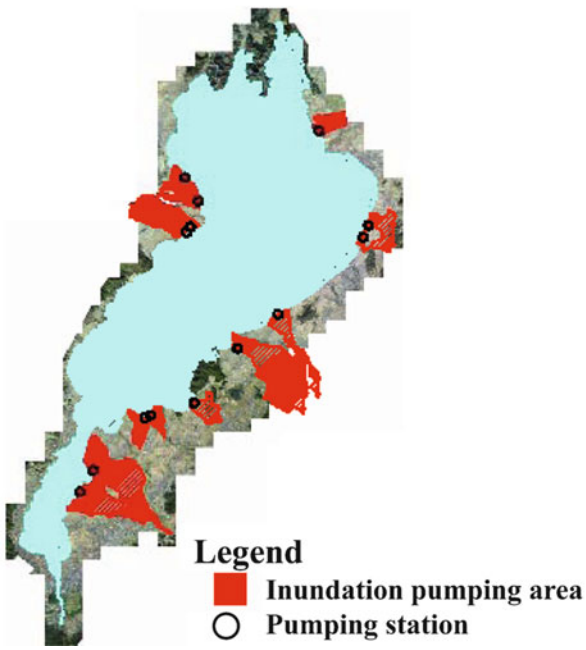


Fig. 9
Pumping stations and Inundation area around Lake Biwa.

be amicably resolved, by means of various sophisticated nonstructural measures for conflict resolution. One such example is the formation of water user associations for effective and equitable water distribution. Another example was unification of the individual diversion intakes in such a way there would be only one water user association along the same diverting river system. This irrigation water use culture evolved over the period of more than 300 years.

Unfortunately, however, even with such measures, the resolution of water use conflicts was always difficult. Specifically in the Lake Biwa region, the unique geo-topological and climatic conditions made paddy irrigation particularly problematic. Simply stated, frequently too little or too much water was available in many parts of the basin. In old days, the structural measures were limited to constructing impoundment ponds and/or earthen barrages to help ameliorate such hardships.

6.3.2 Water Needs and Management Challenges

On the other hand, the communities in the downstream Yodo River have had access to the water, mainly that originating from Lake Biwa, at many water intake locations. The stable water-abundant communities have grown over time to become today's Keihanshin economic region, with a high concentration of industries and populations. In addition, at times of heavy rain over the lake watershed, the flood control weir constructed at the discharging mouth of the lake was operated on the principle requiring the flood waters to be kept within the lake basin. The overall political and economic dynamics remained skewed in favor of the downstream interests over the upstream interests. However, by 1950s and 1960s, the structural measures included construction of large scale, multiple-purpose dams, together with installation of large-scale pumping stations for distribution of the abstracted water through the irrigation pipeline networks. The conjunctive use of river and lake waters was realized for the first time during LBCDP for flood protection and land development of the riparian lowland communities, and for generating additional water rights for irrigation, although its primary purpose was to allow more water to be made available to the downstream region during times of extreme droughts. The additional water rights and the traditional rights had to be properly realigned for equitable allocation.

The era of water resources development has lasted for decades, and by the mid-1990s, the projected severe water shortage for the urban and industrial sectors in the 1960s and 1970s seem to have been significantly moderated with the completion of a sufficient number of dams and reservoirs across Japan. By then, however, the negative impacts to the environment and nature by these hydraulic structures also have grown to become a major contentious issue in many parts of Japan, including in the Biwa-Yodo Basin. The growing concern for the environment and for the wasteful uses of the supplied water made the conventional approach of supply-side water management outdated. There is strong sentiment on the need for a paradigm shift from the supply-side water management to demand-side management.

6.3.3 Low Flow Regulation: Some Dictating Facts

As discussed in previous sections, management of Lake Biwa water, specifically its water level, has historically been highly contentious and conflicting, particularly with respect to supplies of water, and control of floods. Those living in the downstream Yodo River want Lake Biwa water to be kept within the lake during times of floods, and for water to be released downstream during drought periods. Combined with the fact that the demand for Lake Biwa water in the downstream Keihanshin Region has been predominantly for urban and industrial uses, while that in the upstream Lake Biwa region has been dominantly for agricultural use, there are some dictating facts about the ways with which a variety of policy tools has historically been introduced.

The Hirakata Gauging Station

The water quantities required under the water rights for satisfying the thirst of the downstream Yodo River are allocated at Takahama, immediately upstream of the Hirakata confluence point of Uji, Katsura and Kizu Rivers (see *Fig. 1*). At the Hirakata Gauging Station, the low flow regulation is set at 186.51 m^3/s during the irrigation season (May 1 to October 15) and at 169.71 m^3/s in the nonirrigation season. Of these water flows, the minimum requirement for environment protection and nature preservation is set at 85 m^3/s, which consists of 70 m^3/s allocated to the Oh River (Oh-kawa), 10 m^3/s allocated to the Kanzaki River (Kanzaki-gawa), and 5 m^3/s to pass through the Yodo River Big Weir (Yodogawa-Ohzeki). The quantities of water allocated for agricultural use is 16.8 m^3/s, and for industrial and municipal uses together is 101.51 m^3/s.

Ascription of Water Rights

Around 70% of the total water discharge at Hirakata comes from the *Uji* River, which originates from Lake Biwa. During the dry season, the daily releases from Lake Biwa are approximately eleven million m^3 (130 m^3/s) which corresponding to about 1.6 cm of Lake Biwa depth (1 cm of depth from surface corresponds to about 6.8 billion m^3). Based on the Yodo River Water Resources Development Master Plan (or the Yodo River Full Plan, described in detail in Section 6.3.4), 40 m^3/s was ascribed to the water level control of Lake Biwa through LBCDP, 15.175 m^3/s to the first stage Yodo River improvement works, 15.576 m^3/s to the natural base flow, and the remaining flow to various dams (Takayama, *Hinachi*, *Shourenji* and Hiyoshi Dams), and other water control measures (Yodogawa Ozeki Weir and Shorenji Water Intake).

Fig. 10
Torii River Gauging Station and Seta River Weir.

6.3.4 Key Water Resource Development Issues

Seta River Weir and Torii River Gauging Station (*Fig. 10*)

The water level of Lake Biwa, as related to drought and flood management, has always been the focal issue of contention between the upstream and downstream stakeholders. When the Nango Weir was completed in 1905, the baseline elevation of the Lake Biwa water surface, as measured at the Torii River Gauging Station, was determined to be 85.671 m against the Osaka Pail (or the standard seawater level of Osaka Bay). Thereafter, all construction works and water management decisions refer to this B.S.L. as the standard water level of Lake Biwa (Biwako Stand Level, or B.S.L. ± 0 m level). As an aside, this B.S.L. formed the baseline for determining various design parameter values comprising the structural and nonstructural interventions stipulated in LBCDP, including the planned high water level of +1.4 m (of which the free board height is +1.2 m), the planned Lake Biwa water levels during summer months (−0.2 m from June 16 through August 31, and −30 cm from September 1 through October 15), the maximum water level under normal weather conditions of +0.3 m, the usable water drawdown of −1.5 m, and the damage compensation water level of −2.0 m. In other words, the lake level has been meticulously controlled to make Lake Biwa function both as a flood control dam, and as a water supply reservoir, depending on the seasons and the prevailing precipitation phenomena at the time (*Fig. 11*).

Construction of Kyoto Canals and First Stage Yodo River Improvement Works

Prior to industrial development in the late-nineteenth century, the use of Lake Biwa water was limited to small scale drinking water supplies, paddy irrigation in the low-lying lands, fisheries, and navigation. At the dawn of the Meiji Restoration Period (1868–1912), however, the government was intent on developing industries, resulting in a critical need for hydropower generation and water resources. Notable in that respect were two major Lake Biwa projects. The first was construction of Lake Biwa Canals, and the other was the First Stage Yodo River Improvement Works. The Lake Biwa Canals were constructed between 1885 and 1912. Completed in 1890, the First Canal, with a capacity of 8.35 m^3/s, was designed to meet the navigation, hydraulic works, and irrigation needs. Completed in 1912, the Second Canal, with a capacity of 15.3 m^3/s, was designed to meet water supply and hydropower needs. The total design capacities of the two canals amounts to 23.65 m^3/s, being managed by the City of Kyoto for drinking water (12.96 m^3/s), industrial water (0.004 m^3/s), irrigation water (1.12 m^3/s), and other uses (0.781 m^3/s). The hydropower station constructed at Keage at the outlet of the Second Canal was the first such system in Japan and, together with the hydropower dams constructed in Uji River and Shizu River downstream of Lake Biwa, gave the lake an important role in energy production. (See also Topics 21)

The First Stage Yodo River Improvement Works was undertaken mainly to support the war footing in 1943

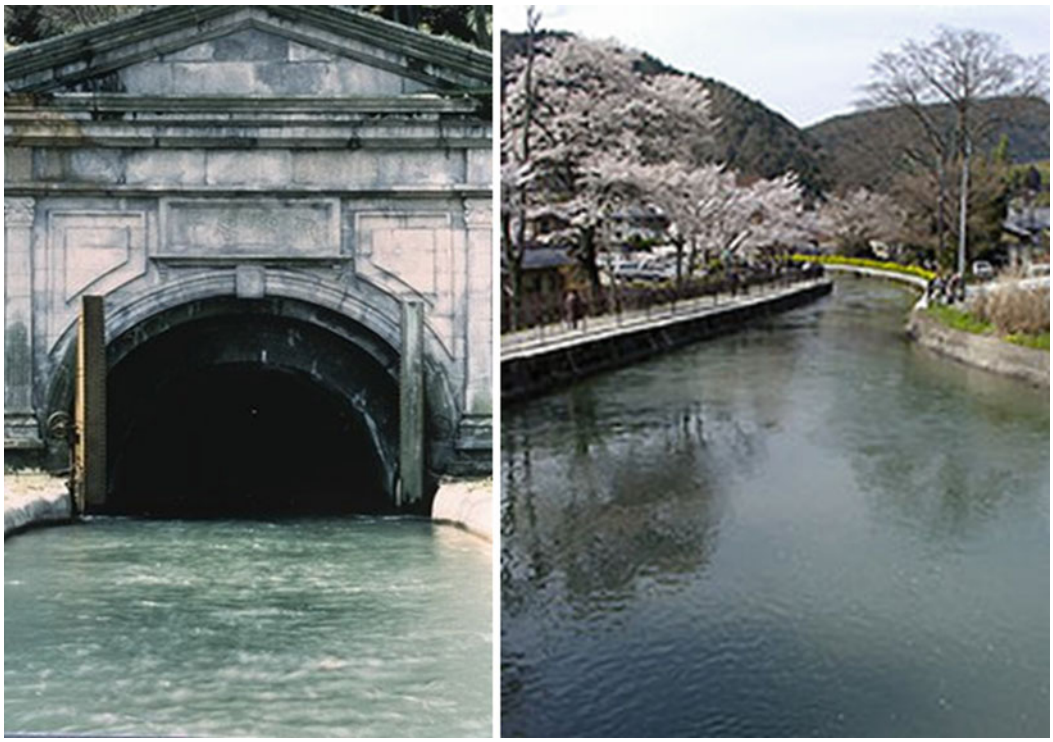


Fig. 11
Lake Biwa Canal inlet and open channel.

during the Second World War. Some 120 m^3/s of Lake Biwa water was to be supplied to industries, to drinking water supply, and to hydropower generation, for which the Lake Biwa water level was lowered down to −1.0 m B.S.L. by dredging the Seta River and realigning the Daido River confluence to the Seta River. The project was only partially completed in 1947 because of the ending of the war in 1945, was later succeeded by the Yodo River Water Resources Development Master Plan (the Yodo River Full Plan) of 1962, being finally completed through LBCDP in 1997 with modifications (see Section 6.4 for details).

Yodo River Water Resources Development Master Plan (Yodo River Full Plan)

To support rapid urbanization and industrialization after Second World War, the national government was intent on developing hydropower generation, urban and industrial water supplies, and irrigation systems. The Law Pertaining to Construction of Multipurpose Dams was enacted in 1957 to discourage wasteful investments in river management. In 1961, the Law for Promotion of Water Resources Development and the related laws were enacted to accelerate water resource development, with a provision to identify seven priority river systems to receive funds for integrated development. The Yodo River was included as one of the seven systems, enabling the development of the Yodo River Master Plan (also referred to as the Full Plan) for water resource development. The Full Plan acknowledged the water rights generated, respectively, by LBCDP (40 m^3/s), Takayama Dam (5 m^3/s), Shorenji Dam (2.49 m^3/s), Murom Dam (1.6 m^3/s), Hitokura Dam (2.5 m^3/s), Hiyoshi Dam (3.7 m^3/s), Hinachi Dam (1.5 m^3/s), and Nunome Dam (1.14 m^3/s). In 1964, the River Law of 1896 was revised, with the new stipulation for water rights and other relevant issues. Based on the Full Plan as a long-term water resources development plan, many water resources, irrigation, and river engineering construction projects were gradually undertaken over the following years.

6.3.5 Developing the Lake Biwa Comprehensive Development Plan

Soon after Second World War, and recognizing the need for a long-term, comprehensive resource development project for Lake Biwa, the Lake Biwa Comprehensive Development

Council was inaugurated in 1952. The Council members consisted of three groups, that is, the national government, three downstream prefectural governments, and the major water user associations. In addition, the Shiga Prefectural government, the reluctant but only upstream stakeholder, was also a member. The main objectives for establishing the Council was to reach an agreement for the downstream users, mainly the Osaka and Hyogo Prefectural governments, to have access to greater quantity of Lake Biwa water. The contention of the Shiga Prefecture was that the first priority should be to fulfill the local community needs, and to develop the infrastructure for local and regional economic development, with provisions for nature conservation and environmental protection.

The Council members elaborated on the assessment of the visible/invisible and/or tangible/intangible values, and on the responsible bodies for taking care of such values. Although the Minister of the Construction had the legal right to decide on the fate of the Lake Biwa water, it would not be possible to decide on the fate of the Lake Biwa water without having the agreement of the Shiga Prefectural government to the terms of the proposed plans and programs. Eventually, the downstream Osaka and the National Government accepted the view expressed by Shiga Prefecture that water resource development for the downstream should be accompanied with regional economic development of the upstream Lake Biwa region. Thus, the scope of the water resources infrastructure development projects stipulated under the Full Plan was expanded and, together with flood control and environmental amenity projects, the Full Plan was transformed into LBCDP of 1972.

It is important to note here that the water resources component of LBCDP involved intricate political settlements among the key stakeholders. The downstream residents insisted the planned drawdown of the lake water level should be −2.0 m, corresponding to 40 m^3/s of additional lake water discharge, as per the engineering computations performed by the Ministry of Consturction, reorganized into the Ministry of Land, Infrastructure, Transportation and Tourism in 2001. The Shiga Prefectural Government, on the other hand, considered the figures unacceptable, and insisted on the discharge to be 30m^3/s, corresponding to −1.5m of drawdown. The two were in strong disagreement, seemingly jeopardizing the conceptual basis of LBCDP. In March 1972, however, the Minister of Construction and the four Governors met and agreed to the Statement of an Exchange of Promises (*Moushiawase* in Japanese) stipulating:

1. The quantity of additional discharge from Lake Biwa at times of extreme droughts is agreed to be 40 m^3/s.
2. The maximum drawdown should be B.S.L.−1.5 m.
3. The Minister of Construction will honor the opinions of the prefectural Governors before making the final decision on the operation of the Seta River Weir during times of extreme drought.

The Statement in effect adopted the politically compromised figures of 40m^3/s and −1.5m, and, although the compensatory engineering works to be performed for the in-lake facilities to the drawdown level down to −2.0m, rather than just to −1.5m was not included in the Statement. Being inconsistent against the results of technical analyses, this political settlement later became a focal issue of discussion on the need for new Weir operational rules for meeting environmental and ecological needs. In other words, the Statement in a way reflects the implied societal consent to let political tensions supersede technical integrity. Having the regional economic development and the environmental enhancement project components added to the water supply and flood control components, the total budget of LBCDP eventually exceeded 1.9 trillion yen. The project, which was originally designed to be one of water resources development, was realized through an extremely intricate political compromise.

6.3.6 Irrigation Improvement Projects in Lake Biwa Surroundings

An extensive part of the lowland area of the Lake Biwa watershed is irrigated for paddy agriculture. The irrigation systems prior to LBCDP were typically limited to cascading of stream waters from the upstream impoundments and barrages. The Shiga farmers were keen to have these systems improved through LBCDP, and various irrigation improvement projects were undertaken with financial support from it. Three categories of the irrigation improvement programs were developed: (a) construction of new lake-water irrigation facilities to compensate for the lowered groundwater level; (b) regional economic development program; and (c) environmental enhancement program. The lake-water irrigation program had two components. One was construction of large-scale pumping stations and water distribution pipelines, and another was construction of the irrigation return flow recirculation systems. The regional economic development program involved farmland consolidation projects with improvement of irrigation and drainage canals/ditches and farm roads. The environmental enhancement program included development of rural wastewater systems. Described below are some typical cases of each of the three programs (*Fig. 12*).

Fig. 12
Ecologically sound irrigation return-flow drain.

Irrigation by Pumping of Lake Water

Today, some 30% of the total farmland of Shiga Prefecture, comprising about 24,000 hectares, is supplied with pumped Lake Biwa water. In addition, about 14% is supplied with river water mixed with lake water. The lands provided with these new irrigation systems used to be those least favorable for paddy agriculture for two reasons. First, they were located quite a distance away from stream water sources, and second, they were located in the low-lying areas prone to inundation (*Fig. 13*).

Recirculation of Irrigation Return Flows

The concentrations of organic substances measured as COD, and nutrients measured as Total Nitrogen (TN), have been increasing in Lake Biwa over the past decades. The irrigation return flows are regarded to have been partly responsible for the increases. The percentage contribution of agricultural nonpoint-source pollution loads are 13% for COD and 15.4% for TN, slightly less than those from the industrial point source pollution loads, except that pollution load reductions from nonpoint sources of pollution are much more difficult to address. The policy measures introduced in Shiga Prefecture include the recirculation of polluted irrigation return flows. The system, consisting of irrigation return flow collection reticulation networks combined with a pumping station attached to a return-flow collecting pond, is designed to minimize the discharge of pollutants into the lake. In addition, some of the drainage canals are recently being replaced with canals composed of gravels and filter materials supplemented with aquatic plants to reduce COD by oxidation and biochemical decomposition processes.

The irrigation return flows are also problematic, however, because of the so-called "irrigation mud-waters," generated during the paddling-planting and transplanting seasons. They contain high concentrations of suspended solids, and can result in serious negative impacts on the lake ecosystem. The recirculation of irrigation return flows is expected to significantly reduce the concentration of suspended solids. As of 2008, some 25% of the total 7 million m^3 agricultural return flow is subjected to recirculation. Introduced below are pilot project cases on the Hino River integrated irrigation development project and on the Akanoi Bay water quality conservation project.

Project Case 1: *Hino* River Integrated Irrigation Development Project

The Hino River basin stretches out from the central highland region of the eastern watershed of Lake Biwa. Within this basin, LBCDP provided for 110 diversion structures,

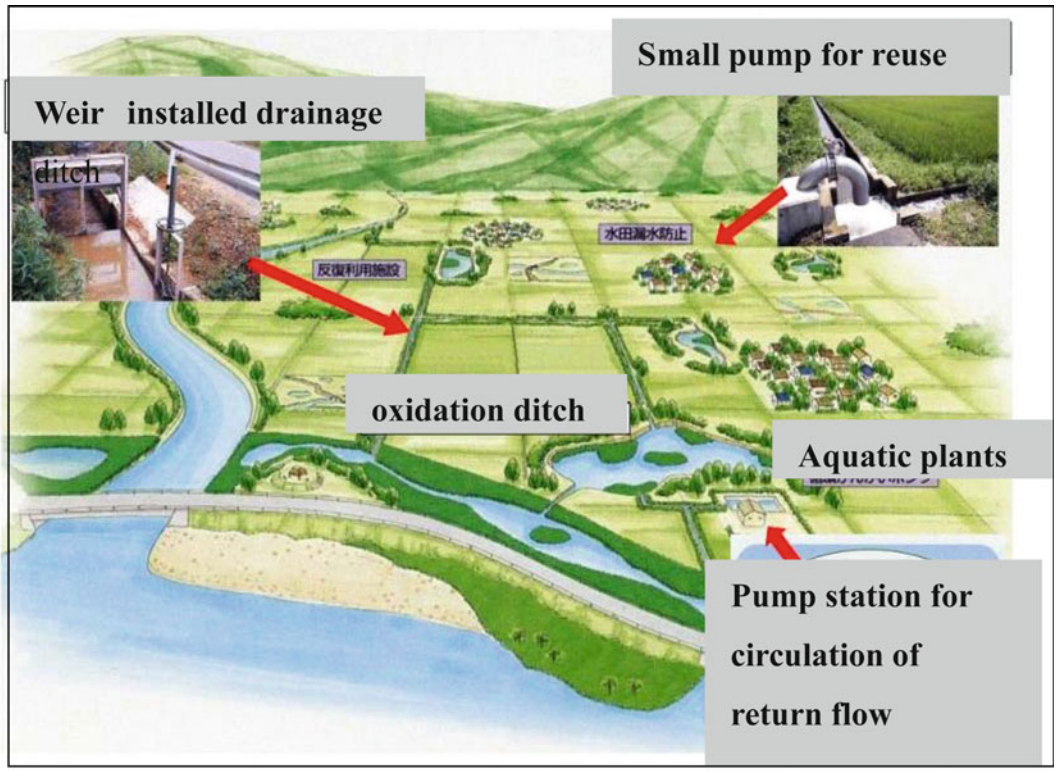


Fig. 13
Irrigation return flow circulation system.

150 farm ponds, 120 pumping stations for groundwater extraction and distribution, as well as for supplying water to the former wetland reclaimed as "polder" farmland. The operation and maintenance of these facilities were carried out individually by many small irrigation associations. Many of the inherent water use conflicts had to be resolved through individual agreements between, and among, the water user associations (*Fig. 14*).

Specifically, the Project, initiated in 1985, consists of construction of the Zao Dam in the upper reach of the Hino River, and a large scale lake-water pumping station with a 4-level boaster pump system to lift the lake water up to the elevation of 220 m. The water intake structure of the pumping station is located some 420 m into the lake to be able to withdraw water even when the lake level drawdown reached the compensation maximum of −2.0m. The maximum quantity of lake water withdrawn is 7.3 m^3/s, the lifting elevation is 60 m, and paddy area coverage is 3,000 ha. Together with the river water captured in the Zao Dam, a total land area of 5,210 ha is irrigated with this system. The lakeshore paddy lands, which used to be prone to inundation, were improved by the drainage network systems equipped with draining pumps. Working conditions and work productivity have been remarkably improved through this project. These newly constructed irrigation systems, however, are not free of problems. The complex maze of creeks containing rich biodiversity has been lost, and the lake-river-paddy linkages have been shuttered for the sake of converting the wetland paddy system to the dry-land irrigation paddy system. There is now the challenge of restoring some of the lost ecosystem properties.

Project Case 2: The "Whirligig Beetles – *Mizusumashi* – Plan" in the *Akanoi* Bay

The Akanoi Bay is a small embayment in the South Lake and one of the most polluted parts of Lake Biwa from urban and agricultural nonpoint-source pollutions, together with the pollution from domestic and industrial wastewater effluents. It has been experiencing occasional blooms of blue-green algae, and the Shiga Prefectural government has given a high priority to its restoration. The plan is called the "Whirligig beetle – *mizusumashi* – Plan." (*Fig. 15*)

Whirligig beetle, or "*mizusumashi*" in Japanese, is a freshwater insect known to feed on aquatic organic debris

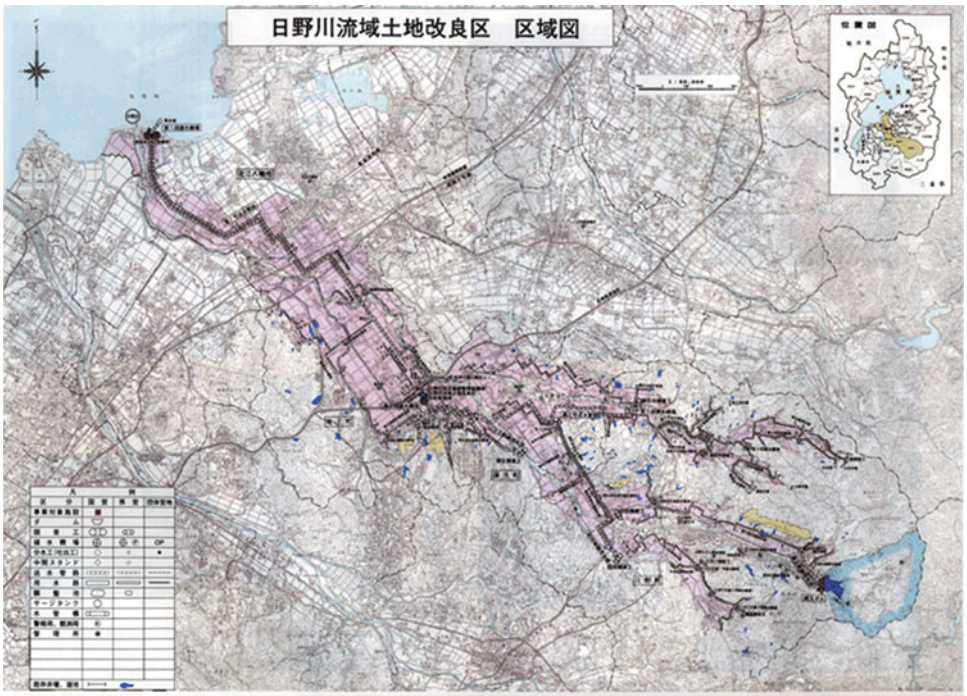


Fig. 14
Hino River project overview map (Source: Shiga Prefecture).

Fig. 15
Location of the *Akanoi* Bay Project (Source: Shiga Prefecture).

and planktonic matters, thus contributing to purifying the water in which they thrive. All of the Shiga Prefecture projects for purifying the agricultural return flow are collectively dubbed as the "Whirligig beetle, or *mizusumashi*, Plan".

The project consists of several engineering components, that is, construction of an oxidation ditch, introduction of aquatic plants for water purification, recirculation by pumping of agricultural return flows, and reconstruction of diversion structures, with a total expenditure of 1.63 billion Japanese Yen. According to the projected achievement, the target reduction of COD is from 199.0 to 85.0, of TN from 67.2 to 37.6, and of TP from 6.3 to 2.43 (all expressed in g/ha/day). At the same time, the plan aims at restoration of aquatic ecosystem health through citizen participation and environmental education.

6.3.7 Water Use Changes in Urban and Industrial Areas

Social Characteristics of Lake Biwa Catchment Area

Japan's population began declining in 2005. Together with the trends of falling birthrate and aging population already evident in the 1990s, Japan is ahead of other industrialized

nations in simultaneously experiencing these three trends. In contrast to these national trends, however, Shiga Prefecture is one of the few prefectures in the country where the population continues to grow. The prefecture's population aging rate is also among the lowest in the country. This is one of the key features characterizing water use patterns in the Lake Biwa region.

The population of Shiga Prefecture declined after the Second World War, reaching its lowest number of 830,000 in 1963. At that time, people and industries were moving into Osaka City, the center of the Keihanshin Area, with the city seeing its population grow to the postwar peak of over 3 million in 1965. The concentration of population and industries in Osaka City was a reason for the population decline in Shiga Prefecture.

Between the mid- and late-1960s, the Osaka metropolitan area expanded in size, resulting in a population decline in Osaka City, with an increased population in the periphery of the metropolitan area. The population of Shiga Prefecture, after reaching its lowest level in 1963, started growing again, and has since been increasing for nearly 50 years. The growth has been particularly significant along the Japan Railway Lake Biwa Line between the Konan (south of the lake) District where Otsu City (Prefecture's capital) is situated, and Koto (east of the lake) District.

Industrial Development in Lake Biwa Region

The locational pattern of industrial establishments in Shiga Prefecture has been greatly influenced by the population growth in the prefecture. Industrialization of Shiga Prefecture was triggered by the establishment in the late-1910s of textile industries such as sericulture, cotton spinning, and rayon productions. It resulted as one of the rippling effects of the development of industries after First World War. The accumulation of the rayon industry in Otsu City was particularly significant, raising the country's rayon output to be the world's number one producer before Second World War. Despite such industrial developments before Second World War, however, Shiga Prefecture was still seen as an agricultural prefecture because of its limited number of industrial activities. It was between the 1960s and early 1970s—the high growth period—that this characteristic fundamentally changed, with the prefecture starting to shift toward an industrial prefecture.

The industrial growth of Shiga Prefecture has much to do with the development of regional transportation systems. At the time of the first peak of industrial accumulation around 1960, the National Artery Road No. 1 was passed through the prefecture, soon to be followed by the National Artery Road No. 8. With the opening of the Shiga portion of the Meishin (Nagoya-Osaka) Expressway in 1964, together with the completion of the Biwako Ohashi Bridge connecting the National Artery Road No. 8 to the Kosei (west of the lake) District's National Road No. 161, the main transportation routes of the prefecture were fairly well-established. As a result, the Shiga Prefecture was connected not only to the Keihanshin Area through the national Artery roads, but also to the Tokai and Kanto areas through the national expressways.

It was in the early 1970s when the textile industry, once the pillar of the prefecture's industries, decreased its share of the prefectural industrial output, being replaced by electric and general-machinery industries. For nearly 40 years since then, these electronic and general-machinery industries, together with many different types of assembly industries, have characterized the industrial profile of the prefecture.

Relocation of Industries from Outside Shiga Prefecture

For the textile industry, established in Shiga Prefecture before the Second World War, Lake Biwa was a major attracting factor. Being constrained by the limited transportation access to the Japan National Railway system (now the Japan Railways) and a small number of regional roads, these industries were mostly confined to the lakeshore area.

On the other hand, during and after the high growth period, the development of road transportation networks with access to the designated industrial lands were a determining factor for industries to be located in the lowland as well as upland areas within Shiga Prefecture. In particular, the Meishin Expressway, which runs through the higher elevation along the foot of the surrounding mountains, allowed industries also to be located in high altitude areas with access to the connecting local roads. The establishment of industrial parks was an additional factor. When the road network was significantly improved in the early 1960s, some 59 industrial parks were constructed, including those in Omihachiman, Konankogyo, Kusatsujutaku, and Minakuchijutaku. The industrial complexes were initially developed in the lowland flat areas, but gradually spread to areas away from the lakeshore. Many of the large-scale complexes today are located in hilly areas, contributing to the concentration of industries in upland areas.

Industrial Water Use Characteristics

Many of the industries established in the prefecture, during and after the high economic growth period, were not

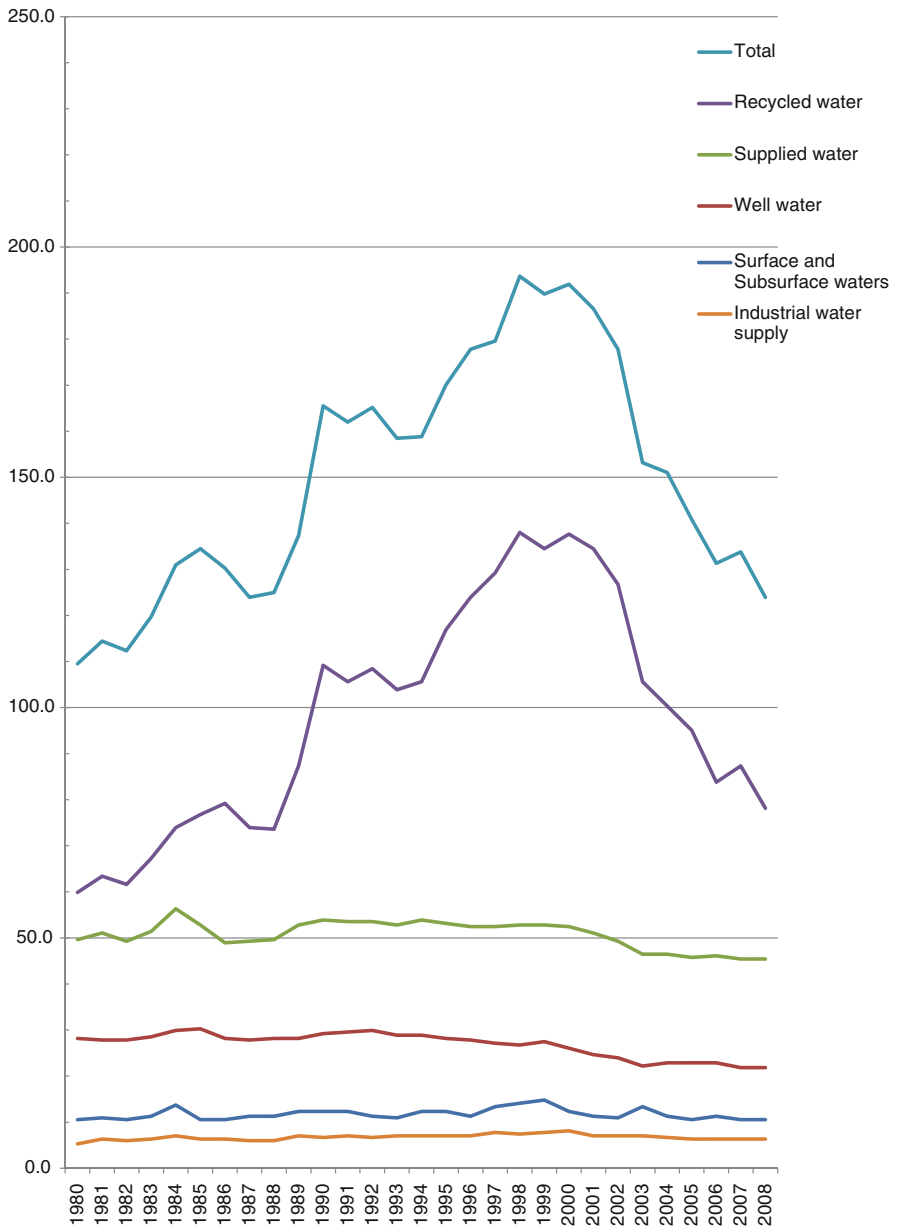


Fig. 16
Industrial water use in Shiga Prefecture by source (Supplied water + Recycled water = Total Industrial water supply + Surface and Subsurface waters + Well water = Supplied water).

dependent on the availability of water. Thus, the availability of local water sources was not a determining factor. *Fig. 16* shows that the total quantity of freshwater use increased 1.7-fold between 1980 and 1998 (the peak year). The quantity then started declining and, in 2008, was at the level of 20 years ago. However, the fact that there was little correlation between the total quantity of water used and the quantity supplied, and that the quantity of water recycled was correlated with the total quantity of water used, suggests that the demands for industrial water could be met by increasing the water recycling rate.

Historically, groundwater has been the major source of water for both agricultural and domestic purposes in Shiga Prefecture. Much of the industrial water has also been groundwater extracted from deep wells, and from subsurface infiltrations (nearly 75% in total). The dependency on public water supplies has been quite low, with this trend changing little since the 1980s. The diverse potential of a local water resource is a unique feature of the Prefecture. In summary, there is little direct relationship between the profile of the prefecture's industries and the use of water from Lake Biwa.

Urbanization and Water Demands

After the late 1960s, Shiga Prefecture was caught in the wave of urbanization and industrialization. Development of residential areas in the Konan and Koto Districts, as well as the growth of catering service industries to business establishments and general households has contributed to an increased demand for domestic and urban water supply.

With a population of approximately 1.39 million, the water supply coverage was 99.2% as of March 2007. The maximum water supply per day per person was 488 liters, a high value. The makeup of water sources in Shiga Prefecture is lake water (69.7%), deep and shallow wells (23.4%), surface and infiltration water (6.5%), and spring and other waters (0.3%). In contrast, river waters are not used at all. The dependency on groundwater, once a major feature of water use in the Lake Biwa catchment area, has been on the decline, being less than a quarter in recent years. In contrast, the dependency on lake water is increasing.

The water source composition varies among regions. In groundwater-rich regions such as the Koto Plain, houses and business establishments have tended to use their private wells, thereby providing little incentive for the introduction of water supply facilities. This has also been the case in the Kosei District. On the other hand, due to unstable groundwater supply and its low quality, the incentive for setting up water supply facilities has been high in the Konan and Koga Districts. Further, these areas also exhibited more industrialization and urbanization than other areas of the prefecture, with a significant increase in water demands — a driving factor for development of water resources.

In the 1960s, the Shiga Government began formulating a water supply development plan. In 1964, the piped water supply coverage in the prefecture was 42.3%, much lower than the national average of 62.8%. This low coverage was due to the fact that people in most parts of the prefecture could use groundwater as a water source. However, the Shiga government predicted this traditional water-supply system would not be able to meet the prefecture's future water demands if industrialization and urbanization continued in the future. During the period of conceptualization of LBCDP in the late 1960s and early 1970s, it was predicted that implementation of the Project would affect the groundwater in the catchment area, causing problems for those depending on. In response, a plan was evolved to shift the water supply source from groundwater to lake water. While cities adjoining Lake Biwa, such as Otsu City, had already been using the lake water, it was LBCDP that facilitated the gradual increase in the dependency on the lake water as a water source (see Section 6.4 for details). As a result, nearly 70% of the current water supply is supplied by the lake.

Lake Biwa is also the final destination of various types of water discharged in the catchment area, as well as the major source of water supply in Shiga Prefecture. The Lake Biwa catchment area has formed a water demand structure that cannot be seen in other areas. Therefore, the people who live in the catchment area invariably have to pay extra attention to their water use and wastewater discharge.

6.3.8 From Water Supply Management to Water Demand Management

The Yodo River Water Resources Master Plan, as transformed into LBCDP, is a supply-based plan of water management, meaning that new water demands would have to be satisfied by the newly developed water source. In other words, the new water users would have access to the needed quantity of water resources by way of constructing water impoundment structures such as dams and reservoirs, or in other ways for creating the additional water rights. The era of this supply-side water management has long passed in Japan, where the need for additional water has become more and more difficult to justify for the major water supply entities in the Keihanshin area because of a declining water demand. Further, the supply-based policy of water resource development resorting to dam construction in the past decades has resulted in a supply of water that far exceeds the demands. There is also strong sentiment against structural approaches of supply-based water management because of the unavoidable negative impacts to the environment, and social disorders and conflicts. The call for change in water resources management from that based on supply, to that based on demand, seems to be a natural change in its paradigm.

The fulfillment of the new water demands can be achieved through: (a) transfer of existing water rights, (b) reorganization of water facilities such as dams and reservoirs, and (c) temporary transfer of water rights, collectively characterized as the water demand management options. The Kinki Regional Bureau of the Ministry of Land, Infrastructure and Transportation, Government of Japan, has indicated the need for the following process in realizing demand-based water management:

1. A thorough investigation of actual water uses and demands
2. Revision of the water right system, particularly with regard to the ban in water right transfers

3. Reorganization of the water resource facilities
4. Restructuring of the drought coordination committee

Demand-based water management, combined with the promotion of various water saving practices, should be sufficient to provide for new water demands. The paradigm shift from supply-based management to demand-based management also means a shift from "construction" to "management," complemented with nature conservation and environmental protection. Such a shift would be realized only through wide-ranging participation of the stakeholder organizations, including the general public. The hardcore structuralism in the Ministry of Land, Infrastructure and Transportation (MLIT), however, is strong, *in* maintaining that the prevailing climate change has been seriously affecting the supply capacity of dams across Japan much less than the design capacity determined decades ago, cancelling the effects of reduced demands.

6.4 LBCDP: Its Frameworks, Accomplishments and Emerged Issues

The primary purpose of LBCDP was to promote economic development of the Keihanshin region by transforming Lake Biwa to a type of artificially regulated reservoir capable of providing additional 40 m^3/s of water through the Yodo River at times of extreme droughts, in order to ameliorate their adverse impacts (i.e., shoreline protection from erosion, reconstruction of the water intake facilities, renewal of ports and harbors, etc.) and those caused by flooding (levy construction around the lake, feeder river flood mitigation facilities, reconstruction of the Seta River Weir, etc.). The design maximum drawdown at times of extreme droughts is 1.5 m below B.S.L., and the design maximum is 2.5 m above B.S.L. The newly created water resources would be able to generate socioeconomic benefits for the downstream Osaka and Kobe regions in the form of urban and industrial development. Shiga Prefectural residents, on the other hand, felt that they might be forced to simply accede to downstream demands for additional water without any direct benefit from the transaction. They were more likely to suffer from the additional discharge of lake water through the Seta River Weir, since it would necessitate alteration of existing, or the construction of new, lakeshore facilities for coping with the lowered lake water level. Thus, the contention of Shiga Prefecture was that the development of additional water resources should not only benefit only those living in the Keihanshin Region, but also those living in the Shiga Prefecture. Thus, LBCDP added the additional objective of contributing to the socioeconomic status of Shiga Prefecture by providing for the improvement of environmental and amenity enhancement infrastructure around the lake shore.

6.4.1 Legal Framework

With such considerations in mind, the "Special Measures Act for Lake Biwa Comprehensive Development" was enacted in June 1972. Article 3 of the Special Act stipulates that LBCDP would be drafted by the Governor of Shiga Prefecture and be approved by the Prime Minister, with the project funds coming mostly from the national government and downstream local governments. A total of 22 project categories were identified and included in LBCDP. Those component projects falling under "regional development" were carried out mainly by the National Government, and relevant prefectural and municipal Governments. The water resources development projects and the Lake Biwa flood control projects, on the other hand, were implemented by the Water Resources Development Public Corporation (*Fig. 17*).

Thus, the conceptual basis of the comprehensive development plan was based on the following considerations:

1. Since those living around Lake Biwa have historically made their livelihoods from the lake, the lake should not be considered as a mere water impoundment or reservoir.
2. The lowering of the lake water level should be kept within limits considered reasonable to those immediately affected.

The balancing of the conflicting interests of Shiga Prefecture upstream and the Keihanshin Region downstream required development of a conceptual framework unique to the water resources management policy-making institution in Japan.

6.4.2 Financial Framework

As a major national water resources development project, with flood control and regional environmental and economic development for Lake Biwa and its watershed, LBCDP needed a special scheme for financing the component projects. The Special Measures Act for Lake Biwa Comprehensive Development was specifically developed for the purpose. The structure of the financial scheme is illustrated in *Fig. 18*. Briefly, it includes the following special measures:

1. *Preferentially elevated subsidy rates:* For some categories of component projects included in LBCDP, the

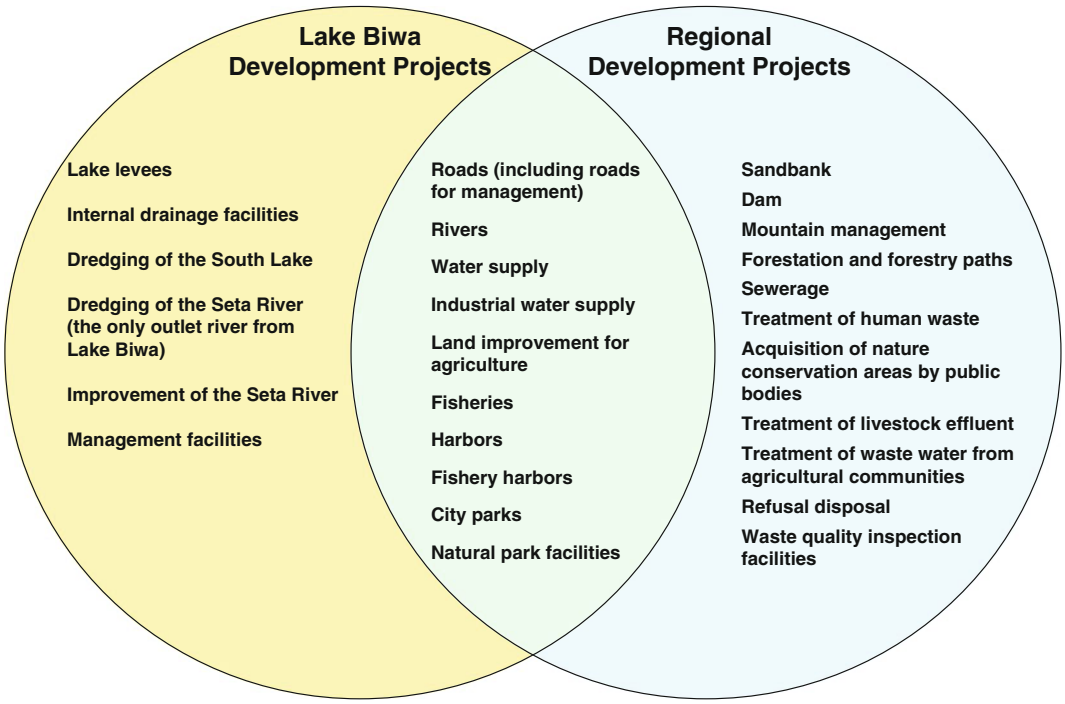


Fig. 17
Sub-projects in the Lake Biwa Comprehensive Development Project.

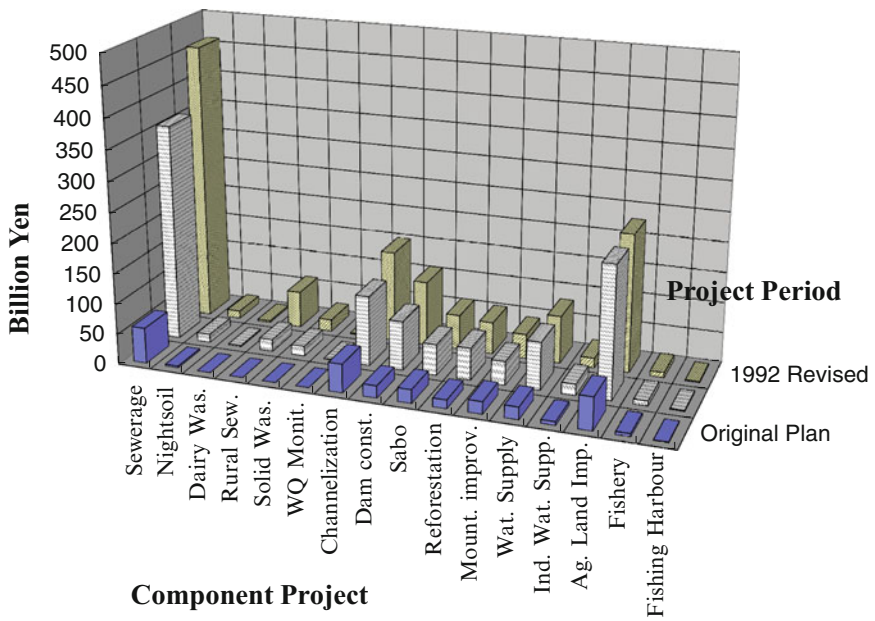


Fig. 18
LBCDP budget structure.

national government provided for "preferentially elevated subsidy rates;"
2. *Financial compensation by the downstream local governments:* The downstream prefectural and municipal governments benefitting from LBCDP agreed to make certain compensatory payments to Shiga Prefecture for the construction of needed facilities and their operations and maintenance. The cost sharing would be based on the extent of water rights allocated out of the newly generated 40 m^3/s resulting from LBCDP. The total compensation from the downstream governments amounted to be 60.2 billion yen. In addition, Osaka and Hyogo Prefectures were required to pay an additional 5 billion yen as a loan to Shiga Prefecture.
3. *Lake Biwa management fund*: At the completion of LBCDP in 1996, Shiga Prefecture was permitted to establish what is called the "Lake Biwa management fund," totaling 10 billion yen, that will be used to undertake projects for maintaining the Lake Biwa water environments and also to maintain and management of the constructed facilities.

6.4.3 Extension of the Act and Inclusion of Water Quality Improvement Projects

This Act was valid only for a 10-year period, to be terminated in March 1982. However, the social and economic conditions of the nation, as well as the surrounding situation of the lake and LBCDP, have changed drastically during the period, with the surfacing of many new issues not adequately taken into account at the time of enactment. In particular, because of the slowdown of the Japanese economy since the first oil crisis in 1973, the national government spending on public works was severely curtailed, and LBCDP was able to achieve only 40% of the goals stated in the Project plan by the end of March 1982. In addition, the forecasted water demands by the downstream Osaka region actually began to decrease soon after the oil crisis in 1973, casting serious doubt about the validity of the very basis of LBCDP.

Furthermore, Lake Biwa water quality began to deteriorate much faster than anticipated, necessitating revision of the original component projects. Thus, the Shiga Prefectural Government consulted with concerned downstream governments and the national government in order to:

1. Extend the validity period of the Act for an additional 10 years to allow for the completion of the initially planned projects
2. Revise the list of component projects by adding projects dedicated specifically to water quality management
3. Maintain the current special financing measures for project implementation

The "Partially Revised Special Measures Act for Lake Biwa Comprehensive Development" was enacted, promulgated, and put into force in March 1982. Four new categories of projects added to the original list of 18 project categories include such items as agricultural dairy waste management facilities, rural community wastewater treatment systems, solid waste management systems, and water quality surveillance and monitoring systems. The total expenditure increased significantly from the original 427 billion yen to 1.525 trillion yen. Together with the originally planned expenditure of 351 billion yen on water resources development and flood control facility development, the total expenditure eventually reached 1.9 trillion yen. *Fig. 19* provides details of the costs of component projects.

The upstream and downstream local governments also reached a consensus in May 1982 that stipulates: (a) the need to establish a forum of joint study by the concerned local governments on the management of the water quality of Biwa-Yodo Basin; (b) the joint financial obligation of the downstream governments to be ¥ 36.0 billion; (c) the extension of the pay-back period for the ¥ 5.0 billion left over from the previous years for an additional 10 years; and (d) the actual release of 40 m^3/s to commence only after the compensatory works have been completed.

6.4.4 LBCDP Accomplishments and Legacies

Flood Control

Lowered Peak Water Levels by Dredging the Seta River

As shown in *Fig. 20*, the increased discharge capacity of the Seta River resulting from the regular dredging practiced since late nineteenth century has lowered the annual peak lake water levels. Notable also was the risk reduction in flooding achieved for the lowlying areas along the lakeshore.

Lowered Flood Peak Water Levels by Prelowering

The lowering of the lake water level before the annual flood season, would lead to the peak lake water level being held down. For example, there was an average rainfall of 257 mm over the period of 9 days in July 2006 over the Lake Biwa catchment area. Because the lake water level was initially at −0.2 m below B.S.L., the peak level was being held to below the peak level experienced in July

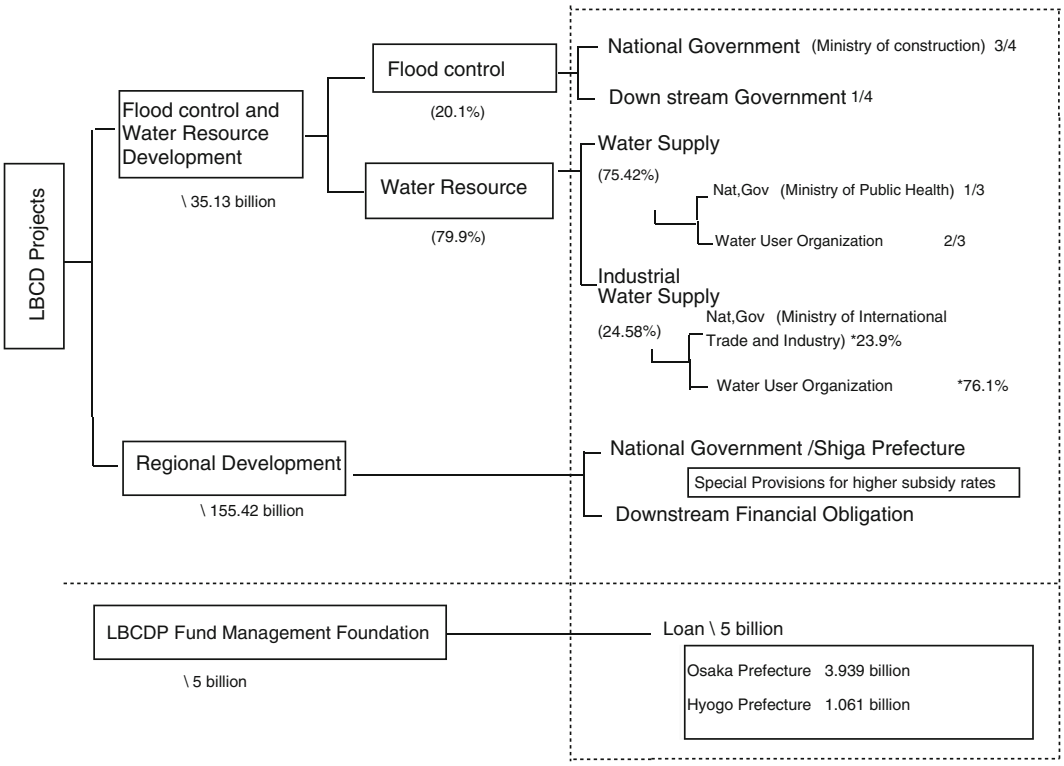


Fig. 19
LBCDP expenditure.

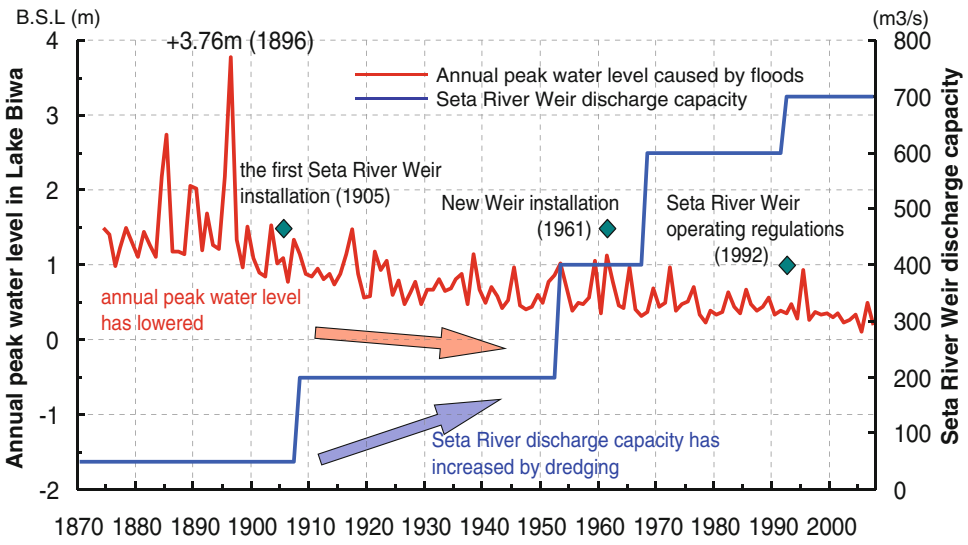


Fig. 20
Dredging the Seta River has brought down the annual peak water level in Lake Biwa.

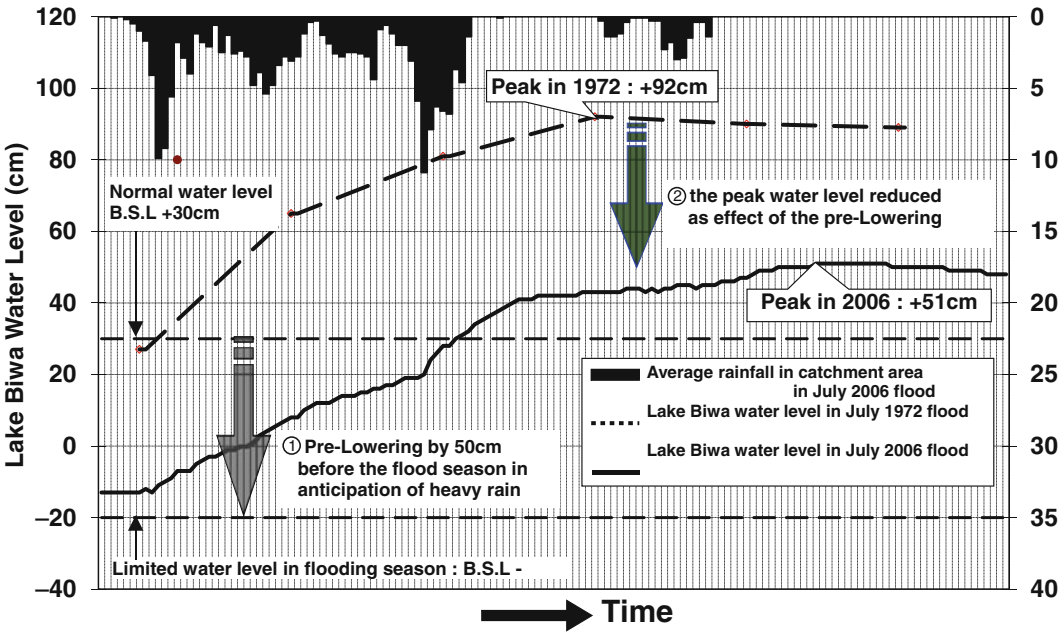


Fig. 21
Reduction of peak water level as a result of pre-lowering.

1972, when there was an average rainfall of 320 mm over the period of 5 days (*Fig. 21*).

Reduced Area and Days of Inundation near the Lake Biwa shoreline

Measures against the inundation caused by the trapping of feeder-river flood water behind the embankments around the lake could be reduced by pumping the inundation water out into the lake, and also by increasing the lake water discharge capacity through the Seta River Weir to the Seta River. For example, although the peak water level of the lake in July 1995, and that in 1972, were both at +0.93 m, the extent of flooding in the former was much less than in the latter in terms of the number of days of inundation (*Fig. 22*).

Water Resources Development

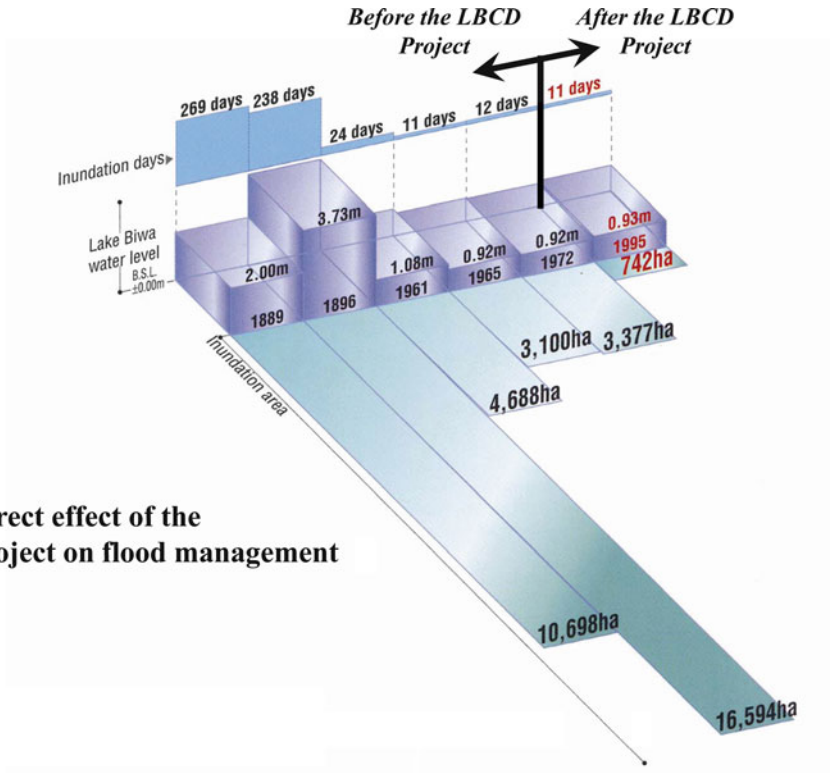
As an example of LBCDP achievement in water resource development, the record drought of summer 1994 did not pose any severe threat in terms of water shortages, despite the fact the lake water level declined down to the historical record of −1.23 m. The number of days of water use curtailments during the 1994 drought was 44 days, or less than 50% of that experienced during the 1973 drought when the maximum decline in water level was only −0.54 m (*Fig. 23*).

Expanded Wastewater Treatment Systems

Among the allocation of public funds invested for LBCDP components, sewerage was highest, followed by land improvement and road construction. Thus, they also are important in regard to impacts on the lake environment.

Sewerage

Sewerage construction was pursued primarily because of its capacity to contribute significantly to the improvement of Lake Biwa water quality, apart from its role in improving the living environment of the people. As a result, the proportion of service coverage in Shiga Prefecture, which had been far below the national average, surpassed the national average by the time LBCDP was completed. Many of the municipal governments within the prefecture, however, face a serious financial burden in having to repay the loan portion of the construction cost, in addition to the heavy costs of operation and maintenance, despite the fact the subsidies by the national and prefectural governments in connection with LBCDP was significantly higher than similar undertakings nationally.



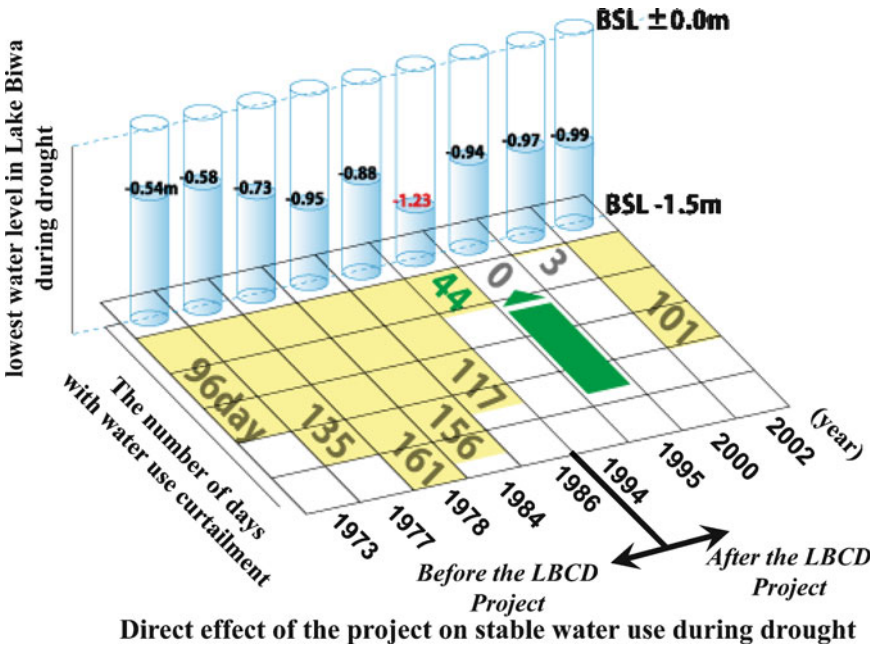


Fig. 22
Reduction in Area and Days of Inundation near the Lake Biwa shoreline.

Fig. 23
Reduction in days of water use curtailment after LBCDP completion.

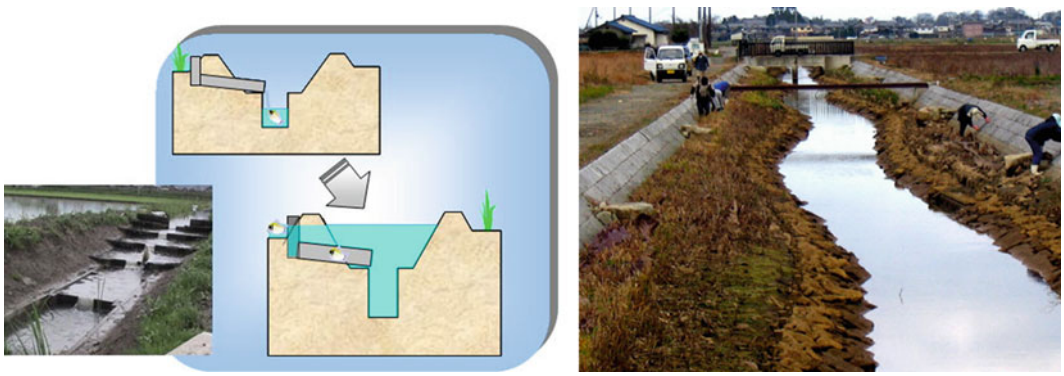


Fig. 24
Fish ladder and draining-ditch aquatic habitat restoration work (Photos: By courtesy of Shiga Prefecture).

Rural Community Sewerage Project

The facility construction for LBCDP related Rural Community Sewerage Project, under the jurisdictional prerogative of the Ministry of Agriculture, started in 1982. A total of 415 units for some 162,000 people have been completed to date, of which 220 units for some 85,000 were financed via LBCDP. The prerequisites to qualify for this project included: (a) the number of beneficially households is more than 20; (b) the number of people to be included in a single project site should be less than 1,000; (c) the area to be served by the system is not within the planned service coverage area of the public sewerage system administered under the jurisdiction of the Ministry of Land, Infrastructure, and Transportation; and (d) the subject household area belongs to the priority area for agricultural infrastructure development. The effluent quality from these treatment plants are generally of high quality, far exceeding the effluent standard. The individual rural homes not served by the Project are provided with onsite treatment units, for which the Ministry of Health and Welfare provide some subsidy.

The treatment facilities within this project scheme are not equipped to treat industrial effluents, unlike the case with the municipal wastewater systems. One of the features of this sewerage system is that the communities themselves take direct responsibility for its operation and maintenance, and also bear their costs as the responsible bodies in the management of these facilities.

Rural Nature Conservation Plan

Emphasis is also given to the restoration as well as enhancement of the Lake Biwa rural environment, particularly with respect to ameliorating the affected ecological habitats. Specifically, a project dubbed as "the water beetle project" has been promoted since 2006. The project aims at improvement of stream water quality, landscape preservation, and conservation of agricultural resource values. The project is financially supported by the prefectural government, and is carried out by the rural communities, with the advice given by the panel of experts. Some 28 projects, such as one shown in *Fig. 24* of construction of fish ladder and in-stream water purification, have already been completed.

Regional Economic Development

Land Improvement

Deployment of the land improvement project, including farm land consolidation, is high for Shiga Prefecture, among the prefectures in the Kinki Basic Planning Region. The irrigation system in the Lake Biwa watershed has evolved over the past several decades with a number of land improvement projects. Today, the paddy water may be managed individually, thanks to the separation of irrigation and drainage, conversion of land to allow for irrigated dry-land paddy agriculture, and paddy land consolidation. They have also helped the farmers to self-support farm management. In spite of such improvements, however, the number of farmers in the watershed has declined, and most of the remaining farmers have transformed themselves to part-time farmers. These new systems and practices also have turned out to have damaged the natural ecosystem and biodiversity, which are subjects of major concern today for those involved in paddy agriculture to pursue.

Roads

For Lake Biwa to meet both its flood control and water supply needs through LBCDP, the lake water level has to be

accurately regulated on the basis of a set procedure, meaning the lake had to be levied in response to flow control at the Seta River Weir. The constructed levies had a flatted top to accommodate passage of vehicles for levy maintenance. The Shiga residents quickly saw the potential of this levy road to be transformed into a major transportation route around the lake, with link roads connecting to major coastal communities and to the existing transportation networks.

The implications of this levy-cum-ring road are many. For example, it has had significant benefits to the local and regional economy. It is used both as a local commuter road and as a means of transporting local commercial goods. It also had a significant impact on the association of the population with the lake. The lake shore, which was hardly accessible before its construction, became quite accessible, not only physically but also psychologically. The scenic view of the lake has changed. Those who previously only felt remotely connected to the lake began to feel much closer to it because the lake is visible from the ring-road. Before its construction, the lake water was hardly accessible from the shore for the casual lakeshore visitors because the passage toward lake was being prevented by the wetland paddy fields, as well as the thick and tall aquatic vegetation, mainly of reeds. It turned out to no longer be the case because much of the land between the levy and the lakeshore has been converted to recreational parks. People now have a close-range view of the lake, in addition to a distant view. On the other hand, the environmental and ecological integrity of the shoreline also has been drastically deteriorated by the construction of the levy-cum-road structure, as well as by the drastic increase in the extent of shoreline activities, making the subject one of the most serious concerns emerging from LBCDP.

Coastal Zone Management

For centuries, growing rice in the complex network of creeks connecting numerous paddy fields was a major form of agriculture along the shore of Lake Biwa. The farm land consolidation policy in the postwar agricultural reform, however, gradually transformed the wetland paddy agriculture to more dependable dry-land paddy agriculture. Though the paddy production became more efficient on dry lands, the farmers' mobility continued to be confined to the lakeshore land due to lack of accessibility. The construction of the levees as part of LBCDP, however, had a dramatic impact on both their life-style and their professional scope. The levees now prevent them from using the lakeshore as temporary agricultural land during the dry season, a customary agricultural practice for centuries prior to the construction of the levees. Further, with the levees serving as an important transportation means along the lake, the farmers no longer need to be confined to the lakeshore land. They can choose professions other than farming. Also, the extent of the shoreline farm lands was reduced through the newly introduced LBCDP policy for the government to purchase the farmland for public use. Finally, the relative importance of this previously primary industry was also decreasing, leading to migration of the population out of the shoreline communities.

Prior to LBCDP, the main stakeholders using the coastal environment were those living in proximity to the coasts, including wetland paddy farmers, fishermen, reed harvesters, tour boat operators, and others affiliated with related professions, whose livelihoods depended on the resource values provided by the lake. Thus, the management objectives and the means for achieving them were rather straightforward. Today, 40 years after inauguration of LBCDP, the stakeholders have grown in number and in kind, and their vested interests have also greatly diversified, making their modes of engagement much more flexible.

Changed Economic Profile of Downstream Region

Industrial Maturation and Change of Policy Concerns

After exceeding the national average in 1981 and reaching among the tops in ranking in the 1990s, the per capita income of Shiga Prefecture has continued to increase, today being in the top third or fourth place among the 47 local governments. Although the proportion occupied by the tertiary industry is higher than that occupied by the other industrial categories in other prefectures, in terms of the gross prefectural product, the proportion of the secondary industry is higher than that of the tertiary industry in the case of the Shiga Prefecture. As previously discussed, the relocated industries from the downstream region to Shiga Prefecture in the 1970s and 1980s have contributed to this trend.

Japan's industrial profile has changed significantly over the past decades because of several major factors. First, her economy transformed from a developing one with a high growth rate in the 1960s and 1970s, to a mature one with a low growth rate in the 1980s. Trade globalization since the second half of the 1980s has also had a major impact on its industrial profile, particularly since many of the manufacturing industries began to relocate their facilities overseas, while decreasing the number of newly established industries within Japan. This brought about what is called the deindustrialization problem, that is, firms began to reorganize the production networks, consolidating and reorganizing

their production facilities and related operations to fewer and fewer numbers. Shiga Prefecture was among those that began to experience this dilemma. When an industrial facility is closed, it can be readily noticeable, but if the functions of an establishment change, this change would not be so readily apparent. For example, an industrial establishment dedicated to manufacturing may transform itself to one dedicated to a research-and-development function. Although such a change would not be easily observable, the impact of this transformation could be profound, in that the overall industrial capacity may be significantly changed.

Further, such a change would impact the employment situation. In the 1960s and 1970s, the surplus labor in the entire region of Keihanshin was absorbed by the accumulation of industries within itself, contributing to its stable employment profile. However, this situation no longer holds today. This is typical of an economy in maturity, with a likely tendency toward a new unemployment problem. The industrial policy, therefore, has to facilitate the conversion of the existing labor force in a way that allows it to be able to cope with the emerging needs, or to stimulate the new business responsive to the emerging market needs under economy in maturity.

Expansion of Metropolitan Area

The economic geography of the Lake Biwa region is highly sensitive to the regional mobilization of goods and services that, in turn, depends on the availability of regional transportation networks. In the early 1960s, the transportation networks began to be expanded toward the eastern part of Lake Biwa, enabling the network to be connected to that of Keihanshin through the already-existing network in the southern part. The networks have grown to reach the Kosei (the western part of Lake Biwa) with the completion of Japan Railway (JR) Kosei Line in 1974, and Kohoku (the northern part of Lake Biwa) by the completion of the Hokuriku National Motor Expressway in 1980. Additionally, they were linked through the nodal points within the Lake Biwa region (such as Maibara in the north), with Japan's major transportation arteries developed in 1960s, connecting the Keihanshin region with such megalopolises in the east as Nagoya and Tokyo.

6.4.5 Environmental Conservation Problem and Lake Biwa Lawsuit

Being a massive infrastructure development project, it was feared from its onset that implementation of LBCDP would have serious implications for the lake's ecosystem integrity, inviting not only heated debates on its merits from the scientists and the mass media, but also strong opposition from various environmentalist groups. Among them was a citizen group formed of concerned scientists and citizens who filed a lawsuit against the central and local governments, particularly with respect to the damage caused to the lakeshore environments by the construction activities across the entire shoreline (levy construction), by the construction of a man-made island (on which an oversized wastewater treatment plant was to be constructed), and by dredging carried out in the South Lake and along the river mouth of the Seta River. The trial started in 1976 and was concluded in 1989, with the court decision refuting most of the plaintiffs' claims. Although this trial had only limited impact in the implementation of LBCDP, it did contribute greatly to the movement toward ecosystem restoration, which ironically subsequently became the main theme of the post-LBCDP policy.

6.5 Post-LBCDP Developments

6.5.1 Changes in Downstream Water Demands

As previously discussed in Section 6.3, the management of the Lake Biwa-Yodo River water has been greatly affected by the water demand profile in the downstream Osaka Bay region, particularly in relation to its industrial activities.

Implications of Changes in Industrial Profile Along Osaka Bay Region

Over the course of decades spanning two World Wars, many nuclei of small industries scattered throughout Osaka, Kobe, and their surrounding suburbs were consolidated to form a major industrial zone called the Hansin Industrial Belt stretching around the Osaka Bay area. By approximately the 1950s, this industrial zone gradually expanded in two major directions, that is, toward Himeji, the western part of Hyogo Prefecture (called the Higahi-Harima region), toward Sakai and the surrounding municipalities and northern Wakayama Prefecture (called the Senshu region), and also alongside the Yamato River toward Nara in the east and alongside the Yodo River toward Shiga Prefecture in the north (Lake Biwa region). The Bay region industrial complex, in particular, evolved to specialize in water-intensive, basic material type industries, while the inland region evolved to specialize in processing and assembly type

industries that were less water-intensive. The former industrial complexes began to face serious problems by the early 1970s. The first problem was industrial pollution created by the complexes. There were many cases of environmental pollution incidents, compounded by serious human health issues. The second problem was the land subsidence along the Osaka Bay coastline due to the over-extraction of groundwater during the postwar industrialization. The typhoon-induced high tides in 1961 inflicted serious damages to the coastal region, due in large part to land subsidence, accompanied with a loss of several hundred human lives. Further, there was a water shortage problem. The increasing demand for industrial water, accompanied by the need to curtail over-extraction of groundwater, motivated the politicians and governments in the region to seek a greater water release from Lake Biwa to the Yodo River. This eventually led to the inauguration of LBCDP.

Regional Development Policy and Redistribution of Industries

Japan's evolving regional development policy also had a significant impact on the management of the Biwa-Yodo Basin. The major emphasis in Japan's post–Second World War regional development policy was to reduce the excessive pressures put on major metropolitan areas. In the Kinki Basic Planning Region (encompassing Fukui, Mie, Shiga, Kyoto, Osaka, Hyogo, Nara, and Wakayama Prefectures) within the Osaka Prefecture, the number of factories in Osaka City was about 60% of the total number in the Planning Region in 1965, when the population of Osaka City surpassed 3 million at its peak. Osaka City also had 52% of the number of workers in the Planning Region, and 53% of the industrial shipments. It was much the same with regard to Kyoto, in relation to the Kyoto Prefecture. The law introduced in 1964, restricting the siting of large-scale factories, was aimed at restricting large-scale factories in parts of the Municipal boundaries of Osaka, Kyoto, and Kobe, as well as in the connecting Hanshin Belt Zone. However, it turned out that the only designated area available to accept those relocated factories was the Harima Industrial Park in the Himeji Prefecture, west of the Hyogo Prefecture.

The need for a legal basis for industrial relocation was addressed with the provision for development of the Kinki Basic Planning Region Improvement Plan, as stipulated in the Kinki Basic Planning Region Improvement Act of 1963, in which the Region was divided into the existing metropolitan zones, suburban improvement zones, urban improvement regions, and conservation zones. The relocating industries and workers were supposed to be settled in industrial parks located in the urban improvement zones to be established in areas approximately more than 50 km outside of the existing metropolitan regions (the eastern Lake Biwa zone, the central Tamba zone in Kyoto Prefecture, the Harima zone, the Wakayama zone). Although the aim of this new policy measure was the diffusion of industries out of the metropolitan centers, it was not necessarily uniformly accomplished. Since housing and industrial developments tended to seek the available land along the major transportation routes, such as JR Tokaido and other private railroad lines, as well as the Meishin National Expressway, the eastern Lake Biwa zone was a popular destination for relocation, in contrast to the other zones, resulting in an imbalance in industrial activities and population distribution among the urban improvement zones.

Changing Water Demands

Over the past decades since the inauguration of LBCDP in 1972, the water demand structure in the Biwa-Yodo Basin has undergone significant transformation as a result of changes in the industrial economy. First, over the period between the mid-1970s through mid-1980s, the declining economic growth brought about a change in the mode of industrial production. Specifically, the industries had to overcome the energy price hike triggered by the successive oil crises in 1973 and 1979. They had to adjust their processes to achieve higher production efficiency by curtailing energy and water uses. Further, the industrial structure has changed from one primarily focused on manufacturing basic industrial goods, to one more focused on the assembly of manufactured goods. This change has also led to lower water consumption per unit of production output. In addition, over the period between the mid-1980s through today, a large number of industries shifted their production base to overseas, to take advantage of lower labor and facility development costs. The strong value of the Yen after the Plaza Accord in 1985 also helped this trend, also contributing to a direct decline in industrial water demands in the region.

There are emerging efforts being made for structural transformation and revitalization of the Osaka Bay region economy today through large scale projects in information technology and service economy in response to economic globalization. However, these newly formed large-scale projects, or even the relocation of large-scale domestic production facilities, do not seem to be increasing the water demands.

6.5.2 Restoration of Ecosystem Integrity and Water Quality

Differences in Upstream and Downstream Perceptions of Water Quality

The upstream and downstream jurisdictional entities in the Biwa-Yodo Basin have experienced long-term conflicts arising from the management of water quantity. The conflicts have been somewhat mediated through the compensatory transactions from the downstream and central governments to the upstream Shiga Prefecture, through LBCDP. The conflicts have not existed for water quality in the sense that everyone wants improved lake water quality, although it is not clear how much improvement is needed, or who will bear the costs of the improvement. Parts of the expenditures on water quality improvement are defrayed through the natural and environmental conservation component of LBCDP. Although the original expectation was that the amount of investment under this category would be sufficient to realize significant improvement in lake water quality, the improvement was only marginal at the time LBCDP was completed in 1997. The Shiga Prefecture wanted the downstream governments to continue to contribute financial resources, even after LBCDP, for improving the lake water quality.

If the scope of water quality improvement is confined to water supply, asking the downstream water users for more funds would not be easily justified. The quality of the drinking water was already more than satisfactory, thanks to investments made in the 1990s for advanced treatment technologies, the cost for which were also borne by themselves. They were not experiencing any taste and odor problem, even during algae blooms. Thus, they would see no point in utilizing more funds to improve the overall quality of Lake Biwa water.

The issues pertaining to ambient lake water quality are different from those pertaining to drinking water quality. First, the ambient water quality target levels for lakes in Japan are expressed in terms of such quality parameters as Chemical Oxygen Demand (COD), Total Nitrogen (TN), and Total Phosphorus (TP), these parameters being used mainly to assess the state of eutrophication. This is in addition to their suitability as drinking water sources for human consumption. The Shiga Prefecture and its residents want to reduce, if not eliminate, the incidence of algal blooms associated with eutrophication, maintain the ecosystem health for aquatic fauna and flora, eliminate invasive species, and improve sediment quality. The concern of the Lake Biwa residents encompasses a broad spectrum of intangible benefits to be shared and enjoyed by people over many generations to come. How convincing such an argument would be depends not only on the willingness of the population to pay for such long-term objectives, with full understanding of the value of protecting the lake and its basin, but also on its capability to pay. The implication is that the emerging structure of the basin-wide water resource management would be dictated by the capability of the people and governments to adjust to emerging water quantity and quality factors, many of which were unknown at the time of inception of LBCDP.

Lake Biwa Comprehensive Conservation Plan (LBCCP)

Though it took much longer than originally projected (25 years, rather than 10 years), basically all the approved LBCDP component projects were properly completed by 1997, under each of the three major project categories, that is: (a) water resources development for Shiga and downstream water users; (b) flood control around Lake Biwa and along the Yodo River, and (c) environmental infrastructure development along the Lake Biwa shoreline and around the watershed. While the downstream governments acknowledged LBCDP accomplishments, their gained benefits were more of an expectancy nature, that is, more water during times of severe droughts (which may happen once in 10 years), and reduced loss of property and human lives from major flood incidents that may happen once in a few hundred years.

On the other hand, the benefits gained from LBCDP for the Shiga government and its residents were more direct and explicit. They saw ports and harbors renovated, levies and embankments constructed around the lake that also now serve as a major artery road around the lake, paddy lands extensively improved with large-scale pumping facilities for irrigation with lake water, and even basic urban infrastructure provided for industrial developments. The Shiga population has increased by nearly three quarters of a million over the period of LBCDP implementation, and its per capita income, which was previously ranked as one of the lowest among the 47 prefectures, increased to be among the top incomes, thanks largely to the transformation of the Shiga economy from being primarily agricultural in nature to being primarily industrial, due in part to migration of population and industries from the downstream Osaka region to the Lake Biwa watershed.

This dramatic change in the profile of Lake Biwa watershed, now very urbanized and industrialized, also meant the paddy-wetlands along the lakeshore, which

used to provide prolific fish habitats, have been lost. During the same period, quite extensive land conversions also have taken place, for example, from paddy land to housing and industrial estates, forest land to industrial estates, etc. Thus, despite the introduction of significant structural and nonstructural environmental control measures, the water quality and ecosystem integrity of the lake and its watershed began to deteriorate. While the point source pollution load has been significantly reduced as a result of the sewerage coverage implemented during this period, the restoration of the natural self-purification capacity lost through transformed land uses, remained as a major challenge at the time of LBCDP completion.

Consequently, toward the terminal years of LBCDP, the Shiga government decided to pursue a new post-LBCDP project focusing on ecosystem restoration. In March 1997, Shiga Prefecture compiled the results of the deliberations of a national council established for this purpose, and prepared a plan called the Lake Biwa Comprehensive Conservation Plan (LBCCP), dubbed "Mother Lake 21 (ML21)." The plan emphasizes that the ultimate solution to the problems facing Lake Biwa lies in restoration of the natural and ecosystem capacities of the coastal zone and watershed, while also pursuing the revival of an environmental culture to allow such retransformation to occur. While Shiga Prefecture wanted the national and downstream governments to be sympathetic to enactment of a special legislation for financial arrangements to help it achieve its long-term ecosystem conservation objective for Lake Biwa, the response from the national and downstream governments was not so accommodating. They courteously declined to facilitate financial arrangements to the Shiga Prefecture.

What then is the ML21 Plan? In fact, it is more a vision than an infrastructure development plan, as in the case of LBCDP. It is not accompanied by any legislated special financial provisions. Those projects that fall within the framework of this vision are financed basically under sectoral budgets, with some preferential subsidy based on their merit within already-existing sectoral plans and programs. Specific elements of the ML21 plan are as follows:

(a) *Targeted Geographic Coverage*
The target area was set to include the jurisdictional area of the Shiga Prefectural Government, although it also takes cognizance of the implications to the downstream Yodo River region;

(b) *Planning Horizons*
The specified period is 22 years, from April 1999 through March 2020, in two phases; the first is from 1999 to 2010, and the second from 2010 to 2020. The provisional long-term planning horizon has been set at 2050.

(c) *Measures of Achievement*
Plan categorized the measures of achievement in terms of improvement: in overall quality of Lake Biwa water, in water infiltration and retention capacities of watershed soils, and in natural environment and landscape ecology. It also stipulated the need for promotion of citizen engagement and networking at sub-basin levels across the watershed. Information dissemination and research promotion were also an important component.

(d) *Compatibility with Other Plans*
The comprehensive conservation plan is meant to be consistent with plans formulated by the central government, including the Comprehensive National Development Plan, the National Land Use Plan, and the Basic Facilities Plan for the Kinki Region, as well as plans formulated by the prefecture, including its long-term vision called New Lake Country Story 2010, and its Environmental Master Plan.

Appraisal of First 10 Years of LBCCP (1998–2010)

In March 2010, with the first phase of LBCCP having reached its terminal year, and the second phase about to be launched, the LBCCP scientific advisory committee issued a review report of the first phase, with recommendations for the second phase. The report's appraisal is that the Plan has generally played a significant role as a long-term vision for Lake Biwa, with the first phase attaining some significant achievements.

Specifically, in regard to improved quality of Lake Biwa water, the achievement during the first phase has been significant, particularly in regard to water transparency and the concentration of TP. In contrast, the rate of reduction in the TN concentration was not as impressive as that for TP. In fact, the altered balance between the phosphorus and nitrogen concentrations has led to a change in types and numbers of phytoplankton species, that is, a decreased variety of species but an increased number of smaller, and more nuisance, species thriving in lake water. Further, the dissolved oxygen concentration in deeper parts of the North Basin has been exhibiting a decreasing trend. The COD has actually gradually increased during the period, a puzzling phenomenon whose implications are not yet clearly understood scientifically. In terms of the inflowing pollution load, the point-source contribution has been significantly reduced, although the nonpoint contribution remained much the same as 10 years before.

In regard to improved water infiltration and retention capacities of the watershed soils, the results are not so

significant. Between the fiscal years 1997 and 2006, the areas for agricultural and forest lands, respectively, decreased by 0.5% and 5.5%, while the areas for housing land and for road, respectively, increased by 7% and 8%, the rates being comparable to, or exceeding, the nationwide averages. Such simple measures indicate the preservation of forest and farmland for rainwater infiltration has not been progressing in the desired direction. The appraisal document states that there must be serious consideration given to halting the ever-increasing trend of land conversion from ones exhibiting natural water infiltration and retention capacities to ones that do not. It is also pointed out that, for forest land to improve water infiltration and retention capacities, the forests themselves have to be well-maintained through thinning and clearing of nuisance vegetations. However, of the artificially forested land requiring such maintenance, only 65% of the land was maintained as of fiscal year 2008. Thus, the appraisal report proposes that the Plan needs a more strategic approach in strengthening the institutions for undertaking maintenance operations, even to the extent of exploring a policy for developing "the green corridor" all the way from the mountain ranges through flat land toward the Lake Biwa shorelines. Additionally, the appraisal report points out the need for the existing water use practices to be further refined to minimize wasteful use of irrigation waters, by devising appropriate instrumentation. It further points out the need to assess the viability of existing irrigation water recycling schemes, giving due considerations to their cost effectiveness for the purpose of the LBCCP. The emerging issues included the deteriorating forest lands due to spreading tree damages from insect pests and nuisance animals. The report points out, more profoundly, the need for the Japanese forest industry to gain competitive strength over inexpensive imported forest products so that an institutionalized system of forest maintenance would be established both for providing for economic viability and for healthy forest land.

The report also points out that the first period target was not very clear for the on-the-ground implementation of plans and programs, particularly with regard to "land acquisition for ecosystem restoration." Further, the activities stipulated under this category were limited in number and extent of spatial coverage, indicating the inadequacy of the pursuits under this category of activities, with most of the issues identified before the LBCCP still remaining problematic. Further, there are issues and problems that did not exist before the LBCCP that are posing major threats to the natural environment and landscape ecology of Lake Biwa, including such problems as the loss of habitat for indigenous species of fish, and the prolific growth of macrophytes in the South Basin of Lake Biwa, particularly in relation to the changed operational procedure of Seta River Weir, all indicating that the future of the LBCCP is directly linked to the Yodo River System improvement policy.

Amendment to the Lake Water Quality Law

The Lake Water Quality Law (the Law concerning Special Measures for Preservation of Lake Water Quality, 1984) was amended in 2005, noting that the stagnant achievement level of water quality targets that is only a little over 50% as in 2004 (see Chap. 7 for details in the case of Lake Biwa). The Amended Law provides for the establishment of special area for nonpoint pollution control, that is, requiring pollutant load control measures from nonpoint sources and formulates plans to implement measures within the designated urban areas and farmlands. The new policy tools under this amendment include new regulatory standards, specification of categories of aquatic plants to be protected, and notification of the permitted activities in the lakeside environment protection areas. Although these policy tools, such as development of an emergency action plan water environment improvement, are expected to serve well for the enhancement of ecosystem properties of Lake Biwa, many of the included measures, including the establishment of protection and preservation areas (e.g., the reed bed protection areas) are already part of the Lake Biwa ordinance.

6.5.3 The Changed Agenda

Amended River Law of 1997

The first River Law in Japan was enacted in 1896 after the occurrence of a series of large-scale floods in previous years. The first Law was subsequently revised in 1964 with the aim of delineating the responsibility of the Central Government and Local Governments in managing the different classes of rivers, and to set the basic design figures for flood control for each class. Over more than three decades, the 1964 Law played an instrumental role for post–Second World War Japan to meet various river management needs, including flood control and water resources development.

The 1964 River Law was amended in 1997, basically to cope with increasing public outcries against the lack of a consultative process involving potentially affected local stakeholders and environmental citizen groups that strongly accused the river improvement works of having caused serious ecological damages to the riverine

environments. The Amended River Law now includes some important provisions to address these points. For example, Article 1 stipulates the purpose to be "to contribute to land conservation and the development of the country, and thereby maintain public security and promote public welfare, by administering rivers comprehensively to prevent occurrence of damage due to floods, high tides, etc., utilize rivers properly, maintain the normal functions of the river water by maintaining and conserving the fluvial environment" (Ministry of Land, Infrastructure, Transport, and Tourism 1997). It also stipulates the need for each river administrator to establish a plan to improve the river concerned, that is, the "*River Improvement Plan*" (hereafter referred to as *the Improvement Plan*) in accordance with the "*Fundamental River Management Policy*," (hereafter referred to as *the Fundamental Policy*) specified for river.

To fulfill the stipulated purpose, the 1997 River Law provides for three feature considerations that did not exist in the Original 1964 Law:

(a) The concept of "river environment" as being equally important as flood control and water withdrawals for consumptive and nonconsumptive water uses
(b) The need for broader participation of stakeholder groups and sectors in the process of developing a river improvement plan
(c) The process of acceptance and approval of the river improvement plan through a societal and political process of consensus building

In regard to the concept of river environment, the Law aims to facilitate the necessary protection and maintenance works to protect animal and plant habitats, and also to preserve the scenic and other intangible values associated with a river system. The Law also stipulates the need for the river improvement plan to be consistent with the Comprehensive National Development Plan and the Basic Environment Plan of the regions.

To address the goal of broader stakeholder participation, the Law stipulates the responsibilities of river administrators to:

- Consider opinions from persons with relevant experience or an academic background when necessary
- Take necessary measures, such as public hearing, etc., to reflect the opinions of the people concerned whenever necessary
- Consider opinions from concerned prefectural governors and mayors in advance, as provided in Government Ordinances

Regarding the process of consensus building, it is to take place in several steps over a period of a few to several years, to ensure that the considerations identified in items (a) and (b) above would be properly integrated in the formalized process.

Development of Yodo River Improvement Plan

The Amended Law stipulates the process of formulating the Fundamental Policy and of developing the Improvement Plan, to be administered by the river administration division of the Kinki Regional Bureau (hereafter referred to as the Bureau) of MLIT in the case of the Yodo River. The process takes the following process:

(a) *Fundamental Policy*
- A draft Policy to be prepared by MLIT
- The draft to be reviewed by the Infrastructure Development Council established under MLIT
- The adoption and announcement of the Policy by MLIT

(b) *Improvement Plan*
- A draft to be prepared by the Bureau, appropriately reflecting the broad public sentiments and vested interests
- The draft to be revised as appropriate, resorting to, as needed, the expert opinions and the affected parties
- The draft to be provisionally finalized
- The draft to be accepted by the prefectural governors within the Yodo River basin
- Adoption and announcement of the finalized Plan by MLIT

In the case of the Yodo River system, the process included preparation of a few more intermediate outputs by the River Basin Committee, to be elaborated below. They area *Proposed Conceptual Framework* (hereafter referred to as the *Framework*), a *Provisional Basic Plan*, and *the Basic Plan*.

For the Yodo River system, the Fundamental Policy was issued in August, 2007. The Improvement Plan was declared as being completed, and was published in March, 2009 by the Bureau. It was after almost several years of intense and heated exchange between the Committee, the Bureau, citizens, NGOs, and various local governments.

The following is a brief account of the long, complicated and controversial sequence of events that took place between early 2001 to data.

Establishment of River Basin Committee

In February 2001, the Bureau took on the process of developing the Improvement Plan, and launched the process of forming the *Yodo River Basin Committee* (hereafter referred to as the *Committee*) as a body consisting of

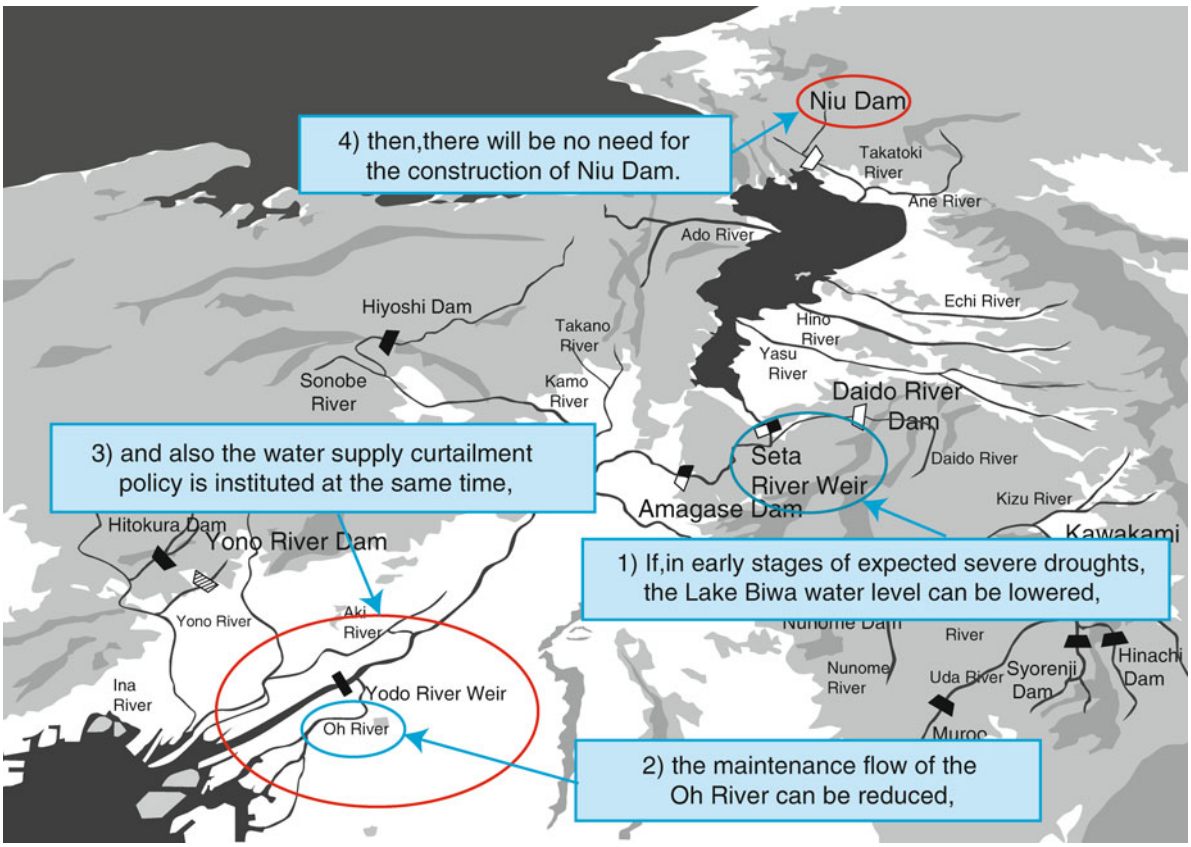


Fig. 25

Some Contentious Points argued by the Committee against the Need to Construct the *Niu* Dam (If, in early stages of expected severe droughts, the Lake Biwa water level can be lowered, the maintenance flow of the *Oh* River can be reduced, and also the water supply curtailment policy is instituted at the same time, then, there will be no need for the construction of *Niu* Dam).

"persons with experience or an academic background." The hope was that the Bureau would be able to benefit from close collaboration with the Committee in its pursuit of the development of what could be an extremely complicated and conflicted Improvement Plan needed to meet the expectations of the basin population over next 30 years or so. It would have to fulfill their overall needs, that is, flood control, water resources provision, and environmental and ecosystem services of the river system, for the subbasins represented by local governments, with different priorities and parochial vested interest fostered over centuries. Among many other issues to be elaborated in the Improvement Plan was an issue of whether or not to proceed with the construction of four dams (*Yono-River*, *Daido-River*, *Niu*, and *Kawakami* Dams) and the renovation of an existing dam (*Amagase* Dam) (see *Figs. 25* and *26*). Prior to the establishment of the Committee, these dams were in some preparatory phases of construction.

Proposed Conceptual Framework

At the outset, the Bureau decided that the Committee members to be selected totally independent of any involvement of the Bureau itself, so that the established Committee would not be regarded as being biased for or against a particular set of sector or stakeholder interests. The Bureau also agreed for the Committee to prepare a conceptual framework for development of the Plan. By January 2003, the Committee completed the Framework and submitted it to the Bureau. Under the part pertaining to river improvement, it stressed the following four factors:

- The precautionary principle, based on a holistic framework of analysis
- The need to enhance the cultural, traditional, historical values and features, while ensuring the river improvement needs are met by the entire basin and the society as a whole

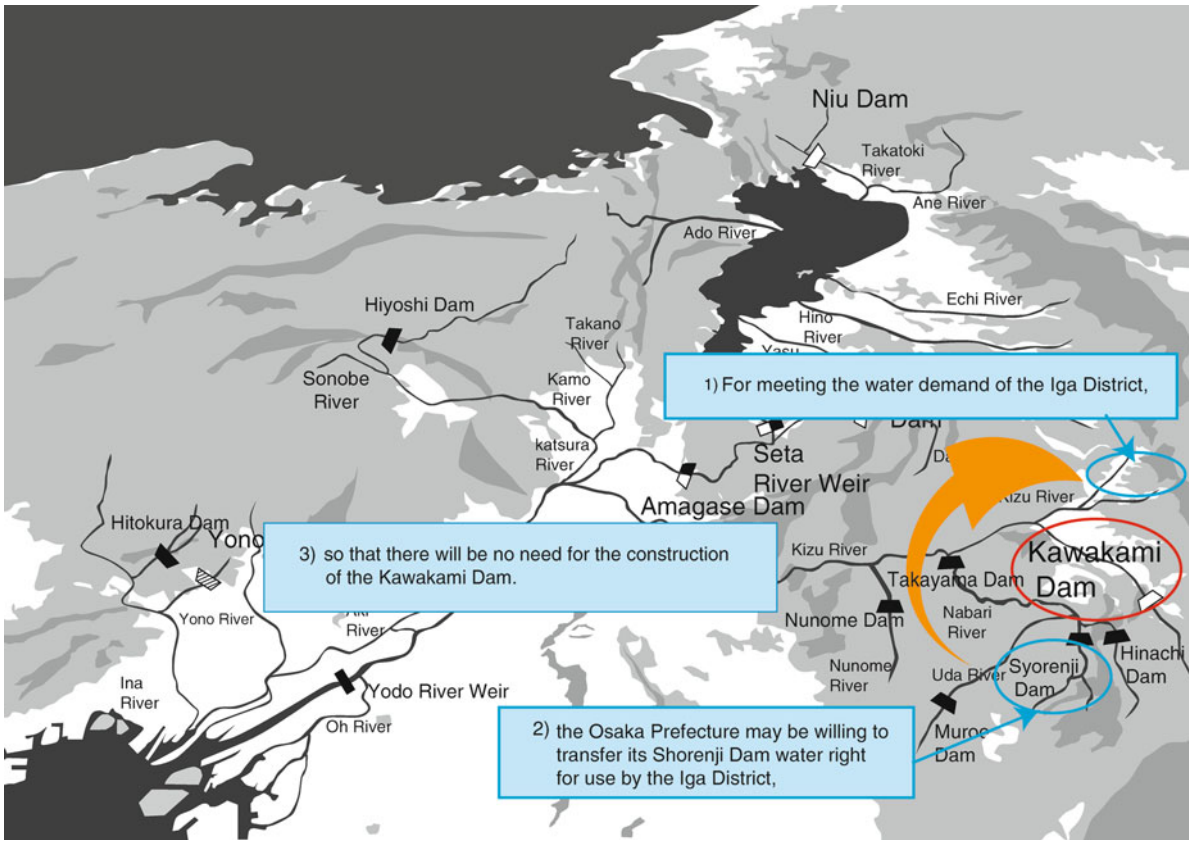


Fig. 26

Some Contentious Points argued by the Committee against the Need to Construct the *Kawakami* Dam (For meeting the water demand of the *Iga* District, the Osaka Prefecture may be willing to transfer its *Shorenji* Dam water right for use by the *Iga* District, the Osaka Prefecture may be willing to transfer its *Shorenji* Dam water right for use by the *Iga* District, so that there will be no need for the construction of the *Kawakami* Dam).

- The mechanism wherein the basin citizen at large would play an important role
- The need to implement planning assessment and pursue adaptive management

Further, under the part pertaining to the fundamental philosophy, the *Framework* recognizes the need to conserve and restore the river ecosystem, and states that "the ultimate goal of this Amended River Law is the preservation and recovery of a river ecosystem." It also states "the implementation of the Improvement Plan should not result in reduction of the existing species of flora and fauna, nor should it result in further deterioration of the ecological integrity that is so crucial for sustainable living of the people." Finally, it pledges that "it is the grave duty of the present generation to succeed the rich natural environment of the Yodo River system properly preserved and restored for the future generations."

Issues of Dam Construction

In regard to the construction of dams, including those already in the process of construction, the *Framework* states that, "The dams should not, in principle, be constructed in view of their possible serious impacts to the natural environment of the river basin system, and, if the construction of a dam is to be pursued, it should be only after all alternative possibilities have been exhaustively examined to prove that the attainment of the river management objective would be possible only with its construction, and the society at large would support that conclusion. As for the possibility of increasing precipitation due to climate change and the consequent societal consent with the need for dam construction, the decision will have to be made adaptively." The *Framework's* progressive assertion was regarded by the media as possibly influencing the mindset of the general public that have long wondered whether or not the use of their tax money

for large-scale public works such as dam construction would continue to be justified.

In the meantime, the major downstream water users, such as Osaka City, Osaka Prefecture, and Hanshin Water Supply Corporation quietly took advantage of the ideas imbedded in the Framework regarding the those dams that they agreed to with MLIT and the Water Resources Development Cooperation to share the construction costs. They in effect admitted that future demands for water that they had projected decades ago have proven wrong, and the storage capacity of the dams allocated for such purposes would no longer be needed. The very presence of the Committee seemed to have made it easy for them to make that move, about which they had long been in a bind.

Yodo River Improvement Basic Plan

Taking full note of the *Framework*, the Bureau formulated and made public the Basic Plan in June 2004. Development of the Basic Plan required an unprecedented collaboration between the Bureau and the Committee, conducting a total of hundreds of joint activities consisting of expert group meetings, workshops, on-site observation tours, and consultative meetings with local residents. The Basic Plan made clear that the conventional approaches concerning river improvement would have to be fundamentally revised, based on the recommendation stipulated in the *Framework*. The five main points stipulated in the Basic Plan were as follows:

1. Flood control, water resource development and management, and environment and ecosystem considerations would be placed within one unified framework. Major emphasis previously had been placed only on the first two considerations, seriously neglecting environment and ecosystem considerations.
2. Utmost priority would be given to protecting human lives, meaning that the conventional approach to flood control, that is, containing the projected floodwaters in dams and their excess within the river embankments, would have to be reconsidered. The Plan should now include a range of structural and nonstructural approaches, including minimization of flood damages and saving of human lives by temporarily vacating people in the potentially high-risk residential areas, with a range of risk avoidance measures supported by proper forecasting and information sharing. The policy shift to be achieved in the Plan therefore is from "flood control" to "flood management."
3. Construction of new water control facilities would be minimized by directing the policy toward more rational use of the existing facilities, greater water demand management, and more rigorous implementation of nonstructural measures.
4. The perimeter land between the water channel and the embankment, often used for gardening, sporting grounds, golf courses, and other uses without permits, will have to be cleared to allow for greater leverages for flood control and restoration of ecosystem integrity.

Construction of dams should be avoided if at all possible, giving full consideration to their potentially adverse effects on river environment during their construction, and taking the severe hardships to people living in the areas designated to be submerged fully into account. If they are to be constructed, a thorough and convincing explanation should be given to, and be accepted by, the basin community at large, regarding its necessity, urgency, and environmental impacts.

Over the next four years, however, a number of complicated turn of events took place, involving various societal sectors with conflicting views on this particular decision by the Bureau. Those communities and residents who had already been relocated from the proposed dam sites, for example, felt they were betrayed by the Bureau, and vocally expressed their anger against the Basic Plan. They had barely overcome the psychological hardship of submitting their precious land for the benefit of the public at large. There also was the issue of compensatory payments already being made by the Bureau to those having to give up their properties and homeland job opportunities. If the dam construction would not proceed, these compensatory considerations would also be subjected to criticism, leaving them with a lost sense of identity. As another example, the municipal governments that had been counting on the dam to cope with flood and drought risks upon its completion would now have to seek alternative means of coping with such risks. Further, those entities already having made installment payments for expected benefits of dam construction want to have the payments returned. The other side of the coin, of course, was the issue of penalty payments to the Bureau from those expressing a desire to now withdraw from the originally agreed plan of decades ago of having the dams constructed with a cost sharing scheme.

Outline of *the Yodo River Improvement Plan*

The finalized Yodo River Improvement Plan consists of six goals of river management and the measures to accomplish them. Six goals are as bellows;

(a) *Interaction between people and nature*

The purpose is to establish relationships between people and river in such a way that people would be interested in, be willing to interact with, and be thinking

together about the river. So that, people will be able to take adequate actions at a time of floods, and the downstream riparian and the upstream riparian will be able to increase the understandings each other.

(b) *River environment*
The purpose is, based on an idea that "the sustainable ecosystem is essential for human life and activity," to preserve and restore the habitats for various species, including endangered species and other endemic species, with observing the effects on river ecosystems.

(c) *Flood management and disaster prevention*
The purpose is to promote both structural and non-structural measures to minimize the damages caused by any kind of flood as much as possible. At that time, the measures should be taken in cooperation with the riparian in the whole basin, based on the policy to improve security from flooding in the entire river system, rather than sacrificing one area of a region to protect another.

(d) *Water resources*
The purpose is to promote the efficient water utilization, taking the recent population decline and harmonies with river environment into account, and to prepare for the possible serious drought due to the global climate change.

(e) *Utilization*
The purpose is to ensure the integrated river management and improvement with community development, because Yodo river flows mainly through the urban region

(f) *Maintenance*
The purpose is, taking the aging facilities and the life cycle cost into account, to execute the efficient and effective maintenance and renewal of the decrepit existing facilities systematically.

For the reasons stated above, the part of the Improvement Plan pertaining to construction of dams is expected to remain in a state of flux for some time into the future. What will happen in the future is not clear. The flow of events from the revision of the River Law, however, and the twists and turns taken place along the way between by the Committee, the Bureau and the Prefectural Governors are all indicative of the simmering transformation in the shape of the governance of the Biwa-Yodo Basin. This extraordinary sequence of events may be fore-telling the future of the public sector decision-making in Japan.

6.6 The Challenges Ahead

The management story of the Lake Biwa-Yodo River Basin can be told in many different ways. It is told here as an intricate, but dynamic, history of management challenges involving the upstream Lake Biwa region and the downstream Yodo River region, with factual illustrations of associated policies, programs, and specific actions for water resources development, flood control, and environmental and ecosystem concerns. These factual illustrations are also interpreted by the contributing authors, with views reflecting their professional backgrounds, as well as their interests and beliefs regarding the contested and conflicting issues.

The geotopographical, climatological, hydrological settings of the Biwa-Yodo Basin have fostered the peculiar geography of the region, with its resulting unique demographic, socioeconomic, and political interactions. Historically, the pressures put on to Lake Biwa and its watershed from the downstream water users has been enormous because of the latter's political, economic, and industrial power. The restrictions on the discharge of Lake Biwa flood water, both geophysically and geopolitically, had been causing an insurmountable stress on the relationship between the upstream and the downstream communities, until a series of physical interventions was introduced in the first half of the twentieth century, including construction of a flood control weir at the outlet of Lake Biwa. With additional interventions to expand the role of the weir to accommodate water resources development through LBCDP, the strained relationship between the upstream and downstream entities seemed to have been ameliorated, at least superficially. The Biwa-Yodo system is today providing water, flood, and drought mitigations, as well as environmental and livelihood amenities to the population of over 18 million living in Shiga and the Keihanshin area, totaling some 1,200 km^2.

The Biwa-Yodo Basin is also characterized by the historic timing of key policy interventions. Whether they were construction of monumental water control facilities, development and implementation of instrumental plans and programs, and/or emergence of controversies and conflicts, their timings seem to have helped shape lake basin governance since they relate to the region's social and economic profile. As previously discussed, for example, completion of the Lake Biwa Canal in late nineteenth century led to a miraculous recovery of Kyoto City from its doomed economy related to limited access to water sources. The installation of Nango Weir in early twentieth century also resulted in a dramatic reduction in the Lake Biwa water level and in the flooding frequency, allowing Shiga Prefecture to pursue greater economic opportunities in succeeding decades. LBCDP, a massive, national-scale public investment project at the helm of Japanese economic growth, has also brought caused a dramatic change in the management profile of water resources and flood control, accompanied by the emergence of new economic geography within the Biwa-Yodo Basin, and in the entire Keihanshin Region. Thereafter, people and

industries began to migrate from the densely packed downstream region to the more spacious upstream region around Lake Biwa.

The fundamental dynamics of contrasting water management needs, however, remain much the same between the upstream Lake Biwa region and the downstream Yodo River region. The former historically being as a resource provider, while the latter serving historically as a resource consumer. The underlying intricacy of this fundamental linkage dynamics resurfaced as a dictating factor in the evolving process of policy development for the post-LBCDP water and environmental management, in relation to implementation of the Lake Biwa Comprehensive Conservation Plan (LBCCP), and specifically its second phase over the time span of 2011 through 2020, as well as the recently completed, and controversial, Yodo River Improvement Plan (YRIP). LBCCP is a plan being developed and implemented by Shiga Prefecture and therefore touches little on the issues facing the entire Biwa-Yodo Basin, while YRIP is a plan being developed as a river management plan, rather than a river basin management plan, to be implemented as a trans-prefectural plan, legally to be dictated by the national government.

The overriding issue in the former is whether or not it will be possible for LBCCP to play a catalytic role in accelerating the lake's ecosystem integrity when the national government and the downstream governments and people consider that they have already fulfilled what they were obliged to do for the lake over the past decades. On the other hand, the overriding issue for the latter is if, and how, the Shiga Prefecture together with the downstream governments may be able to develop a regional institutional framework for resolving the contentious issues imbedded in the YRIP. Among the emerging frameworks is a regionally autonomous governance structure for the Biwa-Yodo Basin, with the national government probably playing much less prominent role in having "the last say" as having historically been the case since late nineteenth century.

Topic 21 Lake Biwa Canals

Masayoshi Maehata

There are two adjacent old canals at the south end of Lake Biwa. These are the first and second route of Lake Biwa Canal, which were built approximately 100 years ago in the Meiji period to supply water to Kyoto (*Topic 27*). As it is called "the water of life for Kyoto citizens," the water flowing here at a rate of 20 m^3 every second has been a precious source of drinking water for those living in Kyoto. While the planning and supervision of significant civil engineering works were all entrusted to foreign engineers during this period, this project was entirely accomplished by Japanese engineers, which was a memorable achievement at that time. It was a large-scaled governmental project comparable to the recent Lake Biwa Comprehensive Development Project, which was carried out from 1972 until 1996 at a cost of 1,500 billion yen (Oda 1987). A construction plan for a canal connecting Lake Biwa to Kyoto seems to have existed as early as 1800 during the Edo period, for which a pictorial diagram remains as the evidence (Tanabe 1920). The main reason for the planning of Lake Biwa Canal in the Meiji period was to restore the declining industries in the city. Kyoto had flourished for over 1,000 years from the time the capital of Japan was established there by Emperor Kanmu. However, the capital was moved to Tokyo in 1869 during the Meiji Restoration. Thereafter, Kyoto suffered a rapid decrease in population and industrial activities. Prior to the construction of the canals, water shortages in the city often affected the irrigation of agricultural fields and the operation of water mills. It also caused serious difficulty for the people to obtain water for drinking and fire-fighting in winter when wells were dried up (Tanabe 1920).

During the construction of the First Canal, a waterpower station (Keage Water Power Plant) was built at the same time, which was a technology invented in the United States. This was the earliest commercial waterpower plant in Japan, which began operating in 1891, being a major achievement in the industrial history of Japan. The Second Canal was built with the intent to address the increasing demand for electricity, and also to settle problems of both the quality and quantity of drinking water for Kyoto citizens. The outline for these two canals is provided below. The objectives of the First Canal include: to supply water for drinking, operation of water mills, generation of electric power, fire-fighting, irrigation, and transportation of goods by boats, Rate of water flow: 8.35 m^3/s, Length: about 11.0 km, Number of tunnels: 6 (the longest one is 2,436 m), Year of completion: 1890. The objectives of the Second Canal include: To supply water for drinking and generation of electric power, Rate of water flow: 15.3 m^3/s, Length: about 7.4 km, Number of tunnels: 1 (the entire line is composed of a tunnel), Year of completion: 1912

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Fig. 27
Lake Biwa Canals.

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7 Environmental Conservation of Lake Biwa

Masayoshi Maehata

After World War II, while Japan's success in achieving high economic growth brought a better life to people, water pollution in Lake Biwa became evident after a massive outbreak of freshwater red tide in 1977 and subsequent outbreak of blue-green algae in 1983.

In Shiga Prefecture, from then onward, local residents have undertaken various efforts in cooperation with the local administration (Shiga Prefectural Government) to prevent the lake from succumbing to water pollution. As a result, water pollution is now fairly under control. On the other hand, a variety of ongoing man-made modifications to attached lakes, the lake shore, and surrounding farmland, as well as an increase in the great cormorant *Phalacrocorax carbo*, have resulted in a serious degradation of the natural environment in and around the lake as well as the local biota. This includes a significant decrease in the abundance of native species in Lake Biwa, including endemic ones.

This chapter introduces various environmental preservation efforts taken by local residents and the prefecture, including issues that have risen recently at Lake Biwa, such as the effects of the increase in alien species, and the role of water level control on fish spawning. At the same time, the prognosis for the natural environment of Lake Biwa in the future is addressed from various points of view.

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7.1 Eutrophication, Citizens Movements, and Administrative Countermeasures

Masayoshi Maehata

In the Lake Biwa area, after the outbreak of a freshwater red tide in 1977, the very first citizens' movement to prevent eutrophication (a movement by local residents to promote soap use instead of phosphate detergents, for the conservation of Lake Biwa) arose in 1978. In the following year of 1979, Shiga Prefecture enacted the Ordinance on Prevention of Eutrophication of Lake Biwa, which took effect in 1980. The Water Quality Conservation Plan for Lake Biwa formulated in 1986 by the Shiga Prefectural Government has been renewed four times up to the present day. On the base of this plan, the government has been making constant efforts toward water purification in cooperation with local residents.

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7.1.1 Water Conservation Policy of Shiga Prefectural Government

Toshiaki Kagatsume

Abstract In 1972, the Japanese government applied the highest class of environmental water quality standards "AA" to Lake Biwa. In the same year, Shiga Prefecture fully revised the Pollution Control Ordinance, aiming to strengthen the effluent regulation. To prevent the progression of eutrophication, which became advanced in Lake Biwa since the 1950s, Shiga Prefecture enacted the Ordinance for Prevention of Eutrophication of Lake Biwa, with enthusiastic cooperation of the residents in 1979. Through the enforcement of the ordinance, the prefecture promoted the construction of sewerage facilities, nitrate and phosphorus effluent regulation of factories and commercial facilities, and banned the use of household detergent containing phosphorus. Consequently, the loads of nitrogen and phosphorus have been significantly reduced, and the concentrations of phosphorus and chlorophyll-*a* in the water of Lake Biwa have declined up to the present. Shiga Prefecture has been successful in curbing the rapid progress of eutrophication of the lake.

Keywords Pollution • Water environmental quality standards • Effluent regulation • Eutrophication • Freshwater red tide • Sewage system • Tertiary treatment

Introduction

Environmental pollution issues have been associated with the development of modern industry in Japan. In the Meiji Period (1868–1912), there is the first record of river pollution caused by mining wastewater. Postwar economic development through industrialization caused significant damage to the environment, such as air pollution and water contamination. To deal with these problems, municipal governments of large cities, including Tokyo, have enacted pollution prevention ordinances. In 1958, the Japanese government also established the "Water Conservation Act" and "Industrial Wastewater Control Act" in the wake of a riot incident caused by the trouble of wastewater from a paper-making company in Tokyo.

However, even after this, the pollution issues were becoming more serious year by year. In order to address these issues, radical improvement of the legal system was needed. In 1970, the so-called Environmental Pollution Diet was convened to revise the Basic Law for Environmental Pollution Control, and the Water Pollution Control Law was enacted with many other related laws.

History of Water Quality Conservation Policies of the Japanese Government and Shiga Prefecture

Under the Japanese legal structure for water pollution prevention, the Basic Environmental Law establishes two kinds of environmental water quality standards as policy objectives for public water areas. One is for human health and is uniformly set nationwide. The other is for the living environment. The standard has classifications that can be applied according to the types of water areas such as rivers, lakes and reservoirs, and seas and coastal areas. In April 1973, "AA", the highest class of the standard for lakes, was applied to Lake Biwa by the announcement of the Environmental Agency.

Based on the Water Pollution Control Law, prefectural governments can set "more stringent effluent standards" than those established by the Japanese government, if necessary.

Since late 1950, due to the increase of pollution loads caused by urbanization and industrialization, various pollution problems also occurred in Shiga Prefecture. To deal with this, in 1969, the Pollution Prevention Control Ordinance was enacted in Shiga Prefecture. The ordinance required factories and other commercial facilities that

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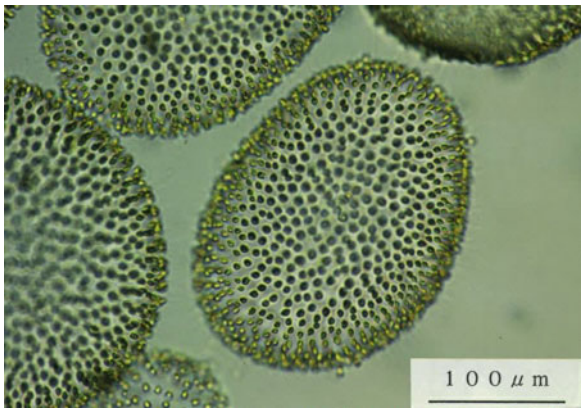

Fig. 1
Colonies of *Uroglena americana* (photograph taken by the Lake Biwa Environmental Research Institute).

discharge wastewater into public waters or generates noise to report to the prefectural government and to comply with the effluent standards and noise control values.

In 1972, the ordinance was fully revised, and more stringent effluent standards were established. Thus, the basic institutional framework was developed for effluent regulations targeting factories and other commercial facilities in Shiga Prefecture. The characteristics of the Shiga Prefecture Pollution Control Ordinance are as follows: stringent emission standards for heavy metals and other hazardous substances, a permit system for the establishment of factories using hazardous substances, and effluent standards that apply to the effluents of factories or commercial facilities that discharge 30 m^3 (10 m^3 now) or more of effluent per day on average.

In 1959, the green algae *Closterium* sp. bloomed, causing the water filtration facilities of Kyoto City to fail. In the period between 1965 and 1967, whenever the outbreaks of phytoplankton such as *Anabena* sp. and *Closterium* sp. occurred, failure of water filtration facilities was seen.

In 1969 and 1970, serious problems of odor and taste in water supplies occurred in Kyoto, Otsu, and Osaka City due to the compounds diosmin and 2-methil-*iso*-boruneor produced by actinobacteria. In 1975, in the Shiga Water Council the governor of Shiga Prefecture addressed the regulation of nitrogen and phosphorus in factory effluents. The Council set up a council committee and a subcommittee, and deliberation began.

On May 27, 1977, a freshwater red tide suddenly appeared in the waters of Lake Biwa. As the result of an investigation, the cause of the red tide was found to be the flagellated alga "*Uroglena americana*" (*Fig. 1*). The red tide was accompanied by a fishy odor, and brought about a significant deterioration of water quality. The mortality of ayu (*Plecoglossus altivelis*) was reported in a fish farm that used the lake water. This outbreak of a freshwater red tide clearly showed the residents that there was a water quality and ecological catastrophe in Lake Biwa, which fostered a sense of crisis, and also was a big opportunity for Shiga Prefectural Government to promote lake water quality conservation policy (Editorial Board the Ordinance for Prevention of Eutrophication of Lake Biwa 1983).

Countermeasures to Eutrophication of Lake Biwa

In March 1979, the Shiga Council submitted an interim report, which detailed the following comprehensive basic policy for nitrogen and phosphorus loads reduction measures:

1. To promote the development of facilities for treatment of sewage, night-soil, and factories' wastewater, the establishment of effluent standards is required.
2. The use and sale of household detergents containing phosphorus should be banned.
3. It is necessary to establish guidelines to reduce the amount of nitrogen and phosphorus loads from agricultural effluent and household wastewater.

The final report was submitted in September 1979. At that time, phosphate was used as a builder in household detergents. The restriction on the use of household detergents was required to reduce the phosphorus loads to the lake. However, regulating the use of household products was beyond the framework of the relevant legal concept of water pollution control.

With the aim of conserving the water of Lake Biwa, residents initiated a voluntary campaign to promote the use of soap powder in place of phosphorus household detergents around the year 1973. In 1978, the Citizen Forum for Conservation of the Aquatic Environment around Lake Biwa was formed, which consisted of 122 groups related to consumers, businesses, and municipalities. Together, the efforts of the Provincial Administration and the movement of these citizens led to the enactment of the Ordinance for Prevention of Eutrophication of Lake Biwa (Shiga Prefectural Government 1984).

The main aims of this ordinance were to ban the use of synthetic household detergents containing phosphorus, and to regulate phosphorus and nitrogen loads in wastewater from factories and business establishments. The news of the approval of this ordinance in the Shiga Council was conveyed with a shock to the entire nation.

In 1982, the Lake Biwa Research Institute was established as a facility for systematic and long-term perspective research for the environment of Lake Biwa and its catchment area.

In order to promote environmental education for all the fifth grade students in Shiga Prefecture, the prefectural school boat "Umi-no-ko [Children of Lake Biwa]" was built.

Since enacting the Ordinance for Prevention of Eutrophication of Lake Biwa, Shiga Prefectural Government has continued to focus on environmental protection administration.

The ordinance had an impact on the national environmental administration of water quality conservation and legislation on the Law Concerning Special Measures for Conservation of Lake Water Quality (1984).

Despite an increasing population of the prefecture, the amount of nitrogen and phosphorus loads flowing into Lake Biwa has been greatly reduced due to the development of sewerage and effective wastewater regulation of factories and other commercial facilities by the Ordinance for Prevention of Eutrophication of Lake Biwa.

Development of Sewerage and Measures for Nonpoint Source Loads

As for the history of sewerage in Shiga Prefecture, the construction of Otsu City Public Sewerage started in 1962, which was placed into service in 1969. The prevalence of sewage facilities in Shiga Prefecture had remained at low levels compared with nationwide rates. In 1971, Shiga Prefecture formulated the Basic Plan for Sewerage around Lake Biwa, which planned four treatment areas. After that, as the sewerage project was also incorporated into the Lake Biwa Comprehensive Development Plan, it proceeded rapidly. In 2009, the percentage of the population served by sewerage systems had risen to 84.7%.

To meet the standards of the Ordinance for Prevention of Eutrophication of Lake Biwa, sewage treatment plants in Shiga Prefecture introduced tertiary treatment processes for removing nitrogen and phosphorus in addition to organic matter (Sewerage Division, Department of Lake Biwa and Environment, Shiga Prefectural Government 2009).

Pollution loads flowing into Lake Biwa can be classified into two types, loads from point sources, such as homes and factories, and loads from nonpoint sources, such as forests, wilderness areas, other natural and agricultural land, and widespread urban areas. The former has been declining because of the improvement of sewerage and industrial effluent measures, while the relative proportion of the latter has been increasing, and so its countermeasures are becoming important.

The Shiga Prefectural Government has been taking the following measures to tackle nonpoint sources. To deal with the loads from urban areas and roads, rainwater is collected and muddy sand is separated by sedimentation, and purified through slime contact oxidation or by the biofilter method. Moreover, the stock ability of the sewerage pipe is used to collect pollutant rich water as wastewater, which is transferred to a sanitary sewer portion. To deal with agricultural drainage, a certification system has been introduced to promote "environmentally friendly agricultural products," which are grown using less than 50% of the amounts of chemical fertilizers and pesticides typically used by conventional farming. During the periods of puddling and rice transplanting, the prefectural government has also been working to raise awareness of farmers to prevent turbid water runoff from paddy fields. In addition, repeated use of agricultural drainage water and the building of cyclic irrigation facilities have been promoted.

For river purification, the Shiga Prefectural Government has been experimentally dredging bottom mud in Lake Biwa's attached lakes ("nai-ko"), and also building temporary storage facilities in the rivers flowing into Lake Biwa.

Status of Long-Term Changes in Water Quality in Lake Biwa

The longest running, regular water quality survey of Lake Biwa has been conducted by Shiga Prefectural Fisheries Experiment Station since 1915.

The changes in water transparency are shown in *Fig. 2*. The water transparency of Lake Biwa was approximately 10 m 90 years ago, which decreased to about 5–6 m in around 1970 due to the progress of eutrophication. However, the water transparency has increased gradually in recent years, and this trend is significant in the south basin, where the bottom of the lake is covered with thick growths of submerged plants (see Sect. 3.1.4.2).

Commissioned by the current Ministry of Land, Infrastructure, Transport, and Tourism, Shiga Prefecture launched the water quality survey of Lake Biwa in 1966. It has been conducting the survey in cooperation with the Kinki Regional Development Bureau, at 49 stations in total (north basin, 28; south basin, 19; Seta River, 2) once a month since 1979. The annual averages of the total chemical oxygen demand concentration (COD (Mn): method of

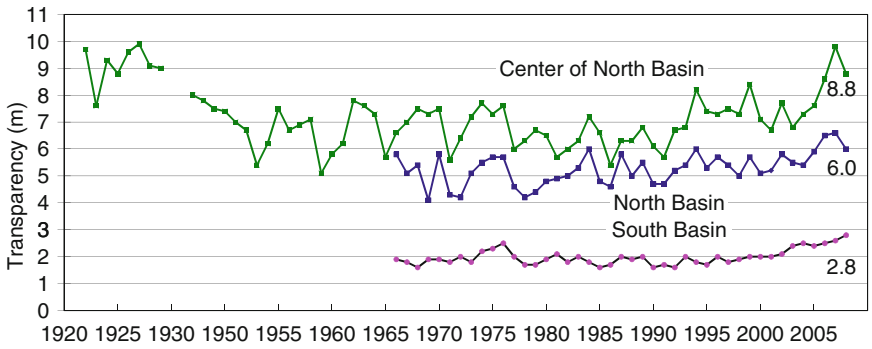

Fig. 2
Changes of the water transparency of Lake Biwa (Shiga Prefectural Government 2009).

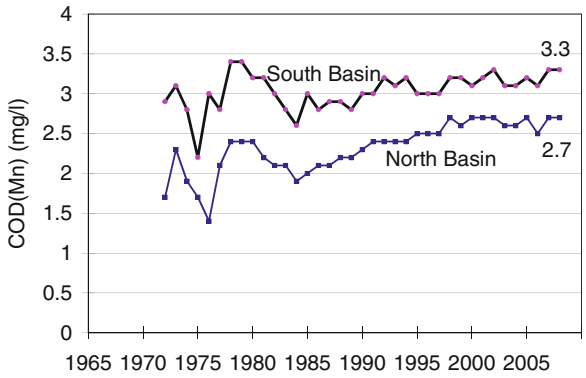

Fig. 3
Changes of the total Chemical Oxygen Demand (COD) of the water of Lake Biwa (Shiga Prefectural Government 2009).

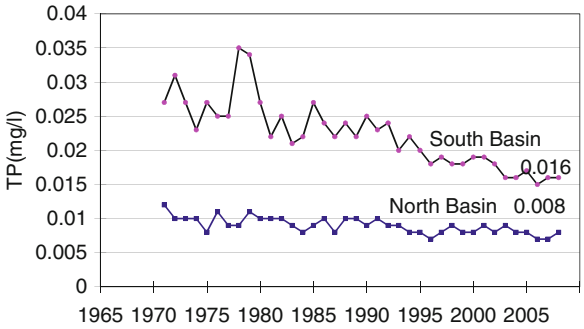

Fig. 4
Changes of the total phosphorus (TP) of the water of Lake Biwa (Shiga Prefectural Government 2009).

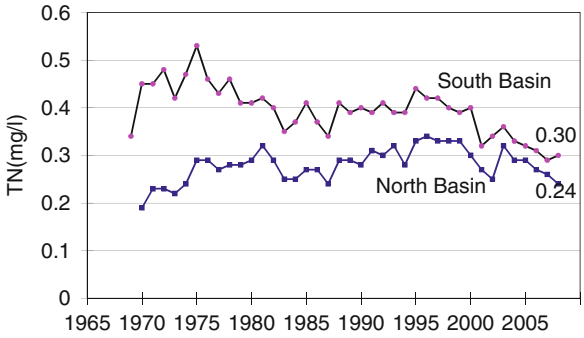

Fig. 5
Changes of the total nitrogen (TN) of the water of Lake Biwa (Shiga Prefectural Government 2009).

the alkaline COD determination with potassium permanganate), which once decreased after peaking in the late 1970s, has been increasing gradually since around 2000 (*Fig. 3*). The total phosphorus (TP) concentration of nutrients was highest in the late 1970s, and has dropped sharply since then. Currently, the TP concentration in the north basin is 0.01 mg/l or less than that (*Fig. 4*). Until the late 1990s, the total nitrogen (TN) concentration was on the increase. In recent years, its concentration has been declining (*Fig. 5*).

Conclusions

In Shiga Prefecture, since the late 1950s, the eutrophication of Lake Biwa progressed rapidly due to industrialization and urbanization, and increasing pollution loads. By around 1970, water quality deterioration was clearly evident. However, the Ordinance for Prevention of Eutrophication of Lake Biwa enacted in 1979, which included a ban on the use of household detergents containing phosphorus, had a revolutionary content, and was implemented successfully with the understanding and cooperation of residents and businesses. The progress in the tertiary treatment of sewage, and the implementation of industrial effluent regulations had outstanding effects. Therefore, the amounts of pollution loads of Lake Biwa were reduced. As a result, the progress of eutrophication has been suppressed, and the lake's water quality has now substantially recovered. In Shiga Prefecture, since the enactment of the Ordinance for Prevention of Eutrophication of Lake Biwa, the trend for management and administrative work of the environmental protection has been continuing for over 30 years.

7.1.2 The Soap Movement

Atsushi Makino

Abstract The "Soap Movement" was a major environmental movement for the conservation of Lake Biwa. The "Soap Movement" started out as a small activity by women to protect their health, but grew into a huge environmental movement gathering national attention, after the first red tide bloom in Lake Biwa. By experiencing a critical water pollution problem, people became aware that the everyday activities could directly affect the environmental condition of the lake, and that everybody could be responsible for an environmental issue and suffer from it at the same time. The "Soap Movement" not only involved many of the residents of Shiga Prefecture, but also the local government, leading to enactment of ordinances to protect the lake. It is still remembered by people as the starting point for the conservation efforts of Lake Biwa.

Keywords Women • Powdered soap • Eutrophication • Lake Biwa Ordinance

The Soap Movement and Lake Biwa Ordinance

July 1 is called "Lake Biwa Day" in Shiga Prefecture. On this day, a cleanup of the lakeshore is carried out by residents, local government employees, residents' neighborhood associations, nonprofit organization members, and fishery association members. Lake Biwa Day was established in 1981, on the first anniversary of the introduction of the Lake Biwa Ordinance concerning the prohibition of the use of phosphorus-containing synthetic detergents and penalties for its violation (Shiga Prefectural Government 2009b). It was an epoch-making event back then. This ordinance, aimed at protecting Lake Biwa from eutrophication, was enacted earlier than the Act on Special Measures concerning the Conservation of Lake Water Quality (1984). Such ordinances were developed as a result of a local environmental movement in the Lake Biwa Basin, the so-called Soap Movement.

The purpose of the "Soap Movement" was to promote the use of powdered soap for washing clothes instead of phosphorus-containing synthetic detergents. In the early 1970s, some women who developed skin disorders, the "housewives' eczema," started to organize activities to promote the use of powdered soap. In the beginning, this attempt was carried out by a small group of volunteers, but gradually grew into a huge environmental movement involving a lot of local residents of the Lake Biwa area (Wakita 1995). *Figure 1* is a scene of the women's activity called "washing workshop," in which women demonstrated washing clothes with powdered soap instead of using harmful synthetic detergents. Thus, the promotion of soap use was done through direct appeals, and this probably contributed to the huge success of the movement in the Lake Biwa area.

Water Pollution Caused by People's Lifestyles

In the exhibition rooms of the Lake Biwa Museum there is reconstruction of a farmer's house from the 1960s, showing the lifestyle of a typical farming family back then (*Fig. 2*). During that time, there were two ways for the family members to wash clothes, either by hand or by washing machine. The water from the washing machine was drained into a nearby waterway, which eventually flowed into Lake Biwa. Around that time, the sanitation coverage in the Lake Biwa area was near-total absence. In spite of such circumstances, washing machines gained popularity in the 1960s. As the washing machine became widely used, the consumption of synthetic detergents increased rapidly. However, such detergents contained phosphorus and nitrogen, which contributed to eutrophication of lakes and rivers. People were becoming the perpetrators of water pollution without knowing, but eventually had to witness the consequences.

In 1977, a huge red tide bloom was discovered in Lake Biwa (see Sect. 7.1.1). Researchers pointed out that

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Fig. 1
The "washing workshop" (Photo courtesy of Shiga Prefectural Government Environmental Policy Division).

Fig. 2
Hand-washing with soap, and a washing machine (From Exhibition Room in Lake Biwa Museum).

wastewater, especially high in phosphorus and nitrogen, was a major cause of such phenomena. Confronted with a critical water pollution situation, the women's activities to promote soap use grew into an environmental movement for the prevention of eutrophication of the lake. It was a shocking fact for the residents and the local government that everybody was both the perpetrator and the victim of the water pollution problem. The Prefectural Government worked on the "Soap Movement" in cooperation with the residents, resulting in the enactment of the Lake Biwa Ordinance.

Conclusions

The use of powered soap for washing clothes has been decreasing in recent years. As a matter of fact, synthetic detergents free of phosphorus were developed and became widely used after the "Soap Movement." Nevertheless, the "Soap Movement" is considered as the starting point for the conservation of Lake Biwa. Witnessing the eutrophication of Lake Biwa, people became aware that everyday activities could directly affect the lake environment, and developed a deeper feeling of being connected to the lake than before. It was also the first case that the local government and the residents worked together on environmental conservation. On the other hand, the ordinance left people with a sense of inadequacy, since it went no further than regulating the use of phosphorus-containing synthetic detergents.

Although the use of soap has been declining in the past 30 years, the "Soap Movement" was successful in raising environmental awareness with the residents of the Lake Biwa basin. It was a very meaningful event, leaving an impression on people's memories.

7.1.3 Issues for Reduction of Pollution Loads from Point and Nonpoint Sources

Takuya Okubo

Abstract The Shiga Prefectural Government has been implementing control measures against point pollution loads, such as (a) expansion of the area covered by the sewerage system and introduction of high performance sewage treatments in large-scale sewage treatment plants, (b) strict effluent regulations targeting small- and large-scale factories, and (c) tertiary treatments at small-scale sewage treatment plants in rural areas. As a result, water quality in Lake Biwa has gradually improved. However, the effects of the control measures against nonpoint pollution loads have not produced observable results so far. The difficulty of determining the amount of nonpoint pollution loading can be attributed to its widely varied occurrence, both spatially and temporally. For the same reason, it is difficult to grasp the effects of control measures of nonpoint sources quantitatively. We have understood from past experience that the self-purification capabilities of rivers, attached lakes, and ponds are not reliable enough to utilize as treatment facilities. Control measures applied to the sources of nonpoint pollution loads are more important than those applied to the downstream areas of the sources. It is also important to reduce the usage of irrigation water for reducing pollution loads from paddy fields.

Keywords Nonpoint pollution load • Point pollution load • Nutrient • Nitrogen • Phosphorus • Muddy water

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Introduction

Nutrients loads flowing into Lake Biwa from the watershed areas of the lake have been decreasing since the 1990s (Fig. *1*) as a result of various measures for reducing pollution loading, for example, construction of sewerage systems and introduction of strict regulations of water quality of effluents from industries including small-scale factories and wastewater treatment plants. Concentrations of nitrogen and phosphorus in the lake have also been decreasing in proportion to the decrease of inflowing nutrients loads (see Sect. 7.1.1, *Figs. 4* and *5* (Shiga Prefectural Government 2009b). In particular, the improvement of the water quality in the south basin of Lake Biwa is a result of the construction of a sewerage system covering the southeast area of the watershed, and discharge of the effluent from the sewerage treatment plant into the Seta River, not Lake Biwa. The change of flow path of wastewater by the sewerage treatment system is a sort of a "diversion." Main projects implemented for the improvement of the lake water quality focused on the reduction of nutrient loads from households and industries, that is, point sources, as shown in *Fig. 1*. Consequently, the percentage of nutrient loads from nonpoint sources, for example, farm lands, urban areas, and atmospheric sources, to the total nutrient loads is increasing. Thus, the reduction of pollution loads from nonpoint sources is becoming more important. In order to promote the reduction of pollution loads from nonpoint sources, we should carry out effective control measures by evaluating the effects of measures implemented in the past. In this chapter, the following issues of pollution loads are explained:

1. The present evaluation of some point and nonpoint pollution loads,
2. The effects of nonpoint pollution loads on lake water quality,
3. The present knowledge of the effects of the control measures for decreasing nonpoint pollution loads.

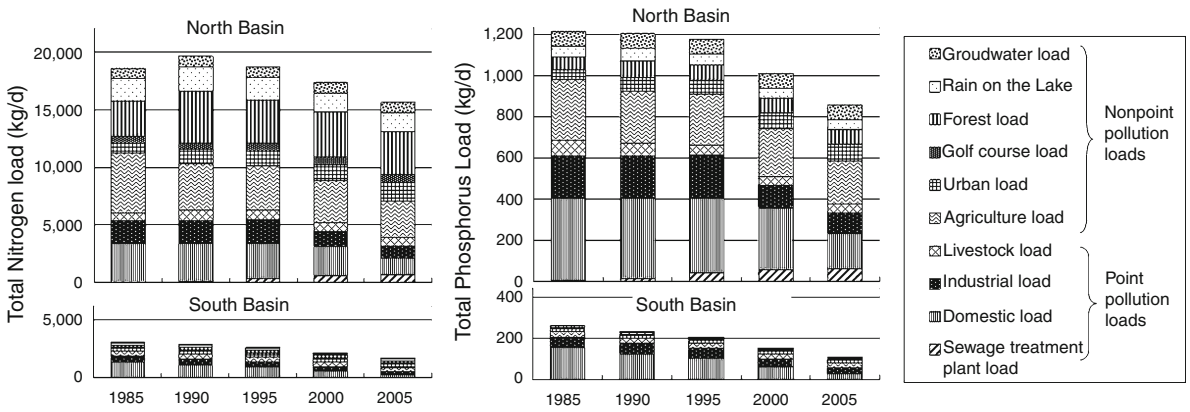

Fig. 1

Changes in nutrient pollution loads flowing into Lake Biwa (Shiga Prefectural Government 2009a).

Specific Pollution Load Per Unit of Each Source for Determination of Pollution Load Flowing into Lake Biwa

In order to improve the water quality of Lake Biwa, the Shiga Prefectural Government has been drawing up Plans for the Preservation of Lake Biwa Water Quality every 5 years from 1985, based on the Law Concerning Special Measures for the Preservation of Lake Water Quality (enacted in 1984). A variety of measures for improving the lake's water quality have been implemented based on these plans. The amounts of pollution loads from all kinds of sources, for example, households, industries, agriculture, forests, atmospheric fallout, etc., should be determined to establish the plans on which Shiga Prefecture sets an order of priority of countermeasures for execution. Nitrogen and phosphorus loads flowing into the north and south basins of Lake Biwa at 5-year intervals since 1985 are shown in *Fig. 1*. Specific pollution loads from households, livestock, and nonpoint sources used to establish the fifth Plan for the Preservation of Lake Biwa Water Quality, which took effect from 2005 to 2010, are shown in *Tables 1–3*.

Nutrient loads discharged from households decreased noticeably because of the expansion of the coverage area of sewage systems. Percent removal rates of nitrogen and phosphorus at large-scale sewerage treatment plants around Lake Biwa are approx. 60–70% and 95%, respectively, owing to advanced sewage treatment technologies. The particularly high percent removal rate of phosphorus is achieved by coagulating the sedimentation of phosphorus in the treatment plants. On the other hand, small-scale individual sewage treatment tanks such as "Tandoku Johkaso," that is, single type private sewage treatment tanks, and "Gappei Johkaso," that is, combined type private sewage treatment tanks, have low removal rates of nutrients. Percent removal rates of nitrogen and phosphorus by those tanks are approx. 10–50%. We should pay attention to the fact that nutrient loads from households increase when we replace cesspool-type toilet with a small-scale, individual sewage treatment tank, because the night soil collected from cesspool-type toilets is treated by advanced treatment processes including removal of nutrients at night soil disposal plants (*Table 1*).

Specific nitrogen and phosphorus loads from livestock, that is, daily nitrogen and phosphorus loads in the treated effluent of a cow, pig, and chicken, are shown in *Table 2*. The specific nitrogen and phosphorus loads of a cow are, respectively, 6 and 1.4 times larger than those of a human household (small scale sewerage treatment plant). Specific nitrogen and phosphorus loads of a pig are, respectively, 1.2 and 5.9 times larger than those of a human household.

Specific nutrient loads from nonpoint sources, for example, agricultural fields, urban areas (not including household wastewater), forests, etc., are shown in *Table 3*. Specific nitrogen loads are high in dry fields, while those of phosphorus are high in paddy fields and urban areas. Those specific loads from nonpoint sources, however, vary with the seasons, locations, amount of precipitation, and other conditions. Therefore, it is difficult to accurately determine the amount of specific loads.

Table 1

Specific nitrogen and phosphorus loads of human waste in Lake Biwa Watershed (Shiga Prefectural Government 2005)

Discharge source	Waste category	Unit	T-N	T-P
Large scale sewage treatment plant	Human waste + gray water	g/cap/day	Using measured data (3.8)[a]	Using measured data (0.047)[a]
Small scale sewage treatment plant	Human waste + gray water	g/cap/day	4.8	0.47
Houses with Gappei Jokaso	Human waste + gray water	g/cap/day	6.0	0.70
Houses with vault toilet (human waste is treated by night soil treatment plant)	Human waste + gray water	g/cap/day	3.5	0.44
Houses with Tandoku Jokaso	Human waste + gray water	g/cap/day	10.2	1.09
Houses with land treatment	Human waste + gray water	g/cap/day	3.9	0.41

[a]Calculated from measured data of Kosei treatment plant in 2007

Table 2

Specific nitrogen and phosphorus loads of livestock[a] (Shiga Prefectural Government 2005)

Livestock	Unit	T-N	T-P
Cattle, cow	g/head/day	29	0.65
Pig	g/head/day	5.6	2.75
Chicken	g/head/day	0.1	0.002

[a]These loads are calculated with consideration of runoff rates

Table 3

Specific nitrogen and phosphorus loads of nonpoint sources (Shiga Prefectural Government 2005)

Land use type	Unit	T-N	T-P
Paddy field	g/ha/day	39.2	2.68
Dry field	g/ha/day	261.0	0.54
Golf course	g/ha/day	261.0	0.54
Urban area	g/ha/day	38.6	2.00
Forest	g/ha/day	15.4	0.31
Rain on Lake Biwa	g/ha/day	26.0	0.75

Difficulty of Determination of Nonpoint Pollution Loads

Reasons for the difficulty of determination of nonpoint pollution loads are as follows:

1. Discharge of nitrogen and phosphorus from paddy fields occurs over a short-time period during some farming activities, such as plowing of a rice paddy, rice-planting, and fertilization. In order to determine the amount of discharged nutrients during those events, we should take water samples at short time intervals, for example, a few hours or 1 day.
2. In paddy fields, specific nutrient loads vary with the seasons. Specific loads of phosphorus and dissolved organic carbon are high in May and June when the paddies are filled with water, while phosphorus is low in winter. The specific load of nitrogen is low in autumn. Accordingly, we should measure nutrient loads throughout the year.
3. Discharges of nitrogen and phosphorus from nonpoint sources mainly occur as a result of rain events. Accordingly, immediate and flexible observation methods are necessary for the determination of the nonpoint pollution loads.

Around Lake Biwa, pollution loads from farmlands have been investigated mainly by the Agriculture Research Center of Shiga Prefecture and the University of Shiga Prefecture, and those from urban areas have been investigated mainly by Ritsumeikan University. However, reported amounts of specific nutrient loads from farmlands and urban areas varied largely. For example, *Table 4* shows reported amounts of nitrogen and phosphorus loads from paddy fields during the irrigation period. The reported amounts varied largely due to the difference in location, quality of soil, sampling interval, consideration of rain events, and others. Shiga Prefecture uses a specific load of TN as 31.5 g/ha/day and TP as 4.82 g/ha/day (excluding the load of irrigation water) for the Plans for the Preservation of Lake Biwa Water Quality. However, these values should only be used as a rough guide. Additional investigations are necessary for the determination of nonpoint pollution loads flowing into Lake Biwa. Also, it is important to utilize numerical simulation models and GIS databases in addition to the accumulation of field research data in order to cover areas of insufficient field data and predict the amount of nonpoint pollution loads.

Table 4

Measured specific nitrogen and phosphorus loads of paddy fields during irrigation period

Research site	Research area	Source of irrigation water	Year	Precipitation during cultivation period (mm)	Nitrogen outflow[a] (g/ha/day)	Net nitrogen outflow[b] (g/ha/day)	Phosphorus outflow[a] (g/ha/day)	Net phosphorus outflow[b] (g/ha/day)	Measurement in rain events	Reference
Hikone City	7 ha	Lake Biwa	1974	1,220	351	103	7.3	0.7	No	Kobayashi et al. (1980)
			1975	1,051	534	187	43.3	36.0	No	
Hikone City	52.7 ha	Lake Biwa	1976	1,243	154	27	6.7	1.3	No	Kobayashi et al. (1980)
			1977	450	253	62	8.0	3.3	No	
			1978	502	210	73	8.7	2.7	No	
Hikone City	18 a	Lake Biwa	1977	360	135	53	4.5	2.7	No	Hasegawa et al. (1980)
			1978	436	140	50	10.0	6.0	No	
Notogawa City	7 ha	Daidou River	1979	726	295	-7	15.8	5.5	No	Hasegawa et al. (1982)
			1980	1,331	290	82	14.2	4.7	No	
			1981	768	219	-22	9.5	-0.5	No	
Ryuou City	3.89 ha	Hino River	1982	–	459	49	49.3	2.7	No	Sonoda et al. (1997)
Kousei City	11.6 ha	On River	1987	650	773	152	79.3	52.3	Yes	Takeda et al. (1991)
			1988	1,202	670	53	118.7	60.0	Yes	
Ryuou City	3.89 ha	Hino River	1993	1,156	191	9	98.0	79.3	Yes	Sonoda et al. (1997)
			1994	509	130	-17	49.3	37.3	Yes	
			1995	923	159	-2	60.7	42.7	Yes	
Moriyama City	30 a	Lake Biwa	1994	483	43	0	6.8	2.5	Yes	Udo et al. (2000)
			1995	1,055	111	38	10.6	7.2	Yes	

Gokasyou	21.8	Eigenji Dam	1998	790	138	43	45.5	38.1	No	Kobayashi et al. (2005)
			1999	975	77	-10	22.2	18.4	No	
			2000	832	69	-31	12.6	6.1	No	
			2001	776	81	-9	17.3	13.3	No	
Gokasyou (improved farming)	30.5	Eigenji Dam	1998	790	10	-2	2.2	1.7	No	Kobayashi et al. (2005)
			1999	975	9	-3	1.8	1.3	No	
			2000	895	9	-5	1.2	0.8	No	
			2001	776	9	-7	0.9	0.6	No	

[a]Outflow load including irrigation water load and rain load
[b]Outflow load without irrigation water load and rain load

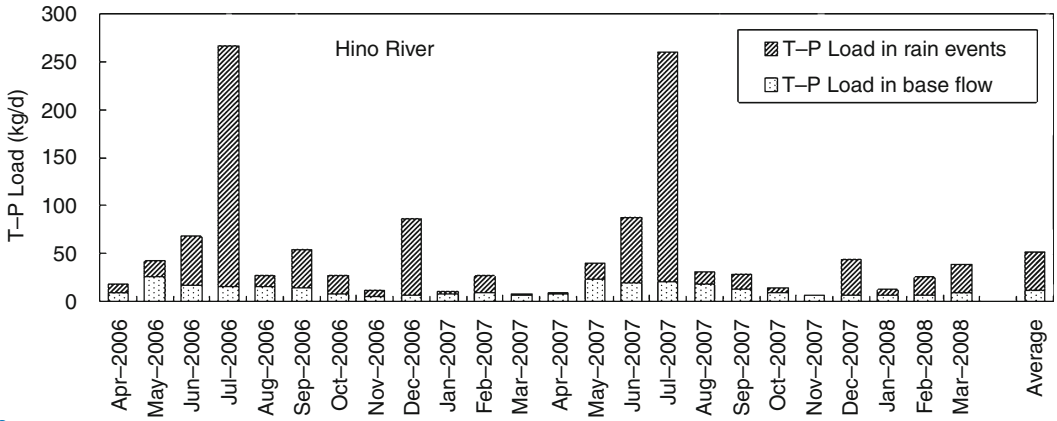

Fig. 2

Changes in monthly average TP loads discharged from the Hino River during April, 2006 and March, 2008 (Okubo, unpublished research).

Figure2 shows changes in the monthly average TP loads discharged from the Hino River observed from April 2006 to March 2008. The loads were determined by water sampling at 12-h intervals using an automatic sampler and of measurement of the water level at 10-min intervals using a water level logger. Monthly average loads are divided into two parts, loads in rain events and loads in the base flow. Almost 90% of the monthly average loads in July 2006 and July 2007 were discharged in rain events. About 70% of the total TP loads in the 2 years were discharged in rain events. This result shows that the observation of pollution loads in rain events is quite important for the determination of nonpoint pollution loads.

Muddy Water Discharge from Paddy Fields and the Control of Agricultural Pollution Loads

A specific problem in Lake Biwa caused by nonpoint pollution loads is the discharge of muddy waters from paddy fields as a result of soil puddling (the process of plowing of rice paddies in preparation for transplanting young rice plants) and rice planting in the period from late April to early May. A picture of muddy waters discharged from the Uso River into the northeast part of Lake Biwa is shown in *Fig. 3*. Nutrients, such as nitrogen and phosphorus, are discharged along with the muddy waters from paddy fields, and the inflow of nutrients may cause eutrophication in Lake Biwa. The spread of muddy water at the mouth of rivers cause the escape behavior of some kinds of fishes like ayu fish (Biwa ayu, *Plecoglossus altivelis* subsp.), which is an important target fish for the fishing industries of Lake Biwa. Fijiwara (1997) reported that ayu fish fled from areas when the concentration of suspended solids became more than 22 mg/l.

In order to decrease the amount of muddy water and nutrients discharged from paddy fields, the Agricultural Section of the Shiga Prefectural Government has been taking many measures. For example, they tried to utilize some of the lakes and ponds that are attached to Lake Biwa for controlling nutrients loads. *Table 5* shows the results of the investigation into the amount of nutrients removal at some attached lakes. The removal of organic compounds (measured by COD) at most attached lakes is below zero, which means that the production of organic matter, for example, primary production by algae, occurs in the attached lakes. The removal of suspended solids is below zero at some attached lakes and above zero at others. This result means that suspended solids cannot always be removed. The author has investigated the amount of nutrient removal at some attached lakes, which revealed that TP removal rates were 30–50% and TN removals were 5–10% (Okubo 2005). These results show that the self-purification capabilities of attached ponds are not reliable enough to utilize as treatment facilities. Control measures applied to the sources of nonpoint pollution loads are more important than those applied to the downstream areas of the sources.

Fig. 3
Discharge of muddy water from the Chonoki River during the period of soil puddling of paddy fields.

There are other measures for controlling the loads of muddy waters and nutrients discharged from paddy fields, for example, reuse of agricultural wastewater in paddy fields, spread of new soil puddling machines that reduce the load of muddy water, spread of improved fertilization methods, saving of irrigation water, and construction of underground conduits for drainage in paddy fields. However, effects of those measures have not been evaluated quantitatively enough despite the efforts of researchers.

Conclusions

To reduce point pollution loads, measures, such as (a) expansion of the area covered by sewerage systems and introduction of high performance sewage treatments at large-scale sewage treatment plants, (b) strict effluent regulation targeting industrial wastewater treatment plants, (c) tertiary treatment at small-scale sewage treatment plants in rural areas, have been undertaken by Shiga Prefectural Government. As a result of these measures, the water quality in Lake Biwa has gradually improved.

However, the effects of measures undertaken by Shiga Prefectural Government to reduce nonpoint pollution loads, as previously mentioned, have not been visible so far. The difficulty in evaluating nonpoint pollution loading can be attributed to its widely varied occurrence, both spatially and temporally. By the same reason, it is difficult to grasp the effects of the control measures of nonpoint sources quantitatively. We have understood that the self purification capabilities of rivers, attached lakes, and ponds are not reliable enough for utilization as treatment facilities by our research observation in the past. The control measures applied to the sources of nonpoint pollution loads are more important than those downstream of the sources. Reducing the amount of irrigation water is also important for reducing pollution loads from paddy fields.

Table 5

Performance of pollution load removal at ponds attached to Lake Biwa (This table was summarized by the author based on field data investigated by the Agricultural Section of Shiga Prefectural Government)

		COD			SS			T-N			T-P		
		Inflow (mg/l)	Outflow (mg/l)	Removal (%)	Inflow (mg/l)	Outflow (mg/l)	Removal (%)	Inflow (mg/l)	Outflow (mg/l)	Removal (%)	Inflow (mg/l)	Outflow (mg/l)	Removal (%)
Nukegawa Pond[a]	Plowing period	7.0	5.5	21	44.4	16.5	63	1.26	1.14	10	0.20	0.16	20
	Cultivation period	3.4	3.5	-3	8.1	3.7	54	0.80	0.68	15	0.06	0.04	33
	No cultivation period	2.5	3.2	-28	9.0	5.4	40	0.70	0.57	19	0.04	0.04	0
	Average	4.3	4.1	-3	20.5	8.6	52	0.92	0.80	14	0.10	0.08	18
Suganuma Pond[b]	Plowing period	4.4	4.5	-3	16.4	10.7	34	0.84	0.81	4	0.13	0.11	15
	Cultivation period	3.3	4.4	-36	6.9	6.9	1	0.65	0.65	0	0.11	0.10	9
	No cultivation period	2.0	3.2	-59	3.7	11.3	-205	0.61	0.61	0	0.06	0.10	-67
	Average	3.2	4.0	-33	9.0	9.6	-56	0.70	0.69	1	0.10	0.10	-14
Nodanuma Pond[c]	Plowing period	3.4	4.2	-22	33.6	16.0	52	1.01	0.73	28	0.25	0.14	44
	Cultivation period	3.8	4.7	-21	11.6	11.3	3	0.95	0.87	8	0.25	0.17	32
	No cultivation period	2.0	2.5	-25	4.5	8.7	-93	0.79	0.62	22	0.14	0.12	14
	Average	3.1	3.8	-23	16.5	12.0	-13	0.92	0.74	19	0.21	0.14	30

[a]Research was conducted monthly during 1986–1990
[b]Research was conducted monthly during 1988-1990
[c]Research was conducted monthly during 1991-1992

7.1.4 New Issue—COD Increase in the Water of Lake Biwa

Kazuhide Hayakawa · Takahiro Okamoto

Abstract The increase of COD is one of the environmental issues in Lake Biwa. We here introduce an outline of this issue from the viewpoint of scientific approaches and administrative actions in order to achieve the environmental quality standard. In general, the COD increase in lakes is a result of a new type of organic pollution. Its causes and mechanisms should be elucidated soon for the sake of conserving lake water quality. To plan comprehensive and effective protection measures against organic contamination, it is crucial to calculate a mass balance of organic matter loaded from various sources in and outside the lake. To realize this goal, adequate monitoring and highly developed simulations of the lake's environments are necessary for a precise estimation of influxes of organic carbon to the lake.

Keywords Chemical oxygen demand (COD) • Dissolved organic carbon • Refractory dissolved organic matter • Environmental quality standard

Introduction: Outline of COD Increase in the Lake

Chemical oxygen demand (COD) and biochemical oxygen demand (BOD) are commonly used to indirectly measure the amount of organic matter in water, and are a useful measure of environmental water quality in lake and coastal sea. The COD and BOD indicate the mass of oxygen consumed by chemical oxidizing reagents and microbial organisms in waters, respectively. Annual means of COD in Lake Biwa have been increasing since 1984, while those of BOD, indicating the microbial availability of organic matter, gradually decreased during that same period (*Fig. 1*). The increasing annual means of COD seem to be caused by accumulations of refractory organic matter (ROM) in the lake. This COD increase is not only far from meeting the environmental water quality standard, but also ineffective in measuring labile organic pollution consuming dissolved oxygen in the lake water. Organic matter loading from the watershed has decreased over the past few decades as the result of sewer system construction and other measures aimed to reduce organic pollution. Data have revealed that COD loads from the watershed, as estimated in the plan for the conservation of lake water quality, decreased after 1985 (*Fig. 2*). Meanwhile, organic matter within the lake also declined; the phytoplankton biomass indicated by chlorophyll-*a* concentrations in the lake has gradually decreased over the past 20 years (*Fig. 3*). Those findings indicate that there are no consistent factors to induce COD or organic matter either inside or outside the lake. The approximately 90% of organic matter detected by COD in the lake water exists in dissolved form. The COD increase can be interpreted as not the increasing amounts of organic matter in the lake, but qualitative changes of dissolved organic matter (DOM) in the lake water, although the chemical components of DOM remain unclear.

Currently, the phenomenon of the uninterpretable COD increase in the lake has also been recorded in other lakes, such as Lake Kasumigaura and Lake Towada, as well as enclosed marine coastal areas, and it has become a major issue in efforts to conserve natural water quality in Japan. The common phenomenon of the COD increases observed in some lakes is that the COD in winter raises the annual averages (National Institute for Environmental Studies 2004). The seasonal increases in the COD in lakes during spring and summer originate from the active primary production of phytoplankton growth, while the increases of COD in winter may be caused by anthropogenic organic pollution (National Institute for Environmental Studies 2004).

COD increases lead to the following setbacks to the conservation of lake water quality (National Institute for Environmental Studies 2004): (a) a loss in the maintenance

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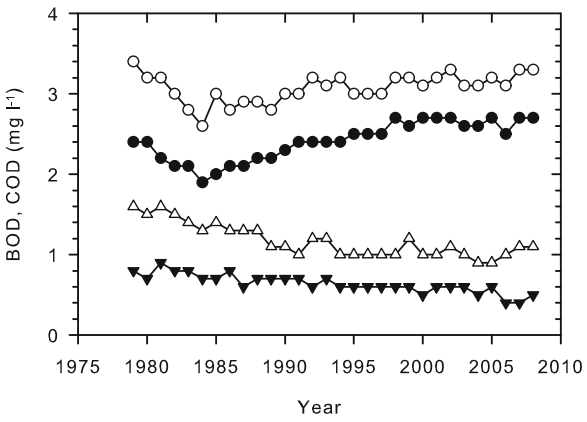

Fig. 1

Changes in interannual values of COD and BOD in Lake Biwa. Open circles denote CODs in the south basin, close circles denote CODs in the north basin, open triangles denote BODs in the south basin, and closed triangles denote BODs in the north basin. Data are quoted from Environmental White Paper of Shiga Prefecture.

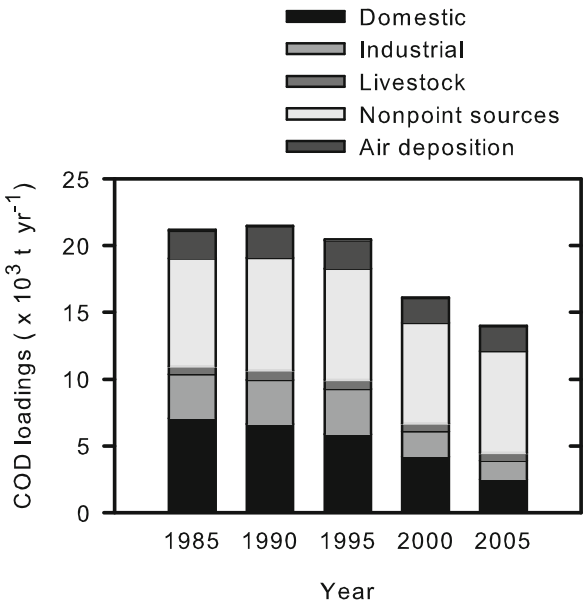

Fig. 2

COD loads from the watershed estimated in the plan to conserve lake water quality decreased after 1985. Data are from the fifth plan for conservation of water quality in Lake Biwa.

of environmental water quality standards, (b) a need to reappraise the effective control of organic pollutants loaded from catchment areas, (c) a destructive impact on lacustrine organisms and ecosystems, (d) an active carrier for harmful heavy metals and pesticides in the water, and (e) an alarming increase in trihalomethane produced during the chlorination process of clean water treatments. The COD increases in lakes constitute a new type of organic pollution. Its causes and mechanisms should be clarified soon for successful conservation of lake water quality (National Institute for Environmental Studies 2004).

There are other opinions that regard COD_{Mn} (Chemical oxygen demand oxidized by potassium manganese) as an inadequate standard to control organic pollution. Since the analytical standard procedure of COD_{Mn} is insufficient for the decomposition of all organic matter, it would be likely to underestimate some organic matters such as organic acids. Therefore, COD offers neither accuracy for summing up nonequivalent organic matter eliminated from various pollution sources nor discrimination of quantitative and qualitative changes of organic matter in lakes. Furthermore, the environmental criteria of COD in lake water were configured based on a misunderstanding of its analytical procedure (Ide et al. 2006), and the criteria proved too difficult to achieve (Hirayama and Ide 2007). Thus, some scientists have proposed an alternative standard for measuring organic matter (cf. Fukushima et al. 1997).

Previous Studies of Dissolved Organic Matter

Since the 1990s, some studies have attempted to clarify DOM and ROM in Lake Biwa. Hori et al. (1998), for example, measured the seasonal variations of dissolved organic carbon (DOC) concentrations in the lake. The DOC concentrations in the surface water fluctuated seasonally derived from aquatic organisms, while those in the deep water are relatively stable throughout the year (Hayakawa 2004, 2006; Kim et al. 2006, *Fig. 4*). Aquatic humic substances and hydrophilic acids were found to constitute certain contents of DOMs in the lake, and possibly consistent with ROMs (Imai et al. 1999, *Fig. 5*). Amano et al. (2004) estimated that the ROMs in the lake originated in discharges from forests and on-site (small) sewerage treatments. Fulvic acids (one of the humic substances) were detected in several zones of the lake by size-exclusion liquid chromatography (Aoki et al. 2004; Sugiyama et al. 2005).

Shiga Prefecture and Lake Biwa Environmental Research Institute (LBERI) initiated a study of ROMs in the lake. They developed various hypotheses for the causes of the COD increase: (a) an increase in ROM loaded from the watershed, (b) production or qualitative change in ROM by long-term transition of the lake ecosystem, and

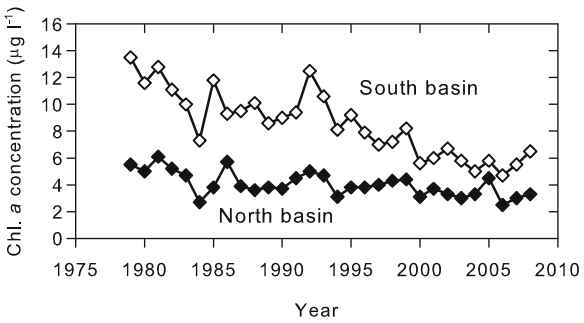

Fig. 3
Changes in interannual values of chlorophyll-*a* concentration in Lake Biwa. Data are quoted from Environmental White paper of Shiga Prefecture.

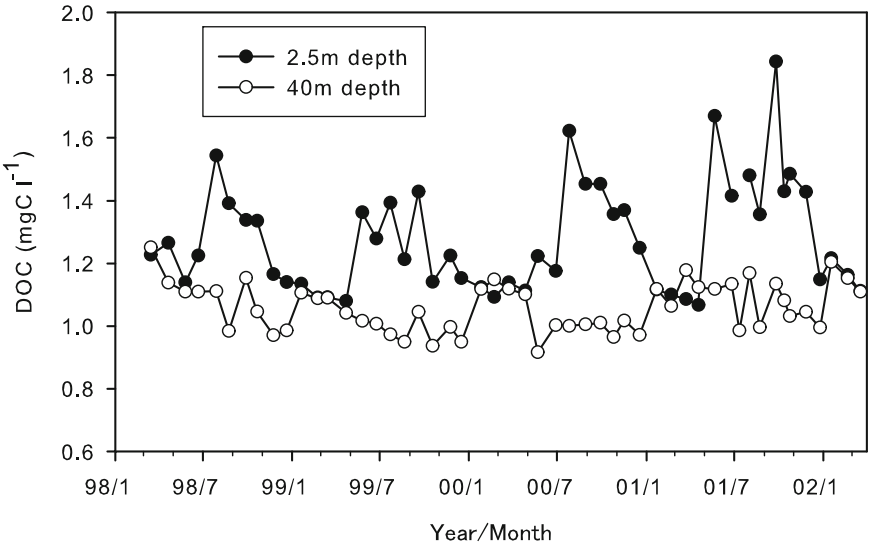

Fig. 4
Changes in DOC concentrations in the north basin in 1998–2001. The figure was redrawed after Fig. 7.1.4.3 in Hayakawa and Takahashi (2005) with permission of Lake Biwa Research Institute. Open and close circles denote the DOC concentrations at 2.5 and 40 m depths, respectively.

(c) ROM accumulation due to changes in water usage among the human society in the catchment area. Based on these hypotheses, they started to study the causes of the increase in COD (Okamoto et al. 2010).

Government Steps to Conserve Lacustrine COD Quality

The Japanese government conserves lake water quality based on the "Law Concerning Special Measures for Conservation of Lake Water Quality," hereinafter referred to as the Lake Conservation Law, enacted in July, 1984. The government designates the lakes that it considers water quality conservation to be critical in. Local administrations around those designated lakes promote comprehensive conservation of lakes' water quality based on an established plan. Over the past quarter century since the law took force, the CODs in all the 11 designated lakes failed to meet the water quality standards, and either worsened or merely maintained the previous levels. The Ministry of Internal Affairs and Communications announced a policy evaluation for the conservation of lake water quality in August, 2004. The Central Environment Council reported on the proposals involved in the conservation of lake environments, charging them to identify the water pollution mechanism including COD contamination, and to precisely assess the loads from several pollution sources. In July 2005, the national government revised the Lake Conservation Law to tighten up the measures against water pollution. The Ministry of Environment announced a "Report of a comprehensive review of ongoing researches and measures for the conservation of lake water quality." The report indicated 12 environmental issues in Lake Biwa.

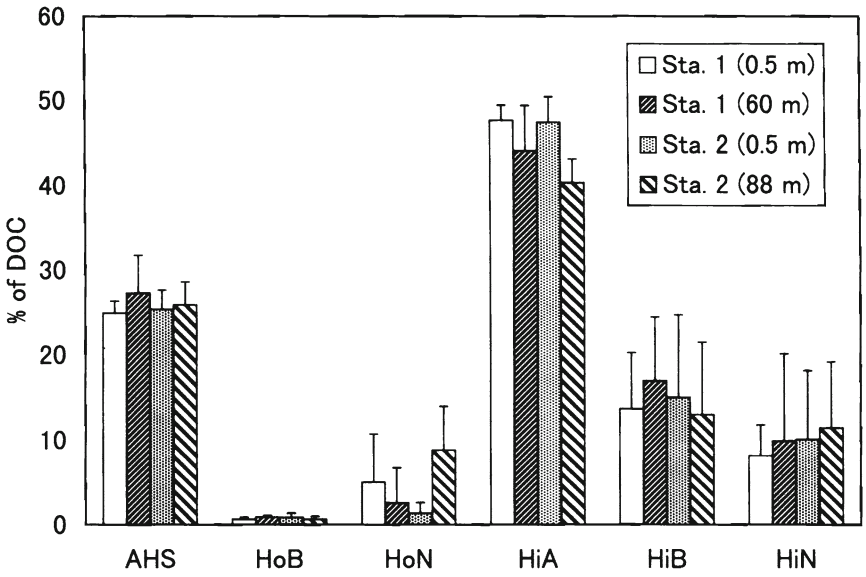

Fig. 5

Hydrophobic–hydrophilic and acidic–basic fractionations of DOM from Lake Biwa. *AHS*, aquatic humic substances, *HoB*, hydrophobic basics, HoN: hydrophobic neutrals, *HiA*, hydrophilic acids, *HiB*, hydrophilic basics, *HiN*, hydrophilic neutrals. Bars represent standard deviations (The figure was quoted from *Fig. 4* of Imai et al. (1999) with permission of the Japanese Society of Limnology).

Two of them are reexamination of validity of COD as an index of organic matter in the lake, and estimation of organic production within the lake. Recently, the Ministry of Environment is also promoting investigation of the methodologies used for understanding the mechanism and accurate loads of organic pollution.

Shiga Prefectural Government Moves to Ameliorate Lacustrine COD Quality

The COD increase in the lake is a significant obstacle in the way of conservation of water quality as well as any assessments of water quality management. Therefore, Shiga Prefecture moved to investigate the causes of the COD increase. Shiga Prefecture's first survey was conducted in 1993–1996 as a project to ameliorate organic pollution in the north basin by the environmental policy division of the prefectural government. Subsequent surveys were conducted by the Department of the Environment in the prefectural government in collaboration with many experts on aquatic environments and analytical chemistry. The surveys produced many valuable findings such as those of Imai et al. (1999) as mentioned above. In 1997–2000, Lake Biwa Research Institute (antecedent of LBERI) conducted a project study on the "Dynamics of Dissolved Organic Matter." This project represented that the DOMs in Lake Biwa have various sources and the possible main source is derived from autochthonous organic matter in the lake. The fifth plan for the conservation of water quality in Lake Biwa in 2006 pointed out that the accumulation of ROM is one of the causes of the COD increase, and it ordered an investigation into the accumulation mechanism of ROM.

Since 2007, the LBERI has started a policy issue study related to the clarification of water contamination mechanisms. They examined various ROMs identified by a 100-day decomposition experiment (Okamoto et al. 2010).

Current Status and Future Challenges

The composition and behavior of the DOM and ROM in Lake Biwa have been the subject of various studies over the past few decades. However, the molecular composition, sources, and behaviors of the ROM in the lake remain unclear. The primary report of the LBERI has revealed that the sources of ROM in the lake are allochthonous as well as autochthonous DOMs (Okamoto et al. 2010).

The administrators who are engaged in countermeasures for reducing COD levels in the lake should discuss the two major sources of ROM from within the lake and catchment areas. In addition, calculating a mass balance of organic matter loaded from various sources in and outside the lake is an important step in achieving comprehensive and effective measures to protect against organic contamination. Fundamental to such efforts are precise estimations of organic carbon influxes to the lake, using appropriate monitoring and highly developed simulations of lake environments. The COD limits precision because of nonequivalent to various emissions. To achieve greater accuracy in organic matter estimations in the lake, a new index of organic matter, such as organic carbon, will be needed. The Lake Conservation Law stipulates that environmental quality standards should be regularly checked and revised as appropriate. Conservation measures of water quality and reviews of the quality standard will be considered based on the forthcoming scientific information.

Acknowledgment

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7.2 Deterioration of the Lake's Ecosystem and Conservation Measures

Machiko Nishino

The Ministry of Environment (2010) showed that loss of biodiversity in Japan caused by human activities had extended to all our ecosystems. In particular, loss of biodiversity is widespread in the freshwater ecosystems, as well as in the coast, marine, and island ecosystems, and it tends to continue today. The loss will be irreversible in the future. It also pointed out that both human activities and invasive alien species were the major factors affecting the deterioration of freshwater ecosystems in Japan. This indication also holds partly true for Lake Biwa.

As shown in the previous section, the long-term monitoring data of measuring the transparency, total phosphorus, and chlorophyll-*a*, of Lake Biwa showed improvements recently (Sect. 3.2.1). This suggested the recovery of water quality, and advance of eutrophication almost ceased in the lake. On the other hand, the first Red List of Shiga Prefecture (Shiga Prefectural Government 2000) revealed that a total of 31 out of 62 endemic species or subspecies, which accounted a half of the endemic species, was assigned as critically endangered, endangered, vulnerable, or near threatened (Chap. 2). The designated species increased to 37 species in the revised list of 2006. Also in the Red List of the Ministry of Environment, a total of 35 endemic species (19 mollusks, 12 fishes, 2 crustacean, a turbellaria, and a hemiptera) and a total of 64 indigenous species (32 mollusks and 32 fishes; among them the above mentioned numbers of species were also endemic) are listed as critically endangered, endangered, vulnerable, or near threatened. As shown in Chap. 2, these facts clearly indicate that loss of biodiversity in and around the lake.

According to the Red Data Book 2006 of Shiga, Nishino (2009) concluded that the greatest threat to the numerous indigenous fishes was the alien fishes, that is, the largemouth bass *Micropterus sarmoides* and bluegill *Lepomis macrochirus* from the USA, both designated as invasive alien species by the Ministry of Environment, and their transfer and raising are prohibited by the Invasive Alien Species Act of 2004. The second threat was so-called river improvement (construction of artificial dams, enclosing bands, etc.), then lake shore improvement (such as construction of dikes along the lake shore, to prevent flood), readjustment of paddy fields, and artificial water level control of the lake. These threats had deteriorated indigenous fish habitats, and segmentalized their spawning migration from the lake to lagoons or attached lakes (called *naiko* in Japanese) or to the paddy fields around the lake.

The threats to the most numerous indigenous mollusk species were the artificial lake water level control, then lake shore improvement, water pollution, river improvement, and readjustment of paddy fields (Nishino 2009). It is noteworthy that eutrophication or organic pollution of the lake or rivers were not regarded as threats to all the indigenous mollusk and fish species except to the sand lamprey *Lethenteron reissneri*, whose habitat is mainly in rivers and cold springs.

The lake's ecosystem was greatly affected by various kinds of human activities. There used to be many lagoons or *naiko*s around Lake Biwa. They were covered with submerged macrophytes and reed beds of *Phragmites* spp., thus they provided good spawning and nursery grounds for the indigenous fishes of the lake. During the period from mid 1940s to 1971, 77% of the *naiko* areas were reclaimed, and a total of 17.9 km^2 of the water bodies were lost (Sect. Topic 7). Issues of eutrophication were also emerged during the 1960–1970s or 1980s. To prevent floods and for other reasons, artificial dikes were constructed along the lake shore, and 37% of the present shoreline became artificial (Sect. Topic 7). Dams and enclosing bands were constructed on the river flowing into the lake. The invasive alien fishes, that is, the largemouth bass *M. salmoides* and the bluegill *L. macrochirus*,

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entered into the lake in the mid 1960s and 1970s, respectively, and they seriously damaged the indigenous fish community (Sect. 3.1.3). Since 1992, water level of the lake had been artificially kept low during early summer to autumn, which coincided with the breeding season for most of indigenous fishes. The low water level inevitably dried up the *Phragmites* reed beds areas of the shore, thus resulted in reduced spawning areas of the indigenous cyprinid fishes (Sect. 2.5). Also, global warming affected the water regime and plankton community of the lake recently, as shown in Sect. 3.3.

To restore the deteriorated lake ecosystem, various measures had been created and implemented by the local governments, ministries, NPOs, and citizens of Shiga Prefecture. Lake Biwa has already been designated as one of the quasinational parks of Japan, and it was protected by various laws such as the River Act, Act on Special Measures concerning the Preservation of Lake Water Quality, and other ordinances. In addition, several ordinances had been enacted by the Shiga Prefectural Government since 1992, to protect the *Phragmites* reed beds around the lake and, the indigenous species and to eliminate the Invasive Alien Species (Sects. 7.2.1 and 7.2.4). One of them was "The Ordinance relating to the Appropriate Leisure Usage of Lake Biwa, Shiga Prefecture," implemented in 2003, in which release of the alien fish species was banned. Then, a range of efforts were made to restore the habitat of endemic and indigenous fishes, such as their spawning migratory pathways from Lake Biwa to paddy fields around the lake, trials of the water level control of the lake, and restoration of the reclaimed attached lakes (Sects. 7.2.1, Topic 22, and 7.2.2).

Other challenges were to control or eliminate the invasive alien species, submerged macrophytes and the great cormorant, which had increased recently (Sects. 7.2.3 and 7.2.4). For example, in the south basin, submerged macrophytes had increased since 1994, and its biomass reached 10,000 tons (dry weights) in 2002 and 2007 (Sect. 3.1.3). In the 1960s, submerged macrophytes used to provide the spawning and nursery grounds for the indigenous fishes. Recently, however, more than 90% of the fish population in the south basin consisted of the two invasive alien fishes in the south basin, and there was of little evidence that the indigenous fishes spawn there. The Shiga Prefectural Government and other ministries were making extensive effort to reduce the overgrown macrophytes since 2003, because of the navigational hazard they cause, bad smell when the dead macrophytes washed up to the shore, and so on. A lot of money has been paid for elimination of the two alien fishes (50–60 million yen), submerged macrophytes (more than 90 million yen), invasive alien plants such as the water lettuce *Pistia stratiotes* and the alligatorweed *Alternanthera philoxeroides*, and the great cormorant *Phalacrocorax carbo hanedae* every year.

Lake Biwa and Nishino-ko, the largest attached lake (*naiko*) existing around the lake, were designated as a wetland of international importance under the Ramsar Convention in 1993 and 2008, respectively (Sect. Topic 23). To conclude, the citizen's participation for environmental conservation and the future vision of the sustainable Shiga Prefecture are introduced in Sects. 7.2.5 and Topic 24.

7.2.1(1) Shiga Prefectural Government Measures for the Conservation and Restoration of Common Reed Marshes: Ordinance on the Conservation of Reed Beds around Lake Biwa

Yuko Kaneko · Minako Ashiya

Abstract The area of reed marsh around Lake Biwa has been declining since 1948. The Shiga prefectural government has now enacted an ordinance to address this, as reed marshes are effective in sustaining the habitats of various living organisms, protecting the lakeshore from erosion, and maintaining good water quality. The three purposes of the ordinance are as follows: (a) to protect reed beds, the Shiga prefectural government has been promoting the conservation of reed communities by designating areas as "reed community conservation areas"; (b) to nurture reed beds, various efforts are being made to recover lost and declining reed beds, including reed planting and performing regular trimming and cleaning; and (c) to utilize reeds and reed beds, the Shiga prefectural government has been attempting to increase the demand for reeds as a material for new products. However, some problems requiring improved conservation methods remain to be solved before sustainable reed communities and ecosystems are possible.

Keywords Ordinance on the Conservation of Reed Beds around Lake Biwa • Reed planting

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Introduction

The area of reed marshes around Lake Biwa has been declining since 1948 (Kaneko 2009). This has been mainly due to direct extensive and destructive causes such as the reclamation of adjacent lagoons and satellite lakes, development of lakefront areas initiated by the Lake Biwa Comprehensive Development Project, and the rapid urbanization of surrounding areas. The recent gradual decline of reed marshes is also due to factors such as environmental stresses from various anthropogenic activities including leisure usage, desilting, and invasive alien plants. Additionally, reed populations have declined due to reductions in suitable areas for their regeneration and growth caused by a lack of natural disturbance due to flood control measures in the Lake Biwa basin.

The Shiga prefectural government is challenged with finding methods for recovering riparian littoral zone ecosystems, which play significant roles in the conservation of lake ecosystems. In particular, reed marshes have attracted attention as a useful and important vegetation type with multivalent ecological and social functions for supporting biodiversity, improving water quality, and forming archetypal lakeshore landscapes, among others.

The Ordinance on the Conservation of Reed Beds around Lake Biwa

In April 1992, "The Ordinance on the Conservation of Reed Beds around Lake Biwa" was enacted and issued. The ordinance is aimed at stopping any activities that lead to the destruction of reed beds around the lake, and at

promoting the conservation of reed communities in designated areas. The Shiga prefectural government enacted this ordinance because reed marshes are effective in sustaining the habitats of various birds and fish, protecting the lakeshore from erosion, and maintaining good water quality. "Reed Beds" in this ordinance refer not only to common reed populations, but also include various species of emergent plants, such as reeds, water oats, and willows (see Sect. 3.1.2 for details).

In 1993, the first "Basic Plan for the Conservation of Reed Beds" was implemented based on the ordinance, and Lake Biwa was designated as a UNESCO Ramsar Wetland, according to the Ramsar Convention (Convention on Wetlands of International Importance Especially as Waterfowl Habitat). The Shiga prefectural government issued a partial amendment to the ordinance in December 2002. The second "Reed Beds Conservation Plan" was decided on in June 2004. The third "Reed Colonies Conservation Plan" will be issued in 2011.

The three purposes of the ordinance are as follows: (a) to protect reed beds, (b) to nurture reed beds, and (c) to utilize reeds and reed beds (Itoh 1993).

Governmental Activities to Protect Reed Beds

The Shiga prefectural government has been promoting the conservation of reed communities by designating areas as "reed bed conservation areas". The "reed bed conservation areas" include three categories: (a) "Reed Protection Areas," which "contain reed communities and ecosystems of particular importance"; (b) "Reed Conservation Areas," which "contain reed communities of considerable size"; and (c) "Ordinary Reed Areas," which are "other areas within the reed conservation areas" (*Fig. 1*).

In "reed bed conservation areas," reed beds are protected by restricting some human activities, such as developments including construction, mining, and cultivation. The planting of trees and bamboos and the use of powered boats and other vehicles are also restricted.

Governmental Activities to Nurture Reed Beds

Various efforts are being made to recover lost and declining reed beds, mainly through maintenance and restoration. Maintenance works include regular trimming and cleaning. Regular trimming is considered one of the best methods to maintain reed communities and to retain their filtration abilities.

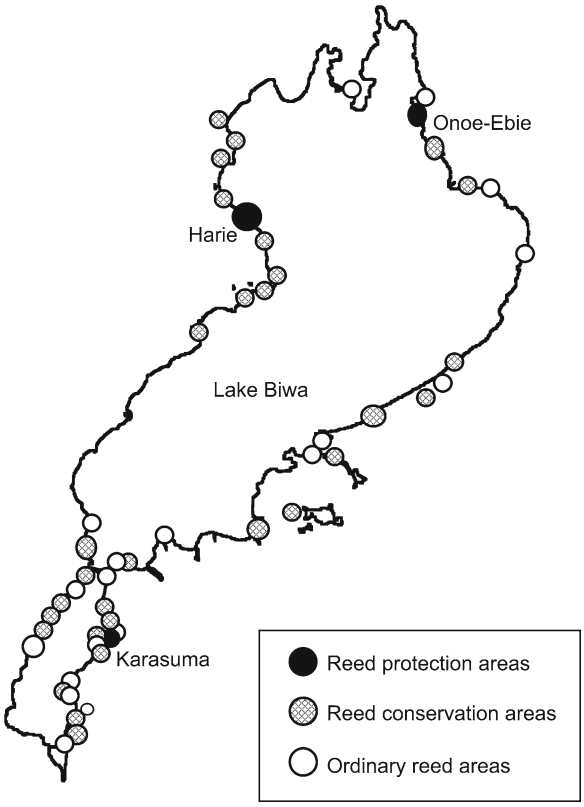

Fig. 1
Reed bed conservation areas.

Restoration works include reed planting. The area of emergent plants around Lake Biwa was 293.6 ha in 1948, but had declined to 127.5 ha by 1992 because of the reasons mentioned above. Reed planting has been carried out mainly to recover reed beds lost from the lakeshore. The total area of reeds planted by the Shiga prefectural government on the lakeshore since 1992 was 32.7 ha by the end of the 2010 fiscal year (*Table 1*, *Fig. 2*).

Governmental Activities to Utilize Reed Beds

In the Lake Biwa region, reeds have been used as an important material for traditional crafts such as reed screens and reed blinds. With the ordinance, the Shiga prefectural government has been attempting to increase the demand for reeds as a material for new products such as paper, pens, and humus, as well as traditional crafts. Research and

campaigns have been carried out to develop new products and to explore new possibilities for reeds as a material.

Using reed beds as places for nature observation and environmental education is another important component of the ordinance. Many such events have been planned and run by the Shiga prefectural government, local governments in Shiga, nongovernmental organizations, and the Omi Environment Conservation Foundation, one of the organizations affiliated with the prefectural government.

Problems to Be Solved

The ordinance has been enforced since 1992, and was revised in 2002 to strengthen penalties for the artificial destruction of reed beds. The "Basic Plan for the Conservation of Reed Beds" has also been revised twice, and the third revision will be made in 2011. Looking back on the past 19 years of this ordinance, some problems have been highlighted concerning effective actions for maintaining reed bed ecosystems in good condition.

The problems mainly lie with the second point of the ordinance—to nurture the reed beds. Regarding maintenance, the optimum frequency and location of trimming to facilitate the sound growth of reed communities has been brought into question (Kira 1992). The trimming itself is also questioned by people in the fishing industry (both fishermen and researchers) who are concerned about its impact on the spawning sites and periods of some endemic fish species. These problems are also related to water level control of Lake Biwa, which is operated by the Kinki Regional Development Bureau, Biwako Office, a branch of the Ministry of Land, Infrastructure, Transport, and Tourism. These doubts about trimming have not been discussed sufficiently or verified objectively, and more time may be needed before solutions can be proposed.

For restoration, the sites and methods of reed planting have been contentious. As the shoreline of Lake Biwa is partially surrounded by embankments and floodgates, which were built to eliminate natural reed communities, restoration sites are mainly inside the embankments. These sites have been chosen as areas where natural reed communities are located or might be formed, but the actual method of constructing suitable reed community habitat involves reclamation. Therefore, the restoration of reed beds sometimes causes the destruction of natural ecosystems in the littoral zone. Furthermore, a long history of reed utilization has promoted the superiority of clonal propagation in reed communities around Lake Biwa and inland satellite lakes.

Other problems include the selection of "reed bed conservation areas" and the planting of, mainly, clonal seedlings. Although no significant association was found between population size and the amount of genetic or genotypic diversity within a reed population (see Sect. Topic 4 for details), reed bed conservation areas are selected based on population size. In fact, the mean clonal diversity of the areas designated as reed bed conservation areas is significantly lower than that of nondesignated areas (Nishino et al. 2007; Kaneko et al., unpublished data).

Furthermore, when reed communities are restored, reed stumps or clonal shoots cultivated or taken from different reed communities are transplanted to the restoration sites. Even when restoration materials are collected from within the restoration sites, only some of the stumps or clonal shoots are cultivated from within the reed populations of restoration sites. Due to the promotion of this method of reed bed restoration, the amount of genetic diversity within a reed population and sexual reproduction among reeds has decreased in reed beds around Lake Biwa and inland satellite lakes (Isagi et al. 2005; Kaneko 2005, 2009). The reed seeds produced by sexual reproduction serve as food during the winter for many birds including rare species, for examples, the Long-tailed rose finch (*Uragus sibiricus sanguinolentus*) and the Black-faced bunting (*Emberiza spodocephala*) (Wild Bird Society of Japan, Kanagawa Branch 2007). These are the Least Concern species as identified by the IUCN Red List of Threatened Species (http://www.iucnredlist.org/apps/redlist/details/136584/0/full). More discussions are needed to determine how best to increase and restore sound natural reed communities.

Acknowledgments

We would like to thank Mr. A. Numata and Dr. T. Yoshikawa for providing us with useful information on the reed planting by the Shiga prefectural government and on the bird species that eat the seed of reed, respectively.

Table 1

Reed planting by the Japan Water Agency and the Shiga prefectural government

Organization	Year	1984	1985	1988	1989	1990	1992	1993	1994	1995
Incorporated Administrative Agency, Japan Water Agency, Lake Biwa Development Integrated Operation & Maintenance Office	Planting area (ha)	0.340	0.370	0.890	0.280	0.685	0.365	–	–	–
	Number of locations	1	3	6	2	3	2	–	–	–
	Kinds of plantlets[a])	S	S	S	S	S	S	–	–	–
Shiga prefectural government, Department of Lake Biwa and the Environment, Natural Environment Conservation Division	Planting area (ha)	–	–	–	–	–	0.043	1.007	0.970	0.658
	Number of locations	–	–	–	–	–	1	3	4	5
	Kinds of plantlets[a])	–	–	–	–	–	T	T	S, C	C, S
Shiga prefectural government, Department of Public Works and Transportation, River and Port Division	Planting area (ha)	–	–	–	–	–	–	–	0.800	–
	Number of locations	–	–	–	–	–	–	–	1	–
	Kind of plantlets	–	–	–	–	–	–	–	–	–
Shiga prefectural government, Department of Agriculture and Fisheries, Fisheries Management Division	Planting area (ha)	–	–	–	–	–	–	–	–	–
	Number of locations	–	–	–	–	–	–	–	–	–
	Kinds of plantlets[a]	–	–	–	–	–	–	–	–	–
Total		0.340	0.370	0.890	0.280	0.685	0.408	1.007	1.770	0.658

[a]*S* seedlings producted from mature seeds; *T* mature plants transplanted from the other place nearby; *C* cutting-propagated clonal plantlets

1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
–	–	–	–	–	–	–	–								2.930
–	–	–	–	–	–	–	–								17
–	–	–	–	–	–	–	–								
0.250	0.620	0.330	0.250	0.190	0.180	0.210	0.05	0.07	–	0.025	0.025	0.025	0.03	0.9	5.833
3	3	2	2	1	1	1	1	1	–	1	1	1	2	1	34
C, S	C, S, T	C	C	C	C	C	C	C	–	S	S	S, C	S, C		
–	0.150	–	0.14	–	0.328	0.410	0.170	0.765	–	0.19	–	–	0.15	0.15	3.103
–	1	–	1	–	2	1	1	1	–	1	–	–	1	1	10
–		–		–	C, T	C	C	C	–	C	–	–	C	C	
0.400	1.500	1.600	2.300	1.000	2.000	1.800	2.400	2.100	1.600	1.300	1.200	2.000	1.600	1.000	23.800
1	2	2	2	1	1	2	2	2	1	1	1	1	1	1	21
		C	C	C	C	C	C	C	C	C	C	C	C	C	
0.650	2.270	1.930	2.550	1.190	2.508	2.420	2.620	2.935	1.600	1.325	1.225	2.025	1.630	2.050	35.666

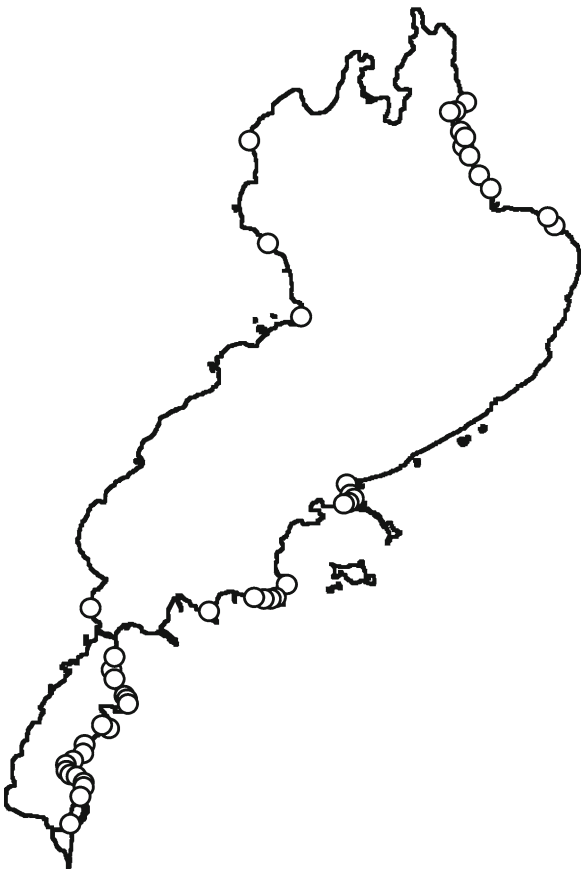

Fig. 2
Reed planting locations.

7.2.1(2) Loss and Reestablishment of Water Networks comprising Rice Fields, Waterways, and Lake Biwa: Implications for Fish Populations

Masayoshi Maehata

Abstract A summary is provided of recent studies on fish species that hatch and undergo their early growth in the waterfront rice fields of Lake Biwa, and the role of these rice fields as spawning and nursery grounds for lacustrine fishes is explained in detail. The original fish spawning sites, such as natural lakeshores and attached lakes, largely have been lost to development in recent decades; therefore, reestablishing the fish-nurturing function of the rice fields will be important for the restoration and conservation of these lacustrine fishes.

Keywords Lacustrine fishes • Rice fields • Network • Nursery grounds • Land consolidation

Introduction

Around 40–50 years ago, a large number of fish, especially crucian carps (Funa-rui, *Carassius* spp.), common carp (Koi, *Cyprinus carpio*), and Far Eastern catfish (Namazu, *Silurus asotus*) would swim up the waterways from Lake Biwa to enter the rice fields for spawning during the rice-planting season, which at that time nearly coincided with the rainy season (mainly May to June). People used to catch and eat these fish as side dishes (Imamori 1996; Kada 2001). Nowadays, such scenes are observed only in very limited areas, because the lacustrine fish population has decreased, and fish are unable to enter the rice fields any more as a result of the nationwide implementation of land consolidation projects over the past several decades (Maehata 2004).

In Lake Biwa, the fish population has dramatically decreased during the past several decades (see Sect. 2.5), and loss of the once pervasive water network comprising rice fields, waterways, and Lake Biwa is considered to be one of the causes of this decline (Maehata 2004). Here, summarized from recent literature, the present condition of the lacustrine fishes and the roles that rice fields play in their life history are described. Methods for reviving the vanishing fish populations are also discussed.

Fishes Occurring in Lakeside Rice Fields During the Rice-Planting Season

Recent studies conducted at two sites representing the waterfront rice fields of Lake Biwa (*Fig. 1*: sites A and B) showed a total of 15 species/subspecies of fish occurring in and around the rice fields during the irrigation season of April–August (*Table 1*) (Maehata et al. 2001, 2002; Maehata 2007a). At site A, where land consolidation was not yet implemented, fish were able to enter the fields from canals and ditches via both the water inlet and the drain outlet. At site B, however, the entry of fish was blocked by the significant elevation gap introduced between the waterways and the rice fields as a result of the implementation of land consolidation. Among these 15 species/subspecies, five of them, that is, common carp, round crucian carp (Nigoro-buna, *C. auratus grandoculis*), silver crucian carp (Gin-buna, *C.* sp.), oriental weatherloach (Dojo, *Misgurnus anguillicaudatus*), and Far Eastern catfish, were presumed to utilize rice fields as their spawning and nursery grounds.

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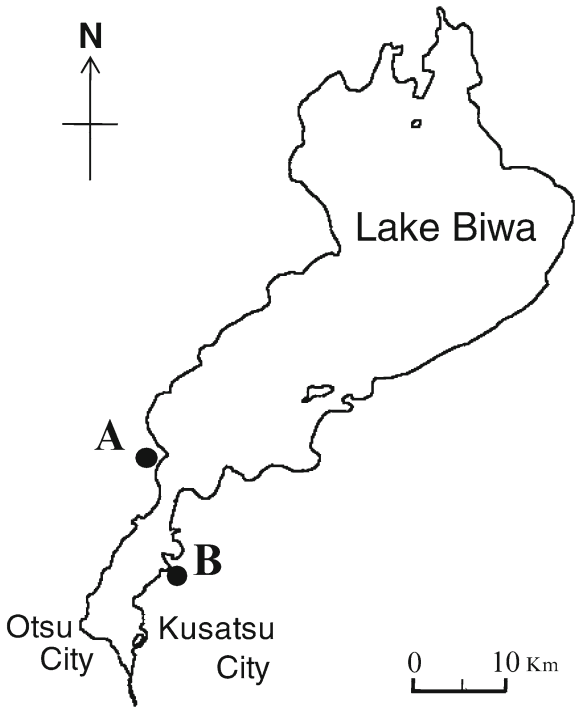

Fig. 1
Study sites. (a) Imajuku, Otsu City, (b) Oroshimo-cho, Kusatsu City.

Spawning behavior of adult fish of these species was observed, and their eggs, larvae, and fingerlings were caught in the rice fields (Maehata et al. 2002). All five were observed in rice fields at site A, but not at site B, where the fish were found only in nearby waterways, as expected. Except for oriental weatherloach, all the fish were presumed to have come from Lake Biwa (Maehata et al. 2002).

Adults of two of the remaining species, namely the Japanese rice-fish (Medaka, *Oryzias latipes latipes*) and northern snakehead (Kamuruchi, *Channa argus*), were also found in rice fields, but were not observed to reproduce there. Japanese rice-fish is observed to spawn and grow in rice fields elsewhere (Maehata, unpublished); the reason for not observing such behavior at the present site could be the small number of individuals found (*Table 1*). The remaining eight species/subspecies were ayu fish (Biwa ayu, *Plecoglossus altivelis* subsp.), flat bitterling (Kanehira, *Acheilognathus rhombeus*), pale chub (Oikawa, *Zacco platypus*), dark chub (Kawa-mutsu, *Nipponocypris temminckii*), largemouth bass (Okuchi-basu, *Micropterus salmoides*), orange-type freshwater goby (To-yoshinobori, *Rhinogobius* sp. OR), floating goby (Uki-gori, *Gymnogobius urotaenia*), and Biwa sculpin (Utsusemi-kajika, *Cottus reinii*). These were considered to have come into the rice field areas not to spawn, but to obtain food in the surrounding area and waterways (Maehata et al. 2002).

Potential Reproductive Capacity of Fishes in the Rice Fields

Several investigations have been conducted to ascertain the potential reproductive capacity of fishes and their growth rate in rice fields bordering Lake Biwa (Ueno et al. 2002; Maehata 2007a; Kanao et al. 2009).

In a small rice field of 1,365 m^2 with its drain outlet improved to let adult fish enter freely, it was confirmed by trapping that a total of 759 individuals of juveniles of six species/subspecies of fish were bred. Except for the freshwater goby, the remaining six species/subspecies (silver crucian carp, round crucian carp, common carp, Far Eastern catfish, oriental weatherloach, and Japanese rice-fish) naturally grew there (*Fig. 2*) (Maehata 2007a). In another case, for an evaluation of fecundity, 10 adult round crucian carp (4 females and 6 males) were released into a field of 2,700 m^2 after the rice had been planted, and more than 40,000 juveniles (average standard length of 2–3 cm) were observed there afterwards (*Fig. 3*) (Maehata 2007a). It is notable that both the survival and growth rate of round crucian carp larvae reared in rice fields for about 1 month were very high compared to those reared in artificial ponds or under natural conditions. This was attributed to the low predation pressure in the rice fields and abundance of available food there (Ueno et al. 2002; Kanao et al. 2009).

These studies furthermore demonstrated that, if there is no elevation gap between the waterways and the fields so the adult fish could enter and exit freely, rice fields are highly preferred by fish as spawning and nursery grounds. In addition, as shown by the fecundity study cited above (Maehata 2007a), even in fields not accessible to adult fish due to an elevation gap, the fish population can be increased by artificially releasing adult fish or fish larvae into the rice fields (Maehata 2007a).

Conclusion

Around the shore of Lake Biwa, it is well-known that several species of lacustrine fish, for example, round crucian carp, silver crucian carp, common carp, and Far Eastern catfish, swim up from Lake Biwa to spawn in rice fields after rains during the rice-planting season (Nakamura 1969; Imamori 1996; Maehata 2001, 2007a, b). In wide areas of Asia including Japan, many freshwater fish spawn at newly

Table 1

Fishes occurring in two rice field areas facing Lake Biwa, with reference to their breeding in the rice fields

Japanese name	English name (Scientific name)	Site A			Site B	
		Adults	Eggs/larvae / immature	Breeding in rice fields	Adults	Eggs/larvae /immature
Ayu	Biwa ayu, Ayu fish (*Plecoglossus altivelis* Subsp.)	-	++	no	-	-
Kanehira	Flat bitterling (*Acheilognathus rhombeus*)	-	+	no	-	-
Oikawa	Pale chub (*Zacco platypus*)	-	+	no	-	-
Kawa-mutsu	Dark chub (*Nipponocypris temminckii)*	-	+	no	-	-
Koi	Common carp (*Cyprinus carpio*)	-	+	yes	+	+++
Gin-buna	Silver crucian carp (*Carassius* sp.)	++		yes	++	
Nigoro-buna	Round crucian carp (*C. auratus grandoculis*)	++		yes	+	
Funa-rui no yogyo (larvae of *Carassius* spp.)[b]			+++			
Dojo	Oriental weatherloach (*Misgurnus anguillicaudatus*)	+++	+++	yes	++	+++
Namazu	Far Eastern catfish (*Silurus asotus*)	+++	+++	yes	++	+++
Medaka	Japanese rice-fish (*Oryzias latipes latipes*)	+[c]	-	no	-	-
Okuchi basu[a]	Large-mouth bass (*Micropterus salmoides*)	-	++	no	-	+[c]
Kamuruchi[a]	Northern snakehead (*Channa argus*)	+	+	yes	-	+[c]
To-yoshinobori	Freshwater goby (orange-type) (*Rhinogobius* sp. OR)	++	+++	no	-	+++
Uki-gori	floating goby (*Gymnogobius urotaenia*)	-	+	no	-	-
Utsusemi-kajika	Biwa sculpin (*Cottus reinii*)	-	+	no	-	-

[a] Introduced species from inside or outside of Japan

[b] *Carassius* sp. and *C. auratus grandoculis*

[c] Single individual

-: no fish, +: under 10 individuals, ++: 11-99 individuals, +++: more than 100 individuals. Data cited from Maehata (2007a)

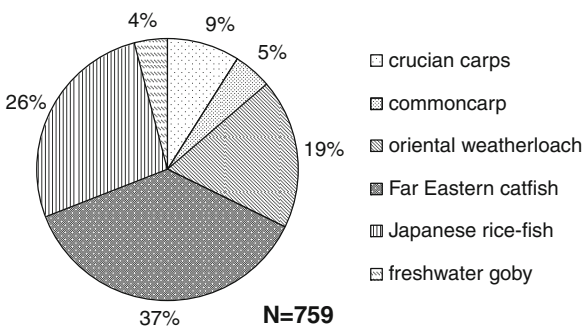

Fig. 2

Proportions of fish larvae bred in a rice field at Site A that adult fishes could freely enter and leave. Cited from Maehata (2007a).

submerged sites formed by floodwaters after rain (Lowe-McConnell 1975, 1987; Alkins-Koo 2000). This sort of reproductive habit is presumed to have been evolved as an adaptation to the Asian Monsoon climatic regime with its distinct rainy season.

The original spawning sites of these fishes would have been the natural shores of inlets and attached lakes, which are often submerged by rising water after rainfall. During the past 40–50 years, however, the potential natural spawning sites have been extremely reduced around Lake Biwa as a result of the drainage of many attached lakes and the construction of embankments along the shores of Lake Biwa (Yamamoto and Yuma 1999; Imai et al. 1999; Yuma 2001). The rice fields, which did not exist before rice cultivation was brought to Japan, might

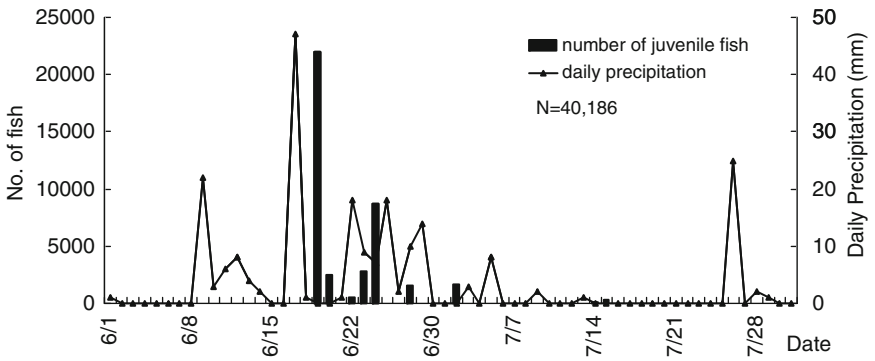

Fig. 3
Temporal changes in precipitation and numbers of *Carassius auratus grandoculis* caught by a fishnet set at the drain outlet of a rice field at Site A. Cited from Maehata (2007a).

have served as an alternative to the natural spawning and nursery grounds for these fishes, if they had remained accessible to the fish. Unfortunately, access to these alternative spawning sites has also been greatly diminished. A significant elevation gap between the irrigation waterways and the rice fields has become standard as a result of the implementation of land consolidation projects during the past several decades all over Japan, including the Lake Biwa area (Saito 1997; Yamamoto and Yuma 1999; Hata 1999). Rice fields accessible to many fish have thus become very few, and the reproductive capacity of these fishes has, in consequence, been seriously affected. Under such circumstances, the restoration of the function of rice fields as spawning and nursery grounds for lacustrine fishes is highly desired. This would help to conserve not only the fish, but ultimately the entire Lake Biwa ecosystem and the various unique cultures formed through long-term human interaction with the lacustrine environment and the natural resources it provides.

7.2.1(3) Water Level Management Trials for Conserving the Lake Biwa Ecosystem

Masayoshi Maehata · Kunihiro Moriyasu

Abstract Management of the water levels of Lake Biwa is operated in accordance with 'the Regulation for Seta River Weir operation' established in 1992, and is one of the achievements of the Lake Biwa Comprehensive Development Project. It has been pointed out that this management of water levels affects survival rates of fish eggs, especially those of cyprinid fishes, which spawn from spring to early summer in the reedbeds along the lakeshore. Therefore, in 2004 the administrative body in charge, the Biwako Rivers Office, organized the "Working Group for Making Improvements to the Water-ecotone". The aims of the working group were to find ways to manage water levels that result in a higher survival rate of fish eggs, and then manage water levels on the basis of the results obtained by the group. As a result, effective management methods for eggs of some fish species have been developed, but the methods are not effective for other fish species. Development of more effective operation methods for controlling water levels for the benefit of all the lake's fish species and eventually the Lake Biwa ecosystem as a whole, are needed.

Keywords Cyprinid fishes • Fish eggs • Water level management • Survival rate • Seta River Wier

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Introduction

As already mentioned in Sect. 2.5, total fish catches from Lake Biwa have drastically decreased since the beginning of the 1990s. Various factors, such as destruction of fish spawning and nursery grounds, increase of nonindigenous fish species, and overfishing, are widely considered to be causes of the decline of the fish catches, but the control of water levels is also a factor (Yamamoto and Yuma 1999). In Lake Biwa, trials of water level management methods to find the best ways for mitigating negative effects to fishes and conserving the Lake Biwa ecosystem have been carried out by the Ministry of Land, Infrastructure, Transport, and Tourism of Japan (MLIT), since 2004.

In this paper, the methods and the results of the trials, and outstanding issues are described in detail.

What Is the Problem with Water Level Controls?

The control of water levels of Lake Biwa has been performed for more than 100 years by operation of the Nango Araizeki Weir (constructed in 1905) and its successor, the Seta River Weir (constructed in 1961; "Setagawa Araizeki" in Japanese), installed on the Seta River, the only natural outlet of the lake (see Profile of Lake Biwa). In 1992, the "Regulation for Seta River Weir Operation," which had not been established until then, was newly introduced by its administrator, MLIT, for the purpose of preventing flood damage and making use of the lake's water. Of course, the regulation was established on the basis of agreements by both upstream and downstream residents. According to the regulation, the water level is to be maintained at B.S.L. (Biwa-ko Surface Level) +30 cm from October 15 to June 14, B.S.L. −20 cm from June 15 to August 31 (corresponding to the rainy season), and B.S.L. −30 cm from September 1 to October 14 (corresponding to the typhoon season) (*Fig. 1*). The spawning seasons of the lake's fishes mostly

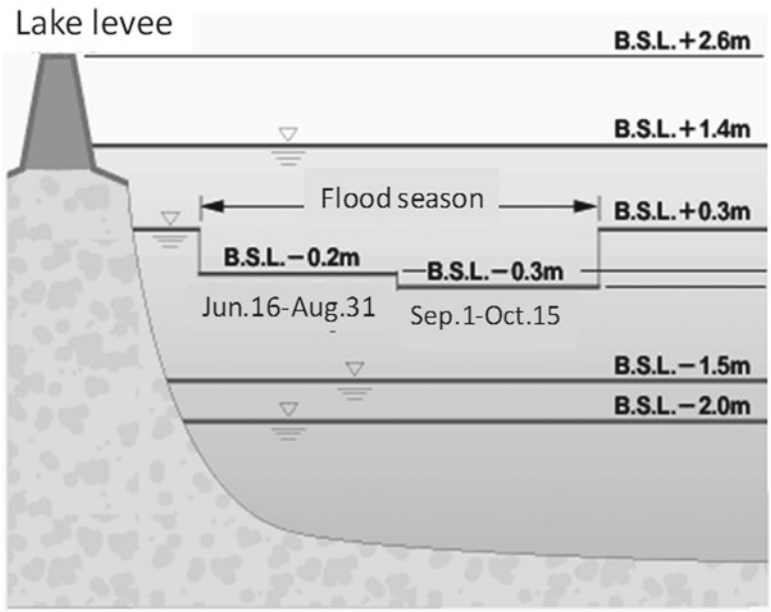


Fig. 1
Planned water levels of Lake Biwa. B.S.L.: Biwa-ko Basic Surface Level (±0 cm). (Partially altered, from HP by Japan Water Agency, Lake Biwa Development Integrated Operation & Maintenance Office).

occur from April to July. The rapid dropping of water levels by operation of the Seta River Weir causes the eggs of some cyprinid fishes, especially crucian carps, "funa-rui" (*Carassius* spp.), common carp, "koi" (*Cyprinus carpio*), and willow minnow, "hommoroko" (*Gnathopogon caerulescens*), which spawn at the paralimnion, to dry up and die. Of these fishes, crucian carps and common carp have a habit of spawning in reed beds when the water level of the lake has risen after rainfall. Willow minnows have a habit of spawning mainly in the vicinity of willow tree roots exposed under water, regardless of rainfall. As eggs of these species have a characteristic of adhering to substrates, they can end up above the water, if the water levels drop (*Fig. 2*). The stem of this problem arises from a mismatch between management of the lake's water levels and spawning habits of fishes.

Trials of Operation of the Seta River Weir to Mitigate Fish Eggs' Loss

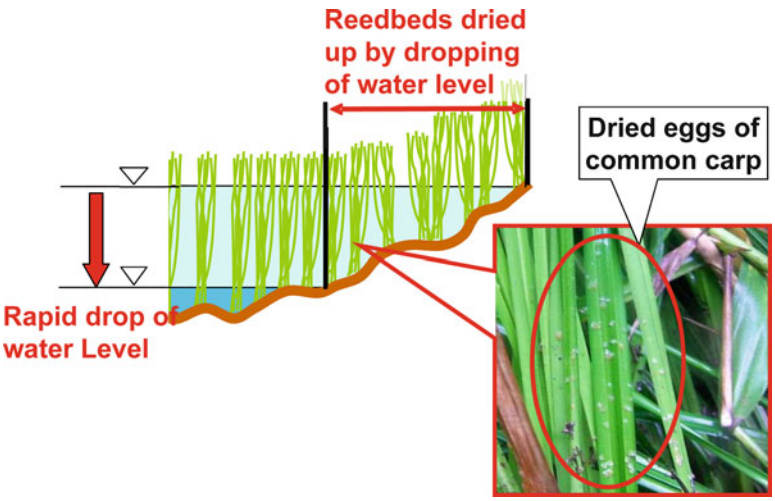
Since 2004, the direct administrator of Lake Biwa water levels, the Biwako Rivers Office, belonging to the Ministry of Land, Infrastructure, Transport, and Tourism of Japan, has been conducting trial experiments of operation of the Seta River Weir in order to mitigate negative impacts to the Lake Biwa ecosystem, especially the death of fishes' eggs, in cooperation with the Japan Water Agency and Shiga Prefecture. In 2004, they first set up two monitoring sites at the margin of the north basin, at Harie in Takashima City and Ensho-ji in Nagahama City, and in 2006 added one more monitoring site, at Shin-hama in Kusatsu City, at the southern margin of the lake (*Fig. 3*), to observe effects of water level management.

In 2004, they organized the "Working Group for Making Improvements to the Water-ecotone (WGIW)" consisting of five people, to investigate effective operation methods of the Seta River Weir to decrease the number of fish eggs that dry up. Since then, WGWI has continued to discuss ideal management methods of the lake water levels by trials and errors (*Fig. 4*), on the basis of the results of operation trials of the weir in each year.

The percentages of fish eggs drying up at the two northern monitoring sites over three periods (i.e., the first period, April 1 to May 10; the second period, May 11 to June 15; and the third period, June 16 to August 31), were analyzed for two groups of fish (i.e., the first group—crucian carps and common carp, second group—willow minnow). According to the results, the percentage of eggs of the first fish group that dry up during the first and second periods rapidly declined from 2004 to 2005, and has been kept at low levels since then (*Fig. 5*). On the other hand, the percentage of eggs of the second group (i.e., willow minnow) that have dried up has not

Fig. 2
Monitoring sites of eggs of cyprinid fishes in Lake Biwa.

Fig. 3
Eggs of crucian carps and common carp drying up after a rapid drop of the lake's water level.



decreased at all in spite of various trials. Therefore, it is important to clarify the spawning habitat (ecology) of the willow minnow in greater detail, and investigations into suitable methods of water level management to prevent drying up of the eggs of all fish species should be continued in the future.

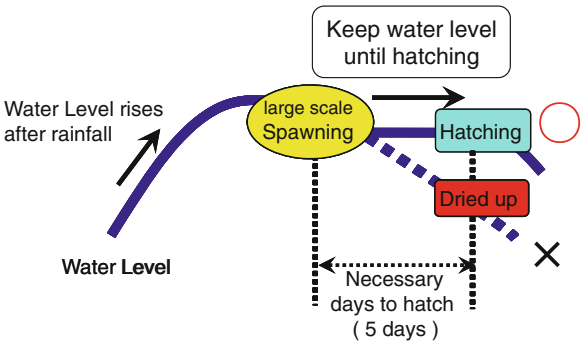


Fig. 4
Trial operation of the Lake Biwa Water Level to conserve fish eggs. When a large scale spawning is found, the water level is maintained for 5 days until hatching occurs.

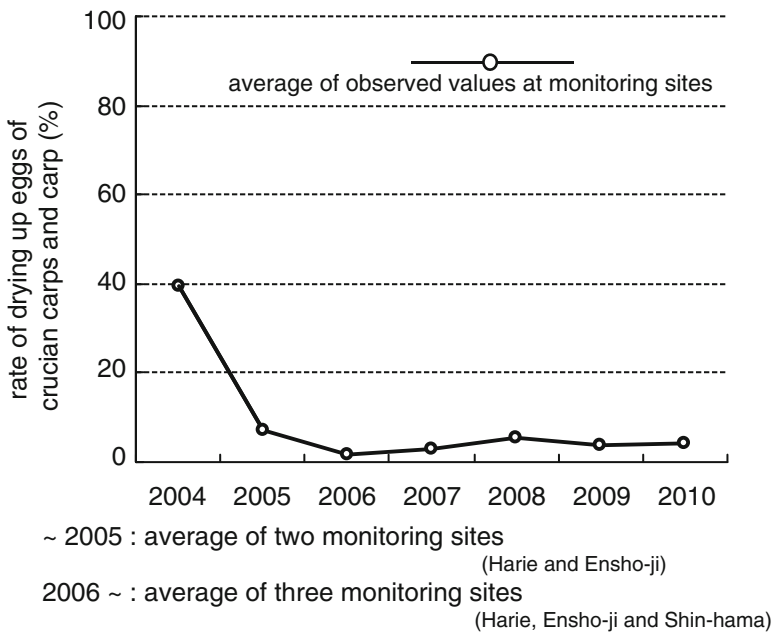


Fig. 5
Changes of the rates of eggs drying up of crucian carp and other carp (%). Values are average of observed values at the three monitoring sites in the lake (Harie in Takashima City, Ensho-ji in Nagahama City, and Shin-hama in Kusatsu City). (Data from Biwako Rivers Office 2010).

Conclusions

Nowadays, it is widely accepted that various human activities, which are introduced to make our lives rich and convenient, often have negative impacts on wildlife, nature, and eventually our lives themselves, all over the world. The water level management of Lake Biwa mentioned here is a good example; water level management is needed to prevent flood damage and to make use of the lake's water, but on the other hand it makes fish eggs dry up and negatively affects the lake's ecosystem. Water level management for the benefit of people and ways to prevent fish eggs from drying up seem to contradict each other. If the number of inhabitants in the Lake Biwa area (and in downstream areas) is few, it might be possible to stop artificial water level management in order to conserve fishes, but in reality it is impossible because a large population of more than one million live around the lake. Accordingly, the best solution of this problem is considered to find common ground between the artificial water level management and the conservation of fish eggs. In order to achieve this goal, the operation trials of the water level of the lake should be continued in the future.

7.2.2 Toward the Restoration of the Reclaimed "Hayasaki Lagoon" around Lake Biwa, Central Japan

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Abstract The Hayasaki Polder is located on the north shore of Lake Biwa, the largest lake in Japan. The Hayasaki Polder used to be a lagoon, and was the largest spawning ground of an endemic cyprinid fish, *Carrassius cuvieri*, and characterized by abundant water weeds. However, it was totally drained and changed into agricultural land in 1971. Since 2001, an area of 17 hectares of the reclaimed land has been resubmerged and biological succession was surveyed. In 2005, "The Exploratory Committee for Restoration of Hayasaki Lagoon", consisting of local residents, representatives of NPO's, local governments, ministries and agencies and scientists, was formed. The committee discussed the restoration plan of the lagoon, and compiled the final report in March 2007. The basic policy of the plan is to make full use of the regional characteristics as well as ecosystem resilience and introduce adaptive management. In the plan future goals were set, based on the biological studies of the lagoon before drainage and the monitoring results of biological succession in the resubmerged areas. Restoration goals include establishing a major stopover for migratory geese and swans, restoring the largest spawning ground in Lake Biwa of an endemic fish *C. cuvieri*, and creating a vegetation zone of various kinds of submerged macrophytes as well as plants on the flood plain. Several kinds of migratory water birds, indigenous cyprinid fishes and plant species are chosen as indicator species of restoration of the Hayasaki Lagoon.

Keywords Restoration • Biodiversity • Lagoon • Goal • Indicator species

Introduction

Lake Biwa is the largest lake in Japan, and one of the ancient lakes of the world. The Paleo-Lake Biwa was formed about 4 Ma, and the present lake originated about 400,000 years ago (Chap. 1). More than 2,400 animal and plant species have been reported so far from the lake and adjacent areas, and a total of 62 species are designated as endemic to the lake (Chap. 2).

However, the significant biodiversity of Lake Biwa has been threatened in recent years. For example, 10, 12, and 16 out of 62 endemic species were designated as endangered, threatened, and rare species, respectively, in the Red Data Book of Shiga Prefecture (Shiga-ken Ikimono Sogocyosa Iinkai 2006). Especially for the fish, 11 out of 17 endemic species were listed, indicating that the 65% of the endemic fish species are in a serious situation. Another example is that the indigenous cyprinid fish catch in 2007 was about 10% of that in 1974, the year when the maximum cyprinid fish catch of the lake was recorded.

Most of the indigenous fishes spawn in the littoral areas of Lake Biwa, lagoons located around the lake, or creeks connected to the lake. According to the Red Data Book, the major cause of the decrease in the fish catch is the reclamation of lagoons or attached lakes, or "*naikos*" in Japanese, around Lake Biwa. In 1905, the Seta Weir, a type of flood control barrage, was constructed a short distance downstream from the outlet of Lake Biwa. Since then, the water level has been successively lowered for the purpose of flood control, hydraulic power generation, and water

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supply to Kyoto, Osaka, and Kobe megalopolis located in the downstream of Lake Biwa. The mean depth of the lake had lowered about 1 m since 1905, diminishing the area and depth of the lagoons, which enabled reclamation of land from these *naikos*. In the late 1940s, lagoons or *naikos* used to comprise up to 40% of the whole shoreline of Lake Biwa, with the total area of 23.3 km^2, comprising 3.4% of the entire area of the present Lake Biwa (Sect. Topic 7). Today, 85% area of lagoons or *naikos* around the lake in 1890s has disappeared. Only 23 *naikos* have remained, with a total area of 425 ha, constituting a mere 0.6% of the present Lake Biwa area.

Other causes of the indigenous fish decrease are the farm land consolidation during 1960s–1990s, and the artificial dikes constructed during 1980s to control floods around the lake. These artificial facilities interfered with their spawning migration from the lake to the lagoons or *naikos* and paddies surrounding the lake. Recently, increase of invasive alien fishes, such as large mouth black bass *Micropterus salmoides* and bluegills *Lepomis macrochilus*, has also become serious threat to the indigenous fish community.

History of the Reclamation and Restoration of the Hayasaki Lagoon

The Hayasaki Lagoon was located at the northeastern shore of Lake Biwa and had an area of 90 ha. It used to be a bay formed by a long shore bar or sand spit, facing Lake Biwa on the northwest side (*Fig. 1*). It was shallower than 2 m, and covered with submerged and floating plants, and a well-established *Phragmites* reed zone. It used to be the largest spawning ground of an endemic crucian carp, *Carassius cuvieri*, which lays their eggs on the floating, submerged and reed plants.

In 1964, the reclamation project of the Hayasaki Lagoon started, to aid in increasing land for agricultural use. The lagoon was completely drained away in 1971. Since then, rice has been grown in the paddy fields on the reclaimed land, the Hayasaki Polder, for more than 30 years. However, with the decay of Japanese agriculture, financial problems of farmers have emerged, for example, bearing the costs of aging drainage facilities and difficulty in finding successors, etc.

Thirty years after reclamation, 17 out of the 89 ha of the reclaimed land were resubmerged by the local government of Shiga Prefecture, in November 2001 (*Fig. 2*). Since then, biological and water quality monitoring has been conducted every season, that is, four times a year. In 2005, "The Exploratory Committee for the Restoration of Hayasaki Lagoon," consisting of local residents, representatives of NPO's, local governments, ministries and agencies, and scientists, was formed. The committee discussed the restoration plan of the lagoon, and compiled "The Restoration Plan of Hayasaki Lagoon" in March 2007. This plan consists of basic principles, goals, indicator species, and constraints of the Hayasaki Lagoon restoration.

Goals of the Restoration of Hayasaki Lagoon

The Exploratory Committee set six kinds of goals for the restoration of the Hayasaki Lagoon as follows: achievement of rich indigenous fauna and flora; promotion of environmental education and studies; regional development to realize secure, affluent, and vigorous community; bringing spiritual enrichment, enjoyment, and recreational venues to people's life; preservation of local tradition as well as creation of new culture; and encouragement of various wetland restoration activities in the world. The committee had made a survey of around 383 local residents on their attitudes. They sent out a questionnaire on the restoration goals of the Hayasaki Lagoon with multiple answers allowed. It received a high response rate of 70%, suggesting a high interest of the local residents in the restoration. The questionnaire results were: 28% of the respondents agreed with the goal for rich fauna and flora, 22% for promotion of environmental education, 21% for regional development, 15% for spiritual enrichment, enjoyment, and recreational venues, 7% for preservation of local tradition and creation of new culture, and 5% for encouragement of wetland restoration in the world (*Fig. 3*). No answer was only 2%.

Indicator Species of the Restoration Goal

The basic policy of the restoration plan is to make full use of the regional characteristics, contribution to the regional development, coexistence of man and nature, to provide a model of the wetland regeneration of the world, to maximize ecosystem resilience, and to introduce adaptive management. In the plan future goals were set, based on the biological survey of the lagoon during early 1960s, just before the drainage (Biological Research Group in Lake Biwa 1966), the monitoring results of biological succession in the resubmerged areas since 2001, and interviews with local elderly people involving retired fishermen.

Indicator species were selected for riparian trees, emergent, floating, and submerged aquatic plants. For riparian

Fig. 1
Aerial photo of Hayasaki Lagoon in 1947 (From Geospatial Information Authority of Japan).

trees, a willow, an alder species, and a nettle tree were selected. *Phragmites*, a manchurian wild rice *Zizania latifolia*, and a pickerelweed *Monochoria korsakowii* were selected for emerged plants. Also, plants characteristic to the flood plain such as *Euphorbia adenochlora* were chosen. These plants require floods, that is, fluctuation in the water level to grow, and have frequently been recorded from the lagoons or *naikos* around Lake Biwa. A floating heart *Nymphoides peltata*, a frogbit *Hydrocharis dubia*, a cow lily *Nuphar japonicum* were chosen for floating-leaved plants.

For submerged plants and fishes, biological indicators were set in the early and future stages, respectively. In the early stage, *Hydrilla verticillata* and *Potamogeton maackianus*, and in the future *Vallisneria* spp. and *Najas marina* were chosen as indicators of submerged plants, respectively. For indigenous fishes, the restoration goal to be achieved within 10 years of restoration was set to the largest spawning ground of the endemic crucian carp, *Carassius cuvieri*, and *C. auratus grandoculis*. Other indicator fishes include several bitterling, whose females lay their eggs into the gills of unionid bivalves.

Fig. 2
Aerial photo of the resubmerged area of Hayasaki Polder in 2003. *Dotted area*: resubmerged area.

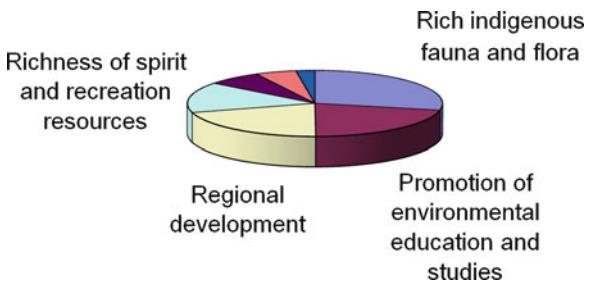

Fig. 3
The questionnaire data from the local residents on the restoration goal of Hayasaki Lagoon.

As an indicator in the future, 20–30 years later, the endemic catfish *Silurus lithophilus* was chosen. This species usually lives in the rocky bottom of Lake Biwa, but in 1960s, appeared in Hayasaki Lagoon several times, perhaps because the lagoon served as feeding ground. Another indicator species in the future is three spine stickleback, *Gastrosterus microcephalus*, which inhabits cold spring. Because there used to be several intake areas in the Hayasaki Lagoon, although there was no record of the stickleback that inhabited the Hayasaki Lagoon. Absence of the invasive alien fish species is another goal for the restored lagoon.

Hosoya (2005) classified the indigenous fishes in Lake Biwa and its watershed according to migration types.

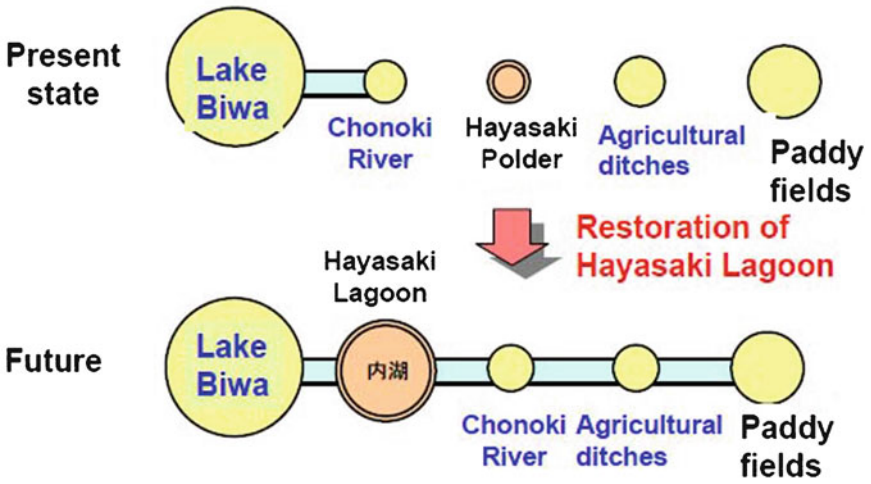

Fig. 4 Paddies-lagoon or *naikos*-Lake Biwa drainage. *Upper* present state; *Lower* after restoration of Hayasaki Lagoon.

Among them, four types of fishes, most of them being cyprinids, migrate into the lagoons or *naikos* or stay there all their lives, such migration taking place through the paddies-lagoon or *naikos*-Lake Biwa drainage. In order to recover these indicator fishes, reconstruction of the paddies-lagoons or *naikos*-Lake Biwa drainage as a combined whole is required (*Fig. 4*).

For bird species, restoration goal is set to establish a major stopover for migratory geese, dabbling ducks, a tundra Swan *Cygnus columbianus*, and a bean goose *Anser fabalis middendorfii*. Another goal is to establish a stopover for snipes and plovers, like stilt *Himantopus himantopus*, painted snipe *Rostrafula benghalensis*, pacific golden prober *Pluvialis fulva*, etc. The third goal is to provide a breeding ground for water birds in the *Phragmites* zone, such as *Fulica atra*, *Anas poecilorhyncha*, *Tachybapfus ruficollis*, etc. Fortunately, most of these water birds have already visited and exploited the resubmerged areas of the Hayasaki Polder. They have visited not only the resubmerged areas but also Lake Biwa and paddies around the lake. They utilize the former two areas as roosts and feeding grounds, and paddies as feeding grounds. Thus, combined areas of paddies-restored lagoon-Lake Biwa should be conserved as a whole for the achievement of these goals.

Constrained Conditions for the Restoration of the Hayasaki Lagoon

There are several constraints to the restoration plan of Hayasaki Lagoon. First is to keep the existing facilities around Hayasaki Polder intact, such as, fish farms, rehabilitation facilities for persons with intellectual disabilities, sewage systems of the local agricultural communities, drainage pumping stations, and a Shinto Shrine. Second is the river passing over the Hayasaki Lagoon must be kept intact, except in the restored lagoon. Third, relocation of the Pumping Station for lift irrigation into upstream. Fourth is the coastal road required to maintain the status quo.

Although the restoration plan has already been compiled, financial problems still remain, that is, land purchase, construction work, etc. Also, maintenance of the restored lagoon, regional development, and involvement of the local residents remain to be solved.

Acknowledgment

We are indebted to all the members of "The Exploratory Committee for Restoration of Hayasaki Lagoon" for their valuable discussions on the restoration plan.

7.2.3 The Explosive Development and Control of Aquatic Weeds

Etsuji Hamabata · Shigenori Sugimura · Kanako Ishikawa

Abstract Submerged macrophyte communities are an important constituent in an aquatic ecosystem, and they play an important role in maintaining good water quality and providing fish juveniles with a place for growth. However, the submerged macrophyte, which was formerly used as fertilizer around Lake Biwa, is presently only seen as being a nuisance. Submerged macrophytes must be properly managed and fundamental research on the succession of aquatic plant communities must be carried out.

Keywords Submerged macrophyte • Alien species • *Elodea nuttallii* • *Potamogeton maackianus* • *Hydrilla verticillata* • Regime shifting

Introduction

From the Edo period (sixteenth to eighteenth centuries) until the beginning of the 1900s, there were disputes about the right to crop the water macrophyte for fertilizer among the Lake Biwa lakefront villages. In the Shiga Fishery Adjustment Rule, defined in 1965, a provision was made that prohibited the extraction of submerged macrophyte during the 2 months, May and June, before the hottest summer months. It was feared that, by extracting the submerged macrophyte in large quantities as agricultural fertilizer, crucian carps (*Carassius cuvieri*, *C. auratus grandoculis*, and *C.* sp.) and willow minnow (*Gnathopogon caerulescens*) would lose their place to spawn. However, the demand for submerged macrophytes decreased with an increase in the use of chemical fertilizers, and there was no longer any need for this provision. It was also deleted from the Shiga Fishery Adjustment Rule in March 1991, because the damage by the floating mat of the water weed *Elodea nuttallii*, in its luxuriant growth stage, was prominent during these two restricted months in the early summer. Accordingly, submerged macrophyte went from being considered an important resource, to being a nursery for fish, then a nuisance in Lake Biwa. However, is it right to either protect or eliminate submerged macrophyte, which are important members of aquatic ecosystems, solely at man's convenience? While surveying the previous use and management of submerged macrophyte, we will mention areas in regard to proper management that should be taken into future consideration.

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The Invasion of Alien Water Weeds

As mentioned in Chap. 2, the *Elodea* invasion of Lake Biwa took place either in 1960 or 1961 (Ikusima and Kabaya 1965). Under favorable conditions, *Elodea* tends to form dense pure stands, which often reach a height of more than 2 m. Fully grown shoots usually detach from the lower part of the stem during the summer (mostly in July) and rise to the surface to form dense drifting mats (*Fig. 1*), while undetached shoots remain on the lake bottom (Hamabata 1997). *Elodea* was a nuisance in the swimming season in July, hindering navigation with its dense mats, and drifting ashore and causing a stench while decomposing. In response to this, the Shiga Prefectural Government has been harvesting macrophyte down to a 1.5 m depth by using macrophyte harvesters (*Fig. 2*). The trend of the harvested amounts of macrophyte is shown in *Fig. 3*. The amount harvested in 1994 was extremely large and the majority of the macrophyte was *Elodea*.

Fig. 1
Large mats of detached *Elodea* shoots floating on the water surface of the south basin (July 17, 1998).

Fig. 2
The submerged macrophyte harvester ship introduced by Shiga Prefectural Government (July 20, 1989). This harvester can clip out waterweeds from the water surface to a depth of 1.5 m.

There are not many records concerning the estimated standing crops of the submerged macrophyte throughout the whole of Lake Biwa. However, Hamabata (1997) estimated the *Elodea* crop in Lake Biwa in 1990 to be 6,500 tons (dry wt.). Since the amount harvested during 1990 was 2,865 tons (wet wt.), dry matter ratio being assumed to be 10%, that is, about 4.4% of the standing crop was harvested. The macrophyte standing stock in 1995 is estimated to have been 6,200 tons (dry wt.) (Shiga Prefectural Fishery Experiment Station 1998), and since the amount harvested in 1995 is 3,618 tons (wet wt.), if the ratio of harvested macrophyte is calculated in the same way, it

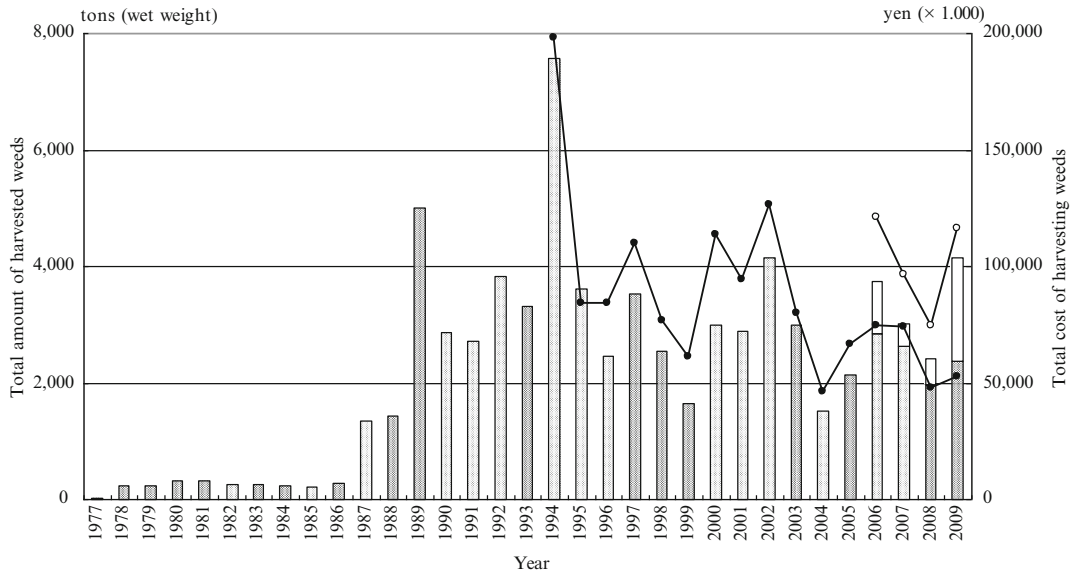

Fig. 3

Yearly trend of total amount of harvested water weeds (*bar*) and the cost (*circle*). The *filled bars* and *filled circles* show the amount harvested by the Natural Environment Conservation Division of Shiga Prefectural Government; the open bar and circle show the total of amount harvested by other divisions of Shiga precectural office and other organizations.

comes to around 5.8%. From these two examples, it is clear that the harvesting ratio during this decade was around 4–6%. However, the cost of harvesting was about 200 million yen in 1994, a great expense, and about 80 million yen annually for the last decade, a burden for the Prefectural finances.

Although the south basin was only 3.5 m in average depth, owing to eutrophication, hardly any submerged macrophyte existed before 1994. After the serious water shortage during the summer of that year, transparency gradually improved and the whole south basin came to be covered by macrophyte beds. The areas surrounding the south basin are densely populated, and, since the water weed that washes up on the lakeshore is considered a nuisance by many of the residents, in addition to water weed being harvested down to a depth of 1.5 m by harvesters, some macrophyte is removed completely from the roots. Although the trend of annual harvested amounts shown in *Fig. 3* is based on data from the Prefectural Natural Environment Conservation Division, the above-mentioned harvesting from the roots, mainly in the south basin, is independently carried out by other divisions of the Prefectural government and other organizations at an annual cost of around 40 million yen since 2006. Although the native species *Potamogeton maackianus* and *Hydrilla verticillata* and the alien species *Egeria densa* are the dominant species in the present south basin, the coverage share ratio (total of this species coverage/total of all species coverage) of *P. maackianus*, in particular, occupies 38.1%, a much greater amount than the other species (*H. verticillata*, in second place, is less than 20%), and serves as the dominant species (Japan Water Agency 2009). *P. maackianus* has high stem density and a dense subterranean root stem, although the height of the community is low compared with *H. verticillata* and other species, and is an obstacle to the navigation of fishing boats and, especially, to the gathering of shellfish. Therefore, harvesting by the roots is mainly carried out to remove *P. maackianus*.

Although the regime shifting in the south basin started with the water level decline during the summer of 1994 (Hamabata and Kobayashi 2002), extensive efforts to reduce the amount of nutrients entering the lake have been continuously made by the local government and citizens since the early 1980s. It is conceivable that the

ecosystem of the south basin has entered into the spiral that transparency improves with the increase in the number of water plants and that the number of water plants consequently increases with the increase in transparency. In other large lakes in Japan, an improvement in water quality has been slow in spite of efforts made to replant submerged macrophytes using soil containing buried seeds from other areas of the same lake (e.g., Kasumigaura). If submerged macrophytes are completely removed at some point in the future, the water quality in the south basin might potentially return to its previous muddy condition.

Changes in the Dominant Species and Prediction for Its Future

109 transect lines were prepared around the shore of Lake Biwa in 1997 (*Fig. 4*), and since then a vegetation survey has been carried out once every 5 years in the range where the water plant grows from the lakeside toward the offing of every 2 m-wide, 10 m-long quadrat (Japan Water Agency 2009). Three vegetation surveys have been carried out to present, one from 1997 to 1998, one in 2002, and one in 2007. Showing only the quadrats that were dominated (coverage 50% or more) by *H. verticillata* or *P. maackianus* (*Fig. 5*), it is clear that *P. maackianus* still maintains its dominance status in the south basin; but in the north basin, *P. maackianus* decreases with *H. verticillata* increasing after 2002.

The cause of this change in species in the north basin has still not been clarified. However, it is known that *P. maackianus* has high shade tolerance (Imamoto et al. 2007). Therefore, although *P. maackianus* is able to become the dominant species when light is insufficient owing to eutrophication, taller *H. verticillata* becomes the dominant species when the light improves and stifles the *P. maackianus*. The fact that *H. verticillata* takes the place of *P. mackianus* in the waters in the northern part of the north basin, in Lake Biwa, where the water quality is comparatively good, seems to support this hypothesis. Since it is clear that a change in species occurs owing to changes in the water quality, the possibility remains that *P. maackianus*, which is the present dominant species in the south basin, may decrease in the future. If this prediction is correct, there will no longer be an urgent necessity to remove submerged macrophyte at great cost. However, since data regarding the natural succession of aquatic plant communities owing to changes in environmental conditions, such as water quality and bottom sediment, are presently insufficient, much more research needs to be carried out to find the appropriate measures required for submerged macrophyte management.

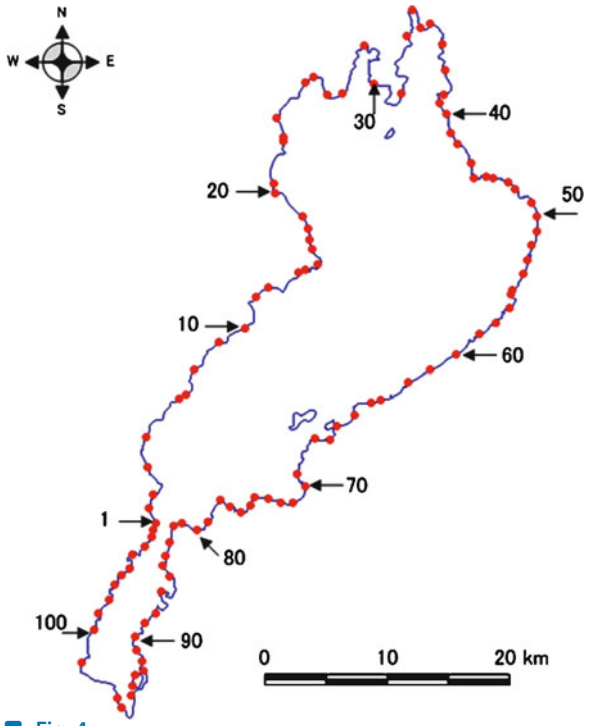

Fig. 4
Distribution map of the lake side reference points of vegetation survey transect lines.

Acknowledgments

We would like to express our sincere gratitude to the Ministry of Land, Infrastructure, Transport and Tourism Kinki Regional Development Bureau Biwako Office, the Shiga Prefectural Government Natural Environment

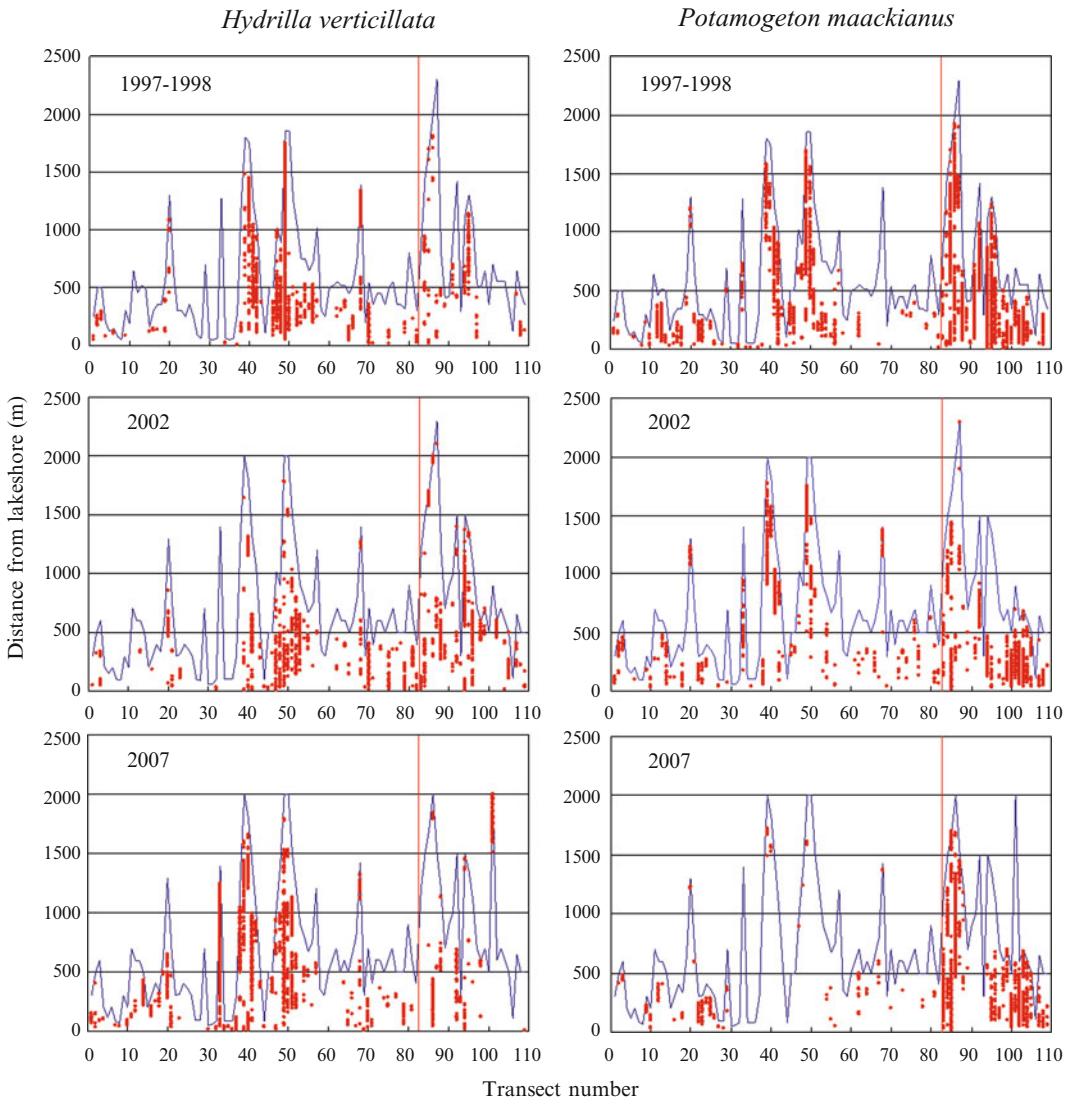

Fig. 5

Yearly changes of quadrats dominated by *Hydrilla verticillata* and *Potamogeton maackianus*. The vertical and horizontal axes, respectively, show the distance from the lakefront and the position in the shoreline as described in Fig. 4. Each *dot* shows the quadrat in which each species has 50% or more coverage.

Conservation Division, Fisheries Management Division, River and Port Division, South-Central Regional Sewerage Office and Northeastern Regional Sewerage Office, and the Hikone City Government Koto Construction Management Department, among others, who provided mowing water weed data. We appreciate Associate Professor Lynne Misaki (University of Shiga Prefecture) for her critical reading of an earlier version of the manuscript.

7.2.4 Countermeasures Against Invasive Non-indigenous Species

Katsuki Nakai

While harboring unique and rich biodiversity owing its various habitats and long geological history, Lake Biwa has experienced a variety of anthropogenic influences including adverse effects of non-indigenous species, reflecting our dense inhabitation and life-style modernization in its watershed. Representatives of such non-indigenous species are described in Sect. 3.1.5 by Nakai and Kaneko. Some of the typical "alien species issues" in Lake Biwa had become socially problematic first time in Japan, followed by the continuous countermeasures for their effective regulations and control. This section deals with such countermeasures against invasive non-indigenous species.

This section comprises of two parts. In the first part, Sect. 7.2.3(1), Nakai describes the projects, legal settings, and other activities related to regulations and control of invasive species in Lake Biwa and other parts of Shiga Prefecture. An example of the projects is the removal of aquatic weeds (macrophytes) that have excessively grown in Lake Biwa. Detailed ecological description of the macrophytes growing the southern basin is given in Sect. 3.1.4, written by Haga. The intensive efforts to suppress invasive alien fishes are recommended to be referred to other chapters related to the target fishes in Sect. 3.1.5, as well as their victims, indigenous species in Chap. 2, etc.

In the second part of this section, Sect. 7.2.3(2), Kaneko illustrates the present status and countermeasures of the six plant species that were selected as Invasive Alien Species designated by the Invasive Alien Species Act enforced in 2005.

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7.2.4(1) Regulations and Control of Invasive Non-indigenous Species

Katsuki Nakai

Abstract Lake Biwa is located in the center of Shiga Prefecture, and the lake's watershed area is almost identical to the prefecture area. In parallel with modernization of our lifestyle and economical growth, the ecosystem of Lake Biwa has suffered from various anthropogenic influences, which includes the adverse effects by invasive alien species. Excessive growth of an alien waterweed in the 1970s was the first experience of the apparent adverse effects caused by invasive alien species. In the 1980s, an explosive increase in the density of an invasive alien predatory fish, the largemouth bass, occurred, followed by another invasive fish, bluegill sunfish. Continuous efforts have been made to control these invasive alien species in Lake Biwa. In addition, in the 2000s, a series of legal settings were established, both nationally and locally, to regulate people's actions related to dealing of alien species. In recent years, volunteering activities and governmental surveys have been carried out for the purpose of strengthening regulations and improving control of invasive alien species.

Keywords Invasive alien species • Waterweed • Alien fish • Invasive Alien Species Act • Shiga

Countermeasures to Excessive Growth of Alien Macrophytes

As briefly mentioned in Haga (Sect. 3.1.5), two species of alien macrophytes, the western waterweed (*Elodea nuttallii*) and the Brazilian waterweed (*Egeria densa*), became dominant in the littoral zone of Lake Biwa in the second period (1963–1994) according to Haga's terminology. The western waterweed was first found in 1961 and subsequently spread over the littoral zone along the whole length of the lake shore, vigorously flourishing in the latter 1960s (Miura 1980). Then, appearing in the lake in 1969, the Brazilian waterweed replaced the western waterweed and became dominant, occupying 93% of the biomass of submerged macrophytes in the latter 1970s (Miura 1980). In the 1980s, the Brazilian waterweed declined and the western waterweed predominated again through the 1990s (Hamabata 1991; Nakajima and Nakai 1994).

Thick growths of macrophytes caused serious adverse effects, forming obstacles for fisheries and navigation of boats, and as odorous wastes washed up on the lakeshores. In response to a marked increase of the Brazilian waterweed, two vessels were constructed that were specialized for effective collection of submerged vegetation near the water surface. Using these vessels, Shiga Prefecture has been carrying out the weed removal program since 1974.

As shown in Haga (Sect. 3.1.5), the coverage and biomass of macrophyte vegetation in the littoral zone started increasing dramatically in Haga's third period, that is, after experiencing the lowest water level recorded (−123 cm) in 1994. The analyses of macrophyte vegetation in the southern basin showed that the total macrophyte biomass recorded was by far the highest (10,735 tons) in 2002, and that the Brazilian waterweed was ranked as the fourth most abundant. While its biomass (1,088 tons) was the highest among the values that had ever been calculated for either of the two alien waterweeds (Brazilian waterweed: 621 tons in 1974, western waterweed: 1,053 tons in 1995) in the southern basin, the Brazilian waterweed occupied only 10.1% in total macrophyte biomass. This suggests that recent growths of macrophytes characterized by predominance of indigenous species can be regarded as excessive, even compared with the past explosions by alien waterweeds.

Due to such excessive growths of macrophytes, the weed removal program in Lake Biwa has been continuously carried out. Affected by its historical background, this program is often misunderstood to be a countermeasure against alien species, because it was started as a response to excessive growths of the Brazilian waterweed, and because the excessive growth of alien waterweeds has been frequently reported thereafter. Since the purpose of

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this program is, however, to secure navigation and to reduce the amount of vegetation washed up on the shores, the target of recent operations of the program is mainly indigenous species of macrophytes. This prefectural project is administratively regarded as one of the management activities for the Lake Biwa Quasi-national Park.

Regulations of Alien Predatory Fishes

Historical Overview (Before 1999)

The largemouth bass (*Micropterus salmoides*) and bluegill sunfish (*Lepomis macrochirus*) are carnivorous fish native to North America. In Japan, largemouth bass were first introduced into the lake Ashi-no-ko in Kanagawa Prefecture in 1925. Later, bluegill was brought to Japan by the then Crown Prince of Japan as a souvenir for his official visit to the USA in 1960.

After its initial introduction to Ashi-no-ko, the largemouth bass had been confined to several water bodies as part of experimental and/or official introductions until 1970 (Kiryu 1992). On the other hand, soon after its arrival in 1960, active efforts to exploit bluegill as a fishery resource were jointly attempted by many national and prefectural fisheries experimental stations, including Shiga Prefecture (e.g., Osaka Prefectural Government 1973). But most of the attempts resulted in failure, partly because of bluegill's unusually slow growth in captivity.

In the Lake Biwa region, however, bluegill was found to be an effective host for the parasitic glochidian larvae of the Biwa pearl mussel (*Hyriopsis schlegeli*) (Furukawa and Kobayashi 1966). In the watershed, wild bluegills were first found in the attached lake Nishi-no-ko in 1965, where pearl mussels were actively cultured. After the first capture in Lake Biwa in 1968 near the mouth of a river flowing from Nishi-no-ko, bluegill rapidly established a lake-wide distribution by the early 1970s (Terashima 1980).

In the 1970s, the distribution range of the largemouth bass expanded over central and western Japan (Kiryu 1992), in parallel with growing popularity for lure-fishing as a new style of recreational fishing. In the process of its dramatic range expansion at a national scale through active intentional introductions, this fish was first recorded in the northern basin of Lake Biwa in 1974.

A sudden increase in the density of largemouth bass in Lake Biwa was noticed in 1983, which increased the anxiety about its negative impacts on indigenous fishes of great importance to the lake's fisheries. Immediate countermeasures by commercial fishermen were introduced to combat the increased bass numbers in the next fiscal year, 1984. In spite of active efforts, the largemouth bass population in the lake continuously increased to reach its peak at the end of the 1980s (Nakai 1996). The explosive increase of largemouth bass was thought to have caused an undesirable change in the littoral fish community; many fish species, especially small-sized ones, eventually decreased in abundance or even disappeared after the increase (Maehata 1993; Nakai 2003).

In 1990, the largemouth bass population appeared to start declining (Maehata 1990). However, replacing the decreasing largemouth bass, bluegill began to increase in the littoral zone, where the fish community had lost its original diversity due to serious predation impacts by largemouth bass. In 1999, Shiga Prefecture estimated the biomass of bluegills and largemouth bass in the lake to be 2,500 and 500 tons, respectively (Nakai 2003).

In response to the nationwide invasion of largemouth bass and bluegill, Director-General of the Fisheries Agency issued an official notice that all the prefectures should prohibit intentional introductions of these invasive alien fishes by an amendment to the Fisheries Adjustment Regulations in 1992. In Shiga Prefecture, long before the issue of this notice or actual invasions of bluegill and largemouth bass, its Fisheries Adjustment Regulations had prohibited introductions of aquatic organisms without the Governor's permission other than the species listed in the article. Thus, their intrusion into and establishment within the lake were unexpected as well as contrary to local regulations (Nakai 2001). To protect indigenous species as important resources and as part of the natural heritage, this kind of clean list (or white list) system, instead of a dirty list (or black list) system, should be more closely evaluated and applied to other regulations.

Intensified Projects Since 1999

Facing an explosive increase in the density of bluegill, especially in the southern basin, Shiga Prefecture decided to intensify the efforts for suppressing the invasive alien fish in the fiscal year of 1999, by increasing the annual budget to 55 million yen from 6.6 million yen in the previous year. Not only was the predominant bluegill a target, but also largemouth bass despite its decreased numbers, because it has a much stronger preference for fish and shrimp in its diet; that is, both bluegill and largemouth bass were considered to cause similar negative impacts on the resource species of the Lake Biwa fisheries (Nakai 2003).

Fig. 1
Alien fish captured in commercial fisheries. They are gathered to fisheries port to wait for arrival of a truck specialized for collecting and transporting them to a fish meal factory. The fish meal from the alien fish is used for cattle's feed and fertilizer in farmland.

In 2000, the financial support changed to a method where payment was made to fishermen in relation to the amount of alien fish caught, in order to activate incentives among commercial fishermen (Okamura 2002). The alien fish captured in commercial fisheries are collected and transported to a fish meal factory for processing them into fish powder used as fertilizer in farmland and feed for cattle. The amount of alien fish collected in commercial fisheries has gradually increased to reach as much as 400–500 tons per year (Tsutsumi et al. 2008).

In addition to suppression efforts by commercial fisheries, Shiga Prefecture proposed to prohibit the "release" of invasive alien fishes captured in recreational fishing in Lake Biwa by enacting a new local ordinance in 2002. This proposal faced strong objection from interest groups that had been benefiting from the presence of naturalized largemouth bass in the lake, because "catch-and-release" was the custom in Japanese bass fishing, and its prohibition was regarded as a restriction of freedom. The most numerous opinions (ca. 22,000) were submitted to the prefecture government in the period of public consultation, most of which were objections against prohibition of "catch-and-release." On the other hand, there were no objections in the replies of a questionnaire answered by selected persons of authority or specialty, 95% of which were positive to the prohibition. Finally, Shiga Prefectural Assembly unanimously agreed the draft of a new ordinance to regulate leisure activities in Lake Biwa, including prohibition of the release of alien species, which was put into effect in April 2003.

To facilitate "no release" of captured fish, in compliance with the prohibition in the ordinance, wooden boxes and floating mesh-cages (60 boxes and 30 mesh-cages in 2009) for collecting the fish caught in recreational fishing were set along the lakeshores. Reevaluation of the ordinance in 2006 resulted in expanding the "no release" area to cover all the prefectural area. In the initial 5 years of the ordinance, until 2007, a campaign to disseminate the idea of "no release" was carried out, in which locally effective 100 yen tickets were issued as reward for every 500 g of the alien fishes brought to exchange stations. In the second year of this campaign, 2004, the amount of alien fish collected in recreational fishing totaled 40.4 tons, either thrown in boxes and cages (11.9 tons) or brought to exchange stations with reward tickets (28.5 tons), which is about one tenth of the amount caught in commercial fisheries. Even after the rewarding campaign, the amount collected in boxes and cages has been continuously increasing, reaching 18.2 tons in 2009, which is almost double the 9.6 tons collected without rewarding in 2003 at the beginning of the campaign *Fig. 2*.

Shiga Prefecture has annually estimated the biomass of bluegill and largemouth bass in Lake Biwa since 2003. In 2003, the estimated value for bluegill and largemouth bass was 2,500 and 500 tons, respectively, equal to preliminary estimates in 1999. The biomass of both species has been decreasing year by year, and the most recent estimation in April 2009 was 1,100 tons for bluegill and 300 tons for the largemouth bass; about a half of their initial values.

Fig. 2
A wooden collection box (*left*) and a floating mesh cage (*right*) to collect alien fish from volunteering anglers.

Such a decreasing tendency in biomass can be ascribed to the active suppressing efforts both in commercial fisheries and recreational fishing.

Legal Setting for Alien Species Control

Selection of Invasive Non-indigenous Species

Shiga Prefectural Government published the local Red Data Book in the fiscal year 2000 (Shiga Prefectural Government 2000). In addition to categorization of indigenous endangered species, this version adopted a category for nonindigenous species, that is, "alien or translocated species that negatively impact ecosystems." In this category for invasive nonindigenous species, 34 animal species were selected; 11 mammals, 1 amphibian, 1 reptile, 5 insects, 7 fishes, 7 mollusks, 1 crustacean, and 1 other invertebrate. Among them, a total of 19 species are aquatic or amphibious species, not including 10 mammal and 5 insect species. Some were confirmed as species that had successfully naturalized, and others were considered to be able to do so and had already been recorded in Shiga Prefecture.

It is unusual that the red data book should cover nonindigenous species, even though they are regarded as

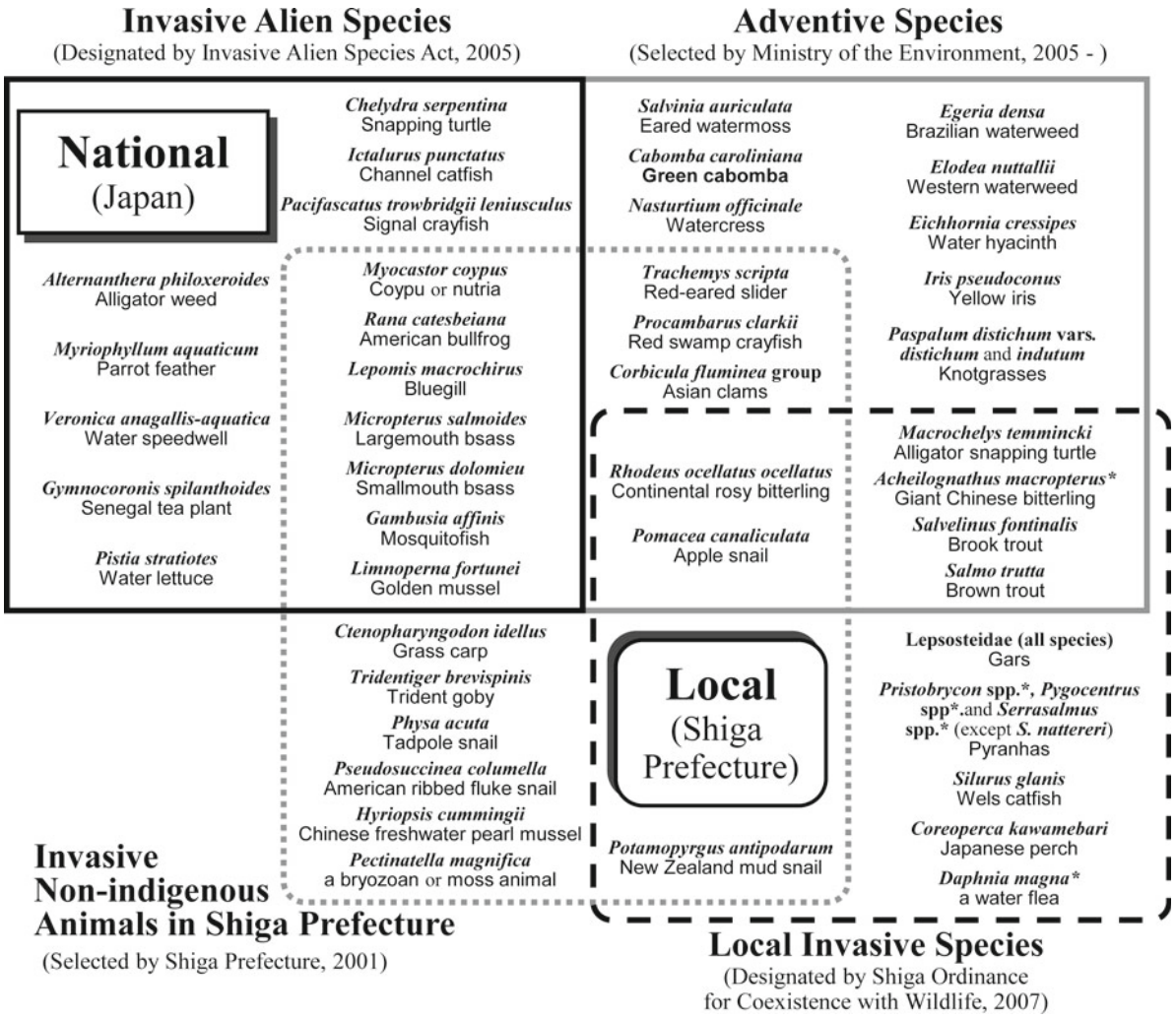

Fig. 3

Relationship between national and local regulations for aquatic or amphibious invasive species in Shiga Prefecture. For Invasive Alien Species and Adventive Species, only the taxa naturalized within Shiga Prefecture are listed, whereas all the aquatic or amphibious species are listed for Local Invasive Species, irrespective of the presence of records in the wild. Invasive Non-indigenous Animals in Shiga Prefecture was selected in Shiga Prefecture Government (2000).

significant threats to red data book species in need of conservation. This uniqueness can be attributed to local public concerns about invasive influences by nonindigenous species, which might have been stimulated by intensive efforts for suppressing invasive alien fishes and macrophytes *Fig. 3*.

Invasive Alien Species Act (2005)

Facing a variety of negative impacts caused by alien species, the "Invasive Alien Species Act" was enforced in June 2005, in which Invasive Alien Species (called "IAS," hereinafter) are stipulated as a target for strict regulation. With high penalties in case of violation, this law prohibits a series of human actions responsible for expanding distribution ranges of the designated IAS, that is, importing, keeping, transporting, releasing, etc. By the end of 2009, a total of 97 taxa (85 animals and 12 plants) are selected as the designated IAS, about a half of which (40 animals and 7 plants) are aquatic amphibious taxa. In addition to IAS, the Ministry of the Environment, Japan selected Adventive Species to arise the public concern and awareness of the other alien species which are not selected as IAS but are required special attention in their treatment *Fig. 3*.

Among amphibious tetrapod IAS, the American bullfrog (*Rana catesbeiana*) is the only species established widely in floodplains, irrigation canals, creeks, attached lakes, and the shores of Lake Biwa itself (see Sect. 2.6), whereas the coypu or nutria (*Mycocastor coypus*) and the snapping turtle (*Chelydra serpentina*) are the other tetrapods whose capture and observation have been occasionally reported in and around the lake. Although their establishment has not been confirmed yet in Shiga, we should be anxious about their success in invasion, considering the establishment of coypus in Kyoto and Gifu Prefectures adjacent to Shiga and the establishment of snapping turtles in Chiba Prefecture next to Tokyo, similarly located in a temperate part of Japan.

Among fish and aquatic invertebrate IAS, the largemouth bass, bluegill, and golden mussel (*Limnoperna fortunei*) have established populations in Lake Biwa and its outlet, the Seta River (Nakai 1996). The largemouth bass and bluegill inhabit a variety of other water bodies in the watershed as well, such as rivers, irrigation ponds, and reservoirs (Uonokai 2005). The smallmouth bass (*Micropterus dolomieu*) and the channel catfish (*Ictalurus punctatus*) have been captured in Lake Biwa several times since 1995 and 2001, respectively. Both IAS fishes can be regarded as immediate threats: the smallmouth bass was found to have established populations in at least three reservoirs in the watershed of Lake Biwa, whereas plural individuals of the channel catfish were captured together in the Seta River, in 2009. Two other IAS, the mosquito fish (*Gambusia affinis*) and the signal crayfish (*Pacifastacus leniusculus*), are established in the watershed. Both species have restricted ranges and have never been recorded within the lake up to now (Biwa-ko Bunka-kan 1980; Uonokai 2005).

Among the plant IAS, the parrot feather (*Myriophyllum aquaticum*) is a submerged plant found in shallow bays, attached lakes, and canals near Lake Biwa (Nakai and Hamabata 2002). In recent years, a floating plant, the water lettuce (*Pistia stratiotes*), and two emergent plants, alligatorweed (*Alternanthera philoxeroides*) and the Senegal tea plant (*Gymnocoronis spilanthoides*), were found in and around Lake Biwa at the early stage of invasion. Water speedwell (*Veronica angallis-aquatica*) and the bur cucumber (*Sicyos angulatus*) are also found on the water-front of Lake Biwa, attached lakes, creeks, and inflowing rivers. Detailed descriptions of these species are provided by Kaneko (Sect. 7.2.3).

Shiga Ordinance for Coexistence with Wildlife (2007)

Shiga Prefecture enforced a new ordinance for coexistence with wildlife in 2007, including both conservation of endangered species and control of invasive nonindigenous species. The framework for regulations of nonindigenous species was installed from the Invasive Alien Species Act, in which Local Invasive Species (called "LIS", hereinafter) are stipulated as the targets to be regulated in this ordinance. The species selected as LIS include certain nonindigenous species that were not designated as IAS because of insufficient information on invasiveness when designating (e.g., the New Zealand mud snail, *Potamopyrgus antipodarum*), supposed introduction date before Meiji era (the masked palm civet, *Paguma larvata*), geographical origin within Japan (the Japanese aucha perch, *Coreoperca kawamebari*), designation of categories in other legal regulations (the alligator snapping turtle, *Macrochelys temminkii* and golden apple snail, *Pomacea canaliculata*), and local (but not national) situations arising social confusion (piranhas). Thus, the LIS can be regarded as the localized and latest follow-up of IAS.

Regulations in this ordinance are basically similar but less severe as those of the Invasive Alien Species Act. Both the act and the ordinance similarly prohibit abandonment of live individuals of the designated species, with penalties for violations. While the act essentially prohibits keeping IAS in captivity unless keepers have permission and satisfy strict conditions, the ordinance generally allows keeping LIS, if the necessary documents detailing the employment of less strict, but satisfactory conditions are submitted. Keepers of LIS are, thereby, asked to take responsibility to keep them properly, and not abandon them or allow them to escape.

A total of 13 animal and 2 plant taxa (some are treated as a group or family) were selected as LIS. All but one animal taxon (the masked palm civet) are amphibious or aquatic, reflecting the importance placed on conservation of aquatic ecosystems in the prefecture *Fig. 3*.

Among LIS, the alligator snapping turtle is also designated as a Specified Animal stipulated by the Act on Welfare and Management of Animals. Establishment of populations of this giant aquatic turtle has not been confirmed in Japan yet, but it has been occasionally found and captured in multiple localities, including some in Shiga Prefecture.

In spite of their tropical origins, piranhas belonging to three genera, *Pygocentrus*, *Serrasalmus*, and *Pristobrycon*, are selected as LIS because of their sharp teeth and reputation as fierce fish; the teeth may injure fishermen when accidentally captured, and their capture may trigger a negative reputation for visitors in summer.

Being giant predators, all the species of gars belonging to the family Lepsosteidae, and the wels catfish (*Silurus glanis*) are selected because of previous captures in the wild and the possibility of successful invasions, considering their temperate origins in North America and Europe, respectively.

Two salmonids, the brook trout (*Salvelinus fontinalis*) and the brown trout (*Salmo trutta*) have been kept in regulated artificial fishing ponds along a mountain stream

Fig. 4
Golden apple snails, recently expanding its range along the shore of Lake Biwa. A female laying eggs above the water surface (*left*) and numerous egg masses on the vertical wall at a fisheries port of Lake Biwa (*right*).

within Shiga Prefecture. Both species are selected as precautions because they are known to establish populations in mountain streams with cold water in Japan, causing adverse effects on native salmonids.

Among the two Asian bitterlings selected as LIS, the continental rosy bitterling (*Rhodeus ocellatus ocellatus*) intruded into Lake Biwa around 1960, where there had been an indigenous subspecies, the Japanese rosy bitterling (*R. ocellatus kurumeus*), endemic to western Japan. Through the hybridization process, however, this indigenous subspecies was completely replaced with the invading alien subspecies. The Japanese rosy bitterling is one of the only two fishes that have become extinct in the prefecture (Shiga Prefectural Government 2000). Another bitterling, the giant Chinese bitterling (*Acheilognathus macropterus*) is circulated in Japan as an ornamental fish as well as all the other LIS fishes except salmonid fishes, which are kept for aquaculture or as target of angling. It has already established populations in the area around the lake Kasumi-ga-ura (Hagiwara 2002). Because of its large body size, this species might be competitively superior to other native bitterlings.

Among LIS, the Japanese aucha perch is the only species native to Japan. The eastern end of its geographical range is Kyoto Prefecture, located to the west of Shiga Prefecture. In recent years, this fish has established new populations in multiple localities outside of its original range, possibly through purposeful introductions intended to save this endangered species. In Shiga Prefecture, the Japanese perch has established two local populations in the watershed of Lake Biwa (Matsuda and Seki 2002). To prevent its expanding tendency, this species was designated as an LIS.

Two mollusks were selected as LIS, both freshwater snails. Golden apple snail initially established a population in Yasu Town, in the eastern side of the lake. Although its range had been confined to the water systems around the initial population, this snail has markedly expanded its range in recent years, including an apparent invasion into the lake (Kanao et al. 2007). Because of its invasive grazing impacts, it was designated as a Quarantine Pest in the Plant Protection Act, which is the reason why this snail was not selected as an IAS. However, in spite of the prohibition of importing live individuals, there is no regulation regarding their domestic translocation; active utilization of this species has been promoted in warmer regions of Japan as a "live herbicide," owing to its grazing ability, irrespective of its invasive ecological impacts. Shiga Prefecture has been cautious of actively distributing this species via irrigation water; one of the circulatory irrigation plants constructed for reducing nutrient loading into the lake from rice paddies has not been operated. The possibility of passive migration by the flow of irrigation water and the supposed ecological influences have been investigated in collaboration between the agricultural sections of the prefecture and the Kinki Branch of the Ministry of Agriculture, Forestry, and Fisheries, Japan *Fig. 4*.

The other LIS snail is the New Zealand mud snail. This small-sized snail can be used as live bait for a stream-dwelling firefly, *Luciola cruciata*, and has already established populations in four water systems within the prefecture. At present, this snail seems to be confined to an area where water temperatures are influenced by groundwater runoff, which locally prevents extremely high water temperatures in summer. A local museum, "Moriyama hotaru no mori siryo-kan" (Moriyama Firefly Museum), has been involved in the dissemination of information about the ecological impacts of this small snail and promotes not using it as bait for firefly larvae.

Volunteering Efforts for Suppression of Invasive Plants

Detailed description on the present status of invasive alien plants will be given in the following chapter by Kaneko (Sect. 7.2.3), but the countermeasures for their control will be briefly outlined here.

The water lettuce was found to be established in irrigation canals and ponds in the floodplain near the eastern shore of the southern basin of Lake Biwa. In the summer of 2009, this floating plant flourished to cover most of Akanoi Bay of the lake. It was successfully eradicated by intensive surveys and collections by the Field Reporters of the Lake Biwa Museum in the floodplain area, and the pest weed removal program by Shiga Prefecture in Akanoi Bay. The most important point for this success was the detection of the source of expansion where this tropical plant could overwinter, owing to a sufficient supply of relatively warm underground water.

For complete eradication of the alligatorweed and Senegal tea plant from Lake Biwa and its adjacent waters, active efforts have been intensively made since the autumn of 2007, in collaboration with many concerned sectors, including volunteer conservationists, environmental NPOs, research institutes such as universities and museums, organizations for environmental management, and administrative divisions of the local government (prefecture and cities). Although this attempt is still underway, both species have dramatically decreased both in abundance and distributional area covered, and complete success in eradication is expected.

"Alien Watchers" Project

Both the Invasive Alien Species Act and Shiga Ordinance for Coexistence with Wildlife selected the target alien species to be controlled. In order to carry out actual, effective countermeasures, it is necessary to grasp the present ecology and distribution of each alien species. In the fiscal year of 2009, Shiga Prefecture started the "Alien Watchers" Project, a 3-year survey on the present situations of distribution and ecology of IAS as an emergency employment measure supported by the Ministry of Health, Welfare, and Labor, Japan.

The prefectural area was divided into 2,146 third-sized geographical grids based on the nationwide geographic map system (smallest grid: 1,130 × 926 m). A total of 17 species were selected as targets of this survey, of which 10 are aquatic or amphibious, including 3 IAS (the American bullfrog, water speedmill, and parrot feather), 2 LIS (golden apple snail and New Zealand mud snail), and 5 other alien species (red-ear slider (*Trachemys scripta*), northern snakehead (*Channa argus*), red swamp crayfish (*Procambarus clarkii*), water hyacinth (*Eichhornia crassipes*), and yellow iris (*Iris pseudoacorus*)).

In the first fiscal year 2009, 493 (23%) meshes were surveyed. The most frequent appearance was observed for red swamp crayfish in 295 meshes (61.2%). This crayfish is known as one of the commonest aquatic alien species, often becoming invasive, but there had been no previous accumulation of distributional data for the prefecture. The present result shows its actual distribution within the prefecture. Because of potential invasiveness to rice fields, an intensive survey on golden apple snail has been conducted in two areas. In spite of lower frequencies, such distributional data were also obtained for other target species.

In the end of this 3-year project, basic distributional data of invasive alien species can be accumulated, which could provide a baseline for their proper regulations and control, including volunteering public participation.

Acknowledgments

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7.2.4(2) Invasive Alien Plant Species in the Shore Areas surrounding Lake Biwa

Yuko Kaneko

Abstract Occurrences of newly introduced alien plant species are increasing every year in Japan. In 2007 and 2008, approximately 44 invasive alien plant species were found along the shore areas of Lake Biwa. A total of seven IAS were observed surrounding Lake Biwa by 2008: *Coreopsis lanceolata* (Asteraceae), *Gymnocoronis spilanthoides* (Asteraceae), *Alternanthera philoxeroides* (Amaranthaceae), *Veronica anagallis-aquatica* (Scrophulariaceae), *Sicyos angulatus* (Cucurbitaceae), *Myriophyllum aquaticum* (Haloragaceae), and *Pistia stratiotes* (Araceae). Several hybrids of *Azolla cristata* (Azollaceae) were also observed. The Omi Wetland Group, an NGO Committee, and the Lake Biwa Environmental Research Institute (LBERI) are currently working with the Shiga prefectural government and the Hikone municipal government to decide how best to exterminate these IAS, particularly *G. spilanthoides* and *A. philoxeroides*.

Keywords Invasive Alien Species Act • *Gymnocoronis spilanthoides* • *Alternanthera philoxeroides* • initial pest

Introduction

In Japan, the Invasive Alien Species Act was adopted in 2004, and put into effect in 2005 (Ministry of the environment government of Japan, http://www.env.go.jp /en/nature/as.html). This Act regulates IAS, uncategorized alien species (UAS), and living organisms required to have a certificate attached (LORCA) during their importation to verify the species types. IAS candidates were selected from alien species, the adverse effects or potential for adverse veffects of which were already reported in academic journals. In total, 12 plant species were denoted as IAS, seven of which had been observed by 2008 in the shore area of Lake Biwa. Several hybrids of the alien *Azora* spp. have also been observed (*Table 1*; Kaneko et al. 2010).

Senegal Tea (*Gymnocoronis spilanthoides* (Asteraceae))

Senegal tea (*Gymnocoronis spilanthoides* (D. Don) DC.) is native to Latin America and has naturalized in Oceania, Taiwan, and Japan. It was introduced to Japan as aquarium material or a water purification plant with no scientific data regarding its ability to purify water, and has become a threatening weed of freshwater habitats (Kadono 2004). The wild form of this species was first found in Aichi Prefecture in 1996. Its distribution area has been rapidly expanding in the Kanto, Tokai, Kinki, and Kyushu areas of Japan. Most of the populations have spread from artificially transplanted sites. It is a large perennial herb and can reach more than 2 m in height. It also exhibits high allelopathic activity (Ishitsuka et al. 2008). Its white spherical flowers are 6–10 mm in diameter and attract many butterflies (*Fig. 1*). Stems are hollow and can spread rapidly by floating on wind and waves. Vegetative propagation also occurs and new plants can be produced from even a small piece of leaf (Suyama and Fujiwara 2003). Many seedlings have also been observed to develop from seeds (Ohmichi and Kadono 2006; Kaneko et al. 2010).

In Shiga Prefecture, a large-scale habitat was first found in July 2007 in Yabase Bay (Kusatsu City) (Fujii et al. 2008). Many wild colonies were found around Yabase Bay in September 2007, and two new areas were confirmed in the shore parks at Kitayamada (Kusatsu City) and Zeze (Otsu City) in December 2007 and April 2008, respectively (*Figs. 2* and *3*; Kaneko et al. 2010). However, soon after this species was confirmed, the "Omi Wetland Group"

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Table 1

List of regulated living organisms of plant kingdom under the Invasive Alien Species Act: Invasive Alien Species (IAS), Uncategorized Alien Species (UAS), and Living Organisms Required to have a Certificate Attached during their importation in order to verify their types (LORCA)

IAS	UAS	LORCA	The oldest record around Lake Biwa	Literature
Coreopsis lanceolata (Compositae)	None	Any species of the genus *Coreopsis*	1993	Kaneko et al.(2010)
Gymnocoronis spilanthoides (Compositae)	None	Any species of the genus *Gymnocoronis*	2007	Fujii et al. (2008)
Rudbeckia laciniata (Compositae)	None	Any species of the genus *Rudbeckia*	None	-
Senecio madagascariensis (Compositae)	None	Any species of the genus *Senecio*	None	-
Veronica anagallis-aquatica (Scrophulariaceae)	None	Any species of the genus *Veronica*	1985	Kaneko et al. (2010)
Alternanthera philoxeroides (Amaranthaceae)	None	Any species of the genus *Alternanthera*	2004	LBRI (2005)
Hydrocotyle ranunculoides (Apiaceae)	*H. bonariensis*, *H. umbellata*	Any species of the genus *Hydrocotyle*	None	-
Sicyos angulatus (Cucurbitaceae)	None	Any species of the genus *Sicyos*	1995	Murase (2005)
Myriophyllum aquaticum (Haloragaceae)	None	Any species of the genus *Myriophyllum*	1926	Kaneko et al. (2010)
Spartina anglica (Poaceae)	None	Any species of the genus *Spartina*	None	-
Pistia stratiotes (Araceae)	None	*P. stratiotes*	1994	Fujii (1995)
Azolla cristata (Azollaceae)	None	Any species of the genus *Azolla*	1990s?	Kaneko et al. (2010)

(an NGO committee) and LBERI started a variety of pest control initiatives such as researching the spatial distribution and population size of each patch in detail, and instantaneously informed the Shiga prefectural government and the municipal governments about the risks of IAS and invasion of *G. spilanthoides* in the Lake Biwa area.

Since 2007, the Omi Wetland Group and LBERI have conducted weed-cutting operations more than 20 times, while improving the operating efficiency (*Fig. 2*). Due to these efforts, the spread of this species has now been suppressed and the total area of the patches has been halved during each growing season (Kaneko et al. 2010). The Omi Wetland Group and LBERI, along with the Shiga prefectural government, are now attempting to exterminate this species.

Alligator Weed (*Alternanthera philoxeroides* (Amaranthaceae))

Alligator weed (*Alternanthera philoxeroides* (Mart.) Griseb.) is of South American origin and has naturalized in North America, Africa, Asia, Oceania, China, and Japan. It has become one of the worst invasive plant species around the world (Spenser and Coulson 1976; Liu et al. 2008). In Japan, this species was first recorded in Hyogo Prefecture in 1989 and was used for ornamental purposes, and in connection with crab farming. Its distribution area expanded rapidly and it became widely established in the western area of Japan (Sugiyama and Kuramoto 2004). It is a perennial herb that can grow in diverse habitats (from swamps to dry lands), although

Fig. 1
***Gymnocoronis spilanthoides* at Yabase Bay, Kusatsu.**

Fig. 2
The weed-cutting of *G. spilanthoide* at Yabase Bay, Kusatsu.

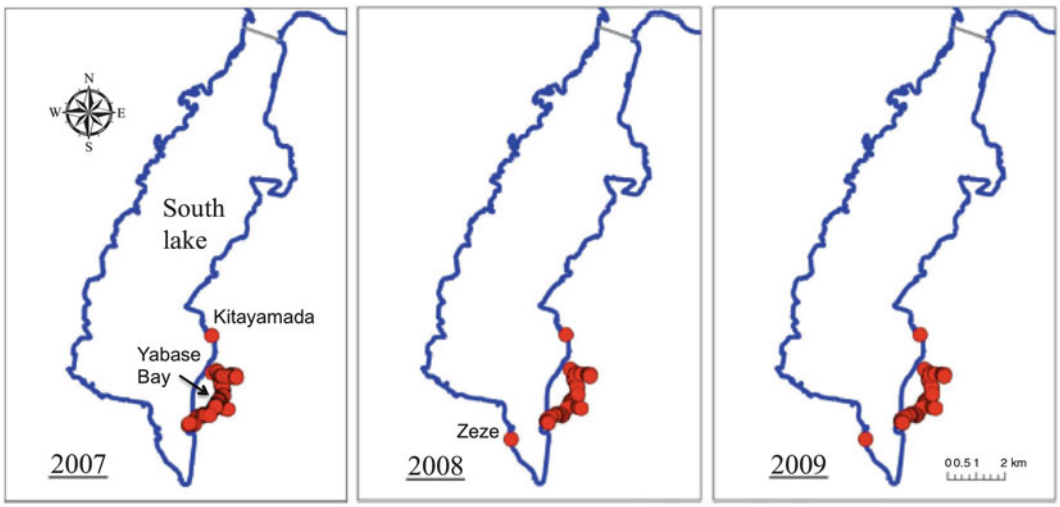

Fig. 3
Distribution maps of *G. spilanthoides* surrounding the south basin of Lake Biwa.

its genetic diversity is very low (Wang et al. 2005). Aquatic *A. philoxeroides* forms dense floating mats over the water surface. Its creeping hollow stems sometimes reach 3 m in length. Vegetative propagation is very effective and new plants are produced from even small pieces of stem; it is a C_3 plant (Balagtas-Burow et al. 1993). Its white spherical flowers are 15 mm in diameter (*Fig. 4*).

In Shiga Prefecture, five small patches (total area of approximately 254 m^2) of this species were found in November 2004 at the Jinjyo Swamp (Hikone City) before it was regulated as an IAS (Kaneko et al. 2010). No action, such as weed removal, was conducted during the initial stage of invasion process until 2007. Then, the area of *A. philoxeroides* at the Jinjyo Swamp was approximately 46 times as large as it was in 2004. The Omi Wetland Group and LBERI initiated pest control actions in 2007 and conducted a trial weed-killing event with volunteers on November 18, 2007. However, after a full day of work by 25 people, less than 5% of the *A. philoxeroides* population was removed. Furthermore, a large new patch of this species was found in November 2007 on the shore of Lake Biwa in Ono (Otsu City). Pest control operations have been conducted, with weed-cutting, or stopping it from spreading by floating, more than 10 times since 2007. The Hikone municipal government started an all-out weed-cutting operation using hovercraft and power shovels in 2009 (*Fig. 5*). However, *A. philoxeroides* has been proliferating along the shore of Lake Biwa since 2008 and the spread of this species has not yet been suppressed. Over 100 patches of populations were found along the shoreline area in 2009 (*Fig. 6*, Kaneko et al. 2010). The number of patches of the species has been increasing exponentially and there is no prospect of this species' extermination currently. The Shiga prefectural government started another all-out weed-cutting operation in 2010.

Parrot's Feather (*Myriophyllum aquaticum* (Haloragaceae))

Parrot feather (*Myriophyllum aquaticum* (Vell.) Verdc.) is native to Brazil and was introduced into Japan as a decorative plant or a water purification plant around 1920. The wild form of this species was first found in Hyogo Prefecture. Specimen of this plant was reported in Lake Biwa, as early as 1926 (Kaneko et al. 2010). In total, 45 colonies were found along the shore of Lake Biwa in 2009, according to a monitoring survey conducted by Shiga Prefecture. Civilian volunteers have been attempting to control its spread in recent years.

Water Lettuce (*Pistia stratiotes* (Araceae))

Water lettuce (*Pistia stratiotes* L.) is native to South Africa and widely distributed in tropical and subtropical regions of the world. It was introduced into Japan as an ornamental or a water purification plant. An explosive expansion of this species has been reported since the early 1990s, primarily in southwestern Japan (Kadono 2004). Around Lake Biwa, it was first found at Haginohama beach (Takashima City) in 1994. Areas dominated by this species have been found at Katada naiko (an attached lake of Lake Biwa in Otsu City), six shoreline areas of the South lake, and Akanoi Bay (Moriyama City) in 2004, 2005, and 2007, respectively (Nakagawa 2005; Kaneko et al. 2010) (see Color page 12). The Shiga prefectural government conducted a waterweed-salvaging operation around Akanoi Bay in 2007 (see Color page 12) in this text, please arrange Color pages, which we already sent to Springer Academic at the end of January, as we laid it out.

Lance-Leaved Coreopsis (*Coreopsis lanceolata* (Compositae))

Lance-leaved coreopsis (*Coreopsis lanceolata* L.) is native to North America and has naturalized in countries such as Australia and Japan. It was introduced into Japan as an ornamental or greening plant in the 1880s. Its distribution area has been rapidly expanding, because it has been used for berm greening throughout Japan. In Shiga Prefecture, it was first found in 1993 at the estuary of Ane River (Nagahama City) (Kaneko et al. 2010). Large colonies have been found on the bank of other rivers, such as Chomeiji (Omihachiman City) and Tagawa (Nagahama City) (Kaneko et al. 2010). The Shiga prefectural government monitored how to control the proliferation of this species from 2007 to 2009.

Water Speedwell (*Veronica anagallis-aquatica* (Scrophulariaceae))

Water speedwell (*Veronica anagallis-aquatica* L.) is native to Europe and North Asia. It has naturalized in North and South America, Africa, Australia, and Japan. In Japan, this species was first collected in Kanagawa Prefecture in 1867, and has become a very common plant in southern and western Japan (Tanaka and Noguchi 1994). In Shiga Prefecture, it was first found in 1985 at Mano beach (Otsu City) (Kaneko et al. 2010). It forms large stands, particularly in habitats disturbed by river construction

Fig. 4
***Alternanthera philoxeroides* at Jinjyo Swamp, Hikone.**

Fig. 5
The weed-cutting *of A. philoxeroides* at Jinjyo Swamp, Hikone.

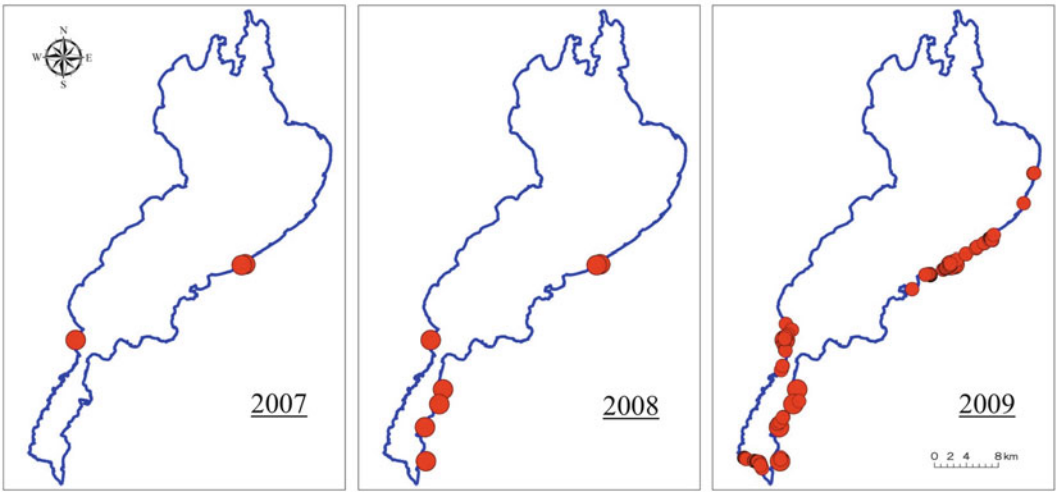

Fig. 6
Distribution maps of *A. philoxeroides* surrounding Lake Biwa.

work, which are seen in many small rivers at Otsu City. A related native species, *Veronica undulate* hybridized with it, and is now endangered due to the invasion of this species, genetically as well as ecologically (Tanaka 1995; Kadono 2010).

Conclusions

Plant invasions have received increasing attention worldwide because of their environmental impacts and huge economic costs (Wilcove et al. 1998; Pimentel et al. 2000; Grosholz 2005). In the past few decades, an increasing number of alien plants have been introduced. Their vigorous spread has threatened the biodiversity of native ecosystems. Although substantial amounts of money have been spent to control alien plant infestations, in some cases, eradication of such plants has proven to be difficult. The native or endemic weed species of Lake Biwa, such as *Vallisneria biwaensis* (Miki) Ohwi and *Potamogeton biwaensis* Miki, have been replaced by invading weed species, such as *Elodea nuttalli* St. John and *Egeria densa* Casp. *Elodea nuttalli* was first found in the northern part of Lake Biwa in 1961 (Ikushima and Kabaya 1965). No control efforts, such as weed removal, were conducted during the initial stages of the invasion process, because the risks of invasive plants were not recognized until large flourishes caused serious socioeconomic problems, such as damage to fisheries. As a result, the species spread throughout the lake and has become the most dominant plant in the lake within the span of several years (Kadono 2004). The number of native waterweed species has been halved over the past few decades. If newly introduced invasive plants, such as *G. spilanthoides* and *A. philoxeroides*, are left to flourish, similar patterns will be repeated in the near future. Thus, promoting rapid preventative pest control during the early stages of an invasion is extremely important to avoid serious damage, to reduce the cost of weed-cutting and to enable effective extermination of the species.

Acknowledgments

I would like to thank the Omi Wetland Group (Mr. Minoru Kuribayashi, Dr. Shinji Fujii, Dr. Naohiko Noma and Dr. Katsuki Nakai) for useful personal communications.

7.2.5 Population Increase of the Great Cormorant *Phalacrocorax carbo* and Measures to Reduce its Damage to the Fisheries and Forests of Lake Biwa

Kayoko Kameda

Abstract The Great Cormorant is a large, colonial, piscivorous bird, the population of which has fluctuated significantly over the last several decades in Japan, including around Lake Biwa. They feed in inland freshwaters, make roosting/nesting colonies in forests, and breed in the trees; thereby they have been causing damage to freshwater fisheries and forests. In particular, the increasingly numerous Great Cormorant population in Lake Biwa is causing damage to the fishery for Ayu fish, the most important fishing industry today in Lake Biwa. It is also causing damage to two local forests, one on Chikubu Island in the lake and the other on the Isaki Peninsula on the lakeshore. The Shiga Prefectural government has drawn up a "Specified Wildlife Management Plan of Shiga (the Great Cormorant)," based on the Ministry of Environment's Specified Wildlife Management Plan System. As a result, large-scale population control of the cormorants has begun, while activities related to habitat management and prevention and amelioration of damage to fishing grounds and forests have continued.

Keywords Adaptive management • Damage to fisheries • Damage to forests • Population changes • Specified Wildlife Management Plan

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Introduction

The Great Cormorant, *Phalacrocorax carbo hanedae*, was distributed throughout most of Japan before the middle of the twentieth century (Johnsgard 1993; Fukuda et al. 2002). The number of birds decreased, however, through the 1960s to a low point in the early 1970s because of the expansion of human activities, development, and water pollution (Fukuda et al. 2002). Thereafter, the cormorant population began to recover, and it is currently undergoing rapid increase and expansion. This is probably because of improvements in freshwater quality including a reduction in toxic contaminants, an increase in accessible fish stocks owing to newly purified freshwater or artificial stocking, and reduced disturbance of cormorants by people (Fukuda et al. 2002; Iseki et al. 2002). At the same time, the increase of the cormorant population has caused damage to fisheries and forests in Japan, and Lake Biwa has not been an exception.

This chapter introduces the current status of the Great Cormorant in Lake Biwa and the measures taken to reduce the damage done by these birds to the lake fishery and to the forests on an island and peninsula in the Lake.

Biological and Ecological Traits of the Great Cormorant

The Great Cormorant is a large, colonial, piscivorous bird, which is widespread all over the world except for the western part of North America and Central and South America (Johnsgard 1993). Of the six subspecies only one, *P. c. hanedae*, lives in Japan. Their bodies are covered with black

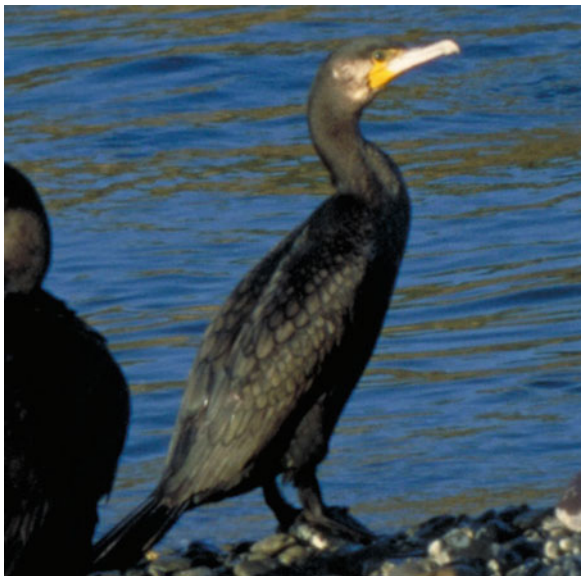


Fig. 1
The Great Cormorant *Phalacrocorax carbo hanedae* (Copyright: Lake Biwa Museum).

feathers (*Fig. 1*), but in prebreeding adults, the top of the head and part of the neck are covered with long, white filoplumes and a white patch is present on each flank. The plumage of juveniles under 1 year old is less glossy, with white feathers mixed in among the black ones on their bellies. The total body length of cormorants in Japan is ca. 80–90 cm and their weight is ca. 1.4–2.4 kg.

Cormorants dive and catch fish in freshwater and coastal areas. In contrast to the other three species of cormorant inhabiting Japan (the Japanese Cormorant *Phalacrocorax capillatus*, the Pelagic Cormorant *P. pelagicus*, and the Red-faced Cormorant *P. urile*), only the Great Cormorant commonly goes inland. They eat 300–500 g of fish per day and are regarded as generalists. They eat any fish that they can easily catch in their foraging sites (Kameda et al. 2002), but their diet does differ between the sexes, seasonally, or in tune with fish species abundance (Kohda et al. 1994; Voslamber et al. 1995; Takahashi et al. 2006).

The breeding season of the Great Cormorant varies geographically in Japan (Fukuda 1995). In Aomori, the northernmost prefecture of Honshu Island, and Shiga, in the middle of Honshu Island, the breeding season is from early spring to fall, while in the Kanto area and Aichi Prefecture, it lasts from fall to spring or sometimes almost all year round. They create a colony in a forest by building nests in trees, which is another way the Great Cormorant differs from the other species of cormorant in Japan. On average, three or four pale-blue eggs are laid in a nest, and the offspring are fledged about two and half months later (Fukuda 2002).

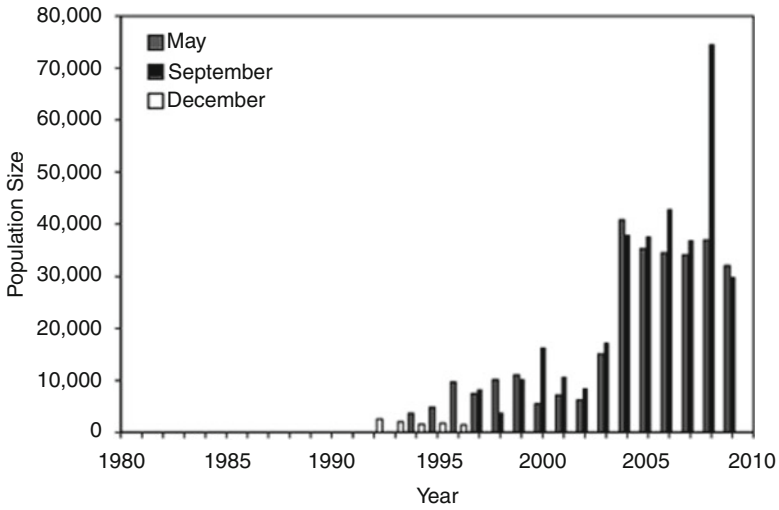
Population Changes of the Great Cormorant in Lake Biwa

The Great Cormorant population in Japan has fluctuated significantly over the past several decades. It began declining in 1960s and reached its lowest count of less than 3,000 birds in 1971 (Fukuda 2000). Only five colonies remained in Japan in 1979: one each in the Aomori, Kanto, and Kyushu areas, and two in the Tokai area (Fukuda et al. 2002). Among those five colonies, Unoyama in Aichi Prefecture was one of the oldest and largest in Japan, and the cormorants of Shinobazunoike Pond in Ueno Park, Tokyo, were protected at that time. The population of these two colonies began to increase in the late 1970s. Thereafter, the distributional range of cormorants began to expand to the whole of Japan, with increasing populations in newly settled areas. Some cormorants settled at Lake Biwa, where the population increased rapidly from the 1980s.

In Lake Biwa, the Great Cormorant was first recorded in a scientific paper in the 1930s. Their habitat in the early part of that decade was Okinoshiraishi, a tiny rocky island in the Lake, but in late 1937 they were also observed on Chikubu Island, breeding together with herons and egrets (Kawamura 1934; Hashimoto 1998a). On Chikubu Island, the number of breeding birds increased, and the herons, egrets, and cormorants were culled in 1937 because of the bad smell and forest degradation (Hashimoto 1998b). After World War II, though, cormorants were rarely observed on Lake Biwa for more than 30 years. The discovery in 1982 of five cormorant nests in an egret colony in the northern part of Chikubu Island was the first postwar record of cormorant breeding in the Lake Biwa area. Soon thereafter, 30–40 nests were discovered on the Isaki Peninsula on the southeastern coast of the lake's north basin. The number of cormorants in Lake Biwa increased rapidly after that (*Fig. 2*). At the same time, the number of nests also increased in the two mentioned colonies—in 2008, 10,804 nests were counted on Chikubu Island and 3,939 on the Isaki Peninsula.

Besides long-term population trends, the number of cormorants in Lake Biwa fluctuates through the year (*Fig. 3*). They begin to increase in February and breed until October. After October, most of the cormorants leave

Fig. 2
Change of population size of the Great Cormorant in Lake Biwa.



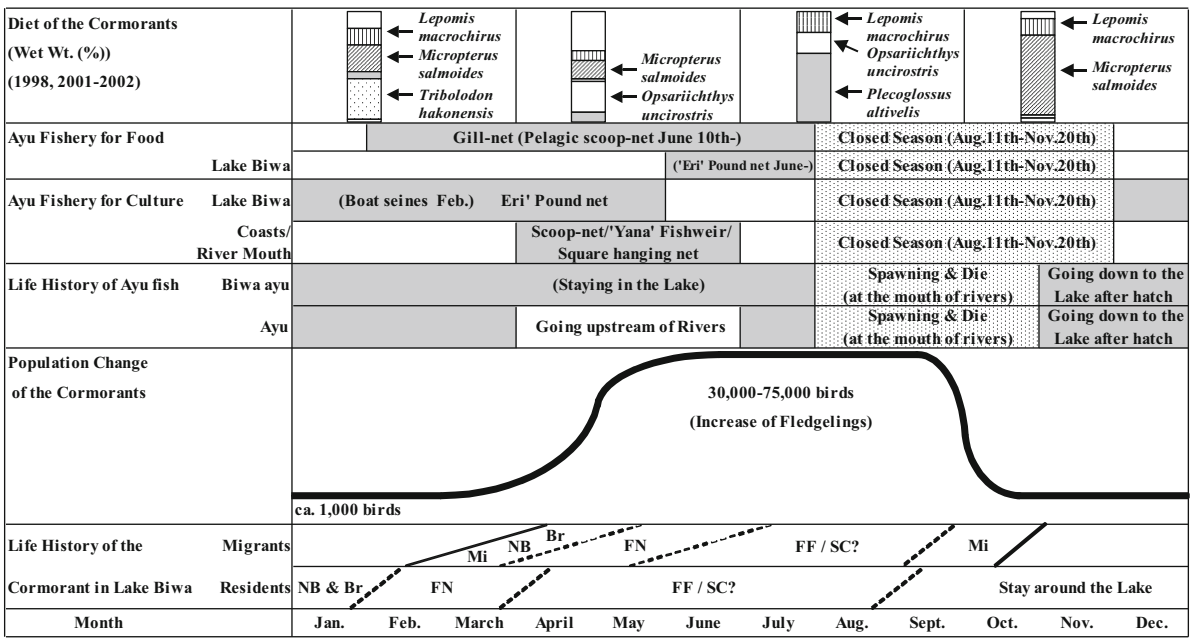


Fig. 3
Schematic model of the life histories of the Great Cormorant and Ayu fish, the seasonal change of fishery methods for Ayu, and the diet of the cormorants in Lake Biwa. *Mi* migration, *NB* nest building, *Br* brooding, *FN* feeding for nestlings, *FF* feeding for fledglings, *SC* Second clutch.

Lake Biwa, probably because most fishes move to the deeper waters of the lake in winter, making it difficult for the cormorants to catch them. The number of these birds decreases to about 1,000 individuals in December or January (*Figs. 2* and *3*).

Damage Caused by the Great Cormorant

Two kinds of problem have risen as a consequence of the increased number of Great Cormorants in Japan: damage to fisheries and damage to forests colonized by cormorants.

Fig. 4
Damage to the forest on Chikubu Island in the northern part of Lake Biwa's north basin.

Damage to fisheries mostly occurs in inland waters, especially with respect to stocked game fish such as the Ayu fish *Plecoglossus altivelis altivelis* (treated as Biwa ayu *P. a.* subsp. in this book) Although the cormorants in Lake Biwa eat a wide variety of fish throughout the year (Takahashi et al. 2006), predation on Ayu is of most concern to the fisheries of Lake Biwa, as well as many other areas in Japan. Many kinds of fish including endemic species inhabit Lake Biwa, and various forms of traditional fishery have developed there; however, the decreasing catch of most species of commercially valuable fish means that the fishers have to rely mainly on Ayu fishing. Ayu acounted for 39.9% of the total catch in Lake Biwa in fiscal 2008 (April 2008–March 2009); moreover, the monetary yield from Ayu was 52.5% of the whole yield of the entire lake fishery that year (Kinki Nosei-kyoku Shiga Nosei Jimusho [Shiga Agricultural Administration Office of Kinki Regional Agricultural Administration Office] 2010). Ayu are migratory fish, many of which go into rivers in the spring, establish territories, and grow larger in the rivers in summer (*Fig. 3*); however, some Ayu remain in schools in the lake. Both kinds of Ayu go to the coastal areas of the Lake for spawning in the fall. Cormorants catch Ayu at the mouths of rivers in spring, in the pelagic zone of the lake in summer, and in coastal areas of the lake in fall (*Fig. 3*).

The other kind of damage caused by cormorants is deforestation. They pluck twigs to build nests and drop a large amount of excreta (guano) on leaves and the soil, thus damaging the trees. A forest that hosts a colony of cormorants thus degrades rapidly (Fujiwara and Takayanagi 2001). In addition, the soil of the forest is enriched by nitrogen and phosphorus supplied by the guano, and the nutrient dynamics and balance are changed (Hobara et al. 2005). The decrease in the canopy coverage and the nutrient enrichment of the soil facilitates the growth of nitrophilous grass and prevents the survival of tree seedlings (Ishida 2002). It is thought to be difficult for areas severely damaged by cormorants to regenerate and recover quickly. A decrease in forestry product values, deterioration of scenic views and ecologically important vegetation, as well as the bad smell of the guano and noise produced by the birds, can be counted among the problems associated with cormorant colonies. Besides damage to the forests themselves, eutrophication of ponds next to the colonies is another problem in some areas (Nakamura et al. 2010).

Around Lake Biwa, forest degradation has become a problem at two colonies—one on Chikubu Island and the other on the Isaki Peninsula. At Chikubu Island, the high density of cormorants is causing severe damage (*Fig. 4*). After about 25 years of colonization, the vegetation has been swept away and, as a result, soil erosion has occurred. Although the Island was selected as one of the eight scenic sites of Lake Biwa in 1950, and it was described as "Shinryoku, Chikubu-shima no chin'ei" ("the island casting a deep green shadow over the water"), its scenic and sacred

value have suffered. Important functions of the forest cover, such as maintenance of water quality and quantity and the prevention of landslides, have also been impaired. Inasmuch as the Isaki Peninsula cormorant colony is situated in a national forest, the degradation of the scenic and functional value of the forest is a source of worry. In particular, degradation of the quality of timber from the peninsula's Japanese cypress, *Chamaecyparis obtusa*, is feared.

Measures Taken to Limit Damage by the Great Cormorant in Lake Biwa

For about two decades the Shiga Prefectural Government has been working on issues related to cormorant pressure on the fisheries and forests of the Lake Biwa region. A "Comprehensive Measures Plan for the Great Cormorant in Shiga" was drawn up in 2007, and likewise a "Specified Wildlife Management Plan of Shiga (the Great Cormorant)" in 2010. The latter Plan was formulated in accordance with the Specified Wildlife Management Plan System instituted by the Ministry of the Environment, which requires that the management plan and target should be continuously reconsidered based on monitoring and feedback. This is because information on wildlife is usually incomplete, and the situation related to wildlife and its conflicts with humans is not steady or certain. This is an example of adaptive management. Following this system, prefectural governors are expected to undertake the management of the population size and habitats of wildlife, as well as the prevention of damage caused by wildlife. Besides this, in 2007, the local branch of the Forestry Agency, under the Ministry of Agriculture, Forestry, and Fisheries, drew up a "Policy of Measures against the Great Cormorant in the Forest Management of Isaki National Forest."

The above-mentioned "Plan" devised by Shiga Prefecture puts emphasis on population control of the cormorants, as their population size in the prefecture was probably the largest of anywhere in Japan in 2008. To control the cormorant population, culling on a large scale was started in both of the main colonies (especially at Chikubu Island) during the breeding season in 2009. At the same time, small colonies and roosts around the Lake were monitored. To prevent damage to fisheries from cormorants, the following measures were carried out: installation of lines or nets to cover ponds and rivers, human patrols, and noisy cannons to prevent access to, or to drive them away from, fishing areas. In the forests, the cormorants have been driven away by the patrols, by means of cutting down some trees at the edge of colony, installing netting or ropes over the trees, and pounding on tree trunks with a hammer. Most of these measures are being conducted in the Isaki forest in accordance with the above-mentioned "Policy." In addition, unique experiments such as the construction of hiking trails and signboards have been undertaken in these areas (*Fig. 5*). The idea was for hikers to drive away the

Fig. 5
Signboard titled, *Isaki National Forest, Project to Create a Forest where Great Cormorants and People can Coexist*. It is installed at the starting point of the hiking trail in the Isaki forest.

cormorants since human disturbance is thought to be one of the most effective deterrents against cormorants. As for managing the habitat, some concrete measures have also been undertaken. For example, broadleaf trees were planted in the area of dead Japanese cypresses in the Isaki forest, since they tend to be resistant to cormorant damage and recover well from any damage they do sustain. Furthermore, appropriate weeding of the forest floor has proven effective for the rapid growth of tree seedlings. To ameliorate the damage to fisheries, it is necessary to increase the productivity and abundance of fisheries resources including other fish than ayu. This can be facilitated by restoration of the river and lake environments, for instance, through the reconstruction of habitats of fish, the improvement of water quality, and the extermination of invasive species.

Conclusions

The population size and conservation status of the Great Cormorant has changed significantly in Japan over the past several decades. In particular, around Lake Biwa this change has been brought about to a large extent by changes in fisheries practices, forest management, and the life style of the human residents around Lake Biwa. Changes in people's concerns or interests related to Lake and nearby forests have probably made the cormorant problem worse. In order to reduce the occurrence of conflicts between cormorants and people, it is necessary to revive other aspects of the Lake Biwa fishery and not rely only on the Ayu fishery. It is also necessary to undertake sustainable management of forests that host cormorant colonies, and also to conduct a well-balanced array of direct measures to counter the damage by cormorants.

Acknowledgements

I wish to thank Masayoshi Maehata (Lake Biwa Museum) and anonymous referees for their helpful advice and comments on this chapter.

7.2.6 New Challenge of Citizen Participation for Environmental Conservation

Yuichi Sato

Abstract This paper focuses on the role of the prefectural government in expanding citizen activities and promoting citizen participation. First, the regional network organizations formulated by the government are reviewed. According to the result, it is clear that the attempt to establish a council in every region and organize government-led civic activities was not necessarily effective. Then, the process and outcome of the project intended to improve the revealed problems are introduced, in which citizens were involved in drawing up the future vision of Lake Biwa from a new viewpoint, namely "rebuilding close ties with the lake." Finally, the framework for adaptive management is shown. In this process, the role of the government is to create opportunities for citizen participation to plans and projects in the Mother Lake 21 Plan (ML21) Second Stage, which would encourage the citizens to take a proactive role.

Keywords Citizen participation • Mother Lake 21 Plan • Future vision • Adaptive management

Introduction

There are a number of citizens' activities for the environmental conservation of Lake Biwa and its basin, which are implemented by various groups and in various areas. Since we utilize the water of Lake Biwa for drinking, agriculture, and so on, what happens to the rivers flowing into the lake could significantly affect our everyday lives. Therefore, efforts for comprehensive conservation and improvements have to be made at the river basin level.

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In Shiga Prefecture, the "Lake Biwa Comprehensive Preservation and Improvement Project (Mother Lake 21 Plan)" (ML21) was established as the most long-term and comprehensive plan involving Lake Biwa. This plan comprises two stages, the first lasting from 2000 to 2010, and the second, from 2010 to 2020. The comprehensive conservation efforts consist of (a) maintaining water quality, (b) improving the recharge capacity of the soil, and (c) preserving the natural environment and scenic landscapes, together with encouraging participation and practice, research, information access, and exchange in order to promote such activities (Shiga Prefecture 2000). In this plan, the government also attempted to organize many citizen activities by river basins.

In this chapter, we focus on the role of the government—in expanding citizen activities and promoting citizen participation.

Citizen Participation Since 2000

In the ML21 First Stage, "the Basin Councils" (13 groups) and "the Lake Biwa Basin Network Committee" were established for activities at the river basin level (*Fig. 1*). The former groups consist of residents, private enterprises, and so on. The latter consists of all of the Basin Councils. These associations were established to fulfill the following aims: First and foremost, to understand and mutually appreciate the conditions and concerns specific to each region, to allow for comprehensive conservation efforts. To understand the linkage of the upstream, midstream, and downstream regions and initially follow the familiar activities of neighborhood associations and other local associations in each river basin. To evolve these activities into partnerships between different community groups based on a deep understanding of other regions and personal commitment to protect Lake Biwa (Shiga Prefecture 2000).

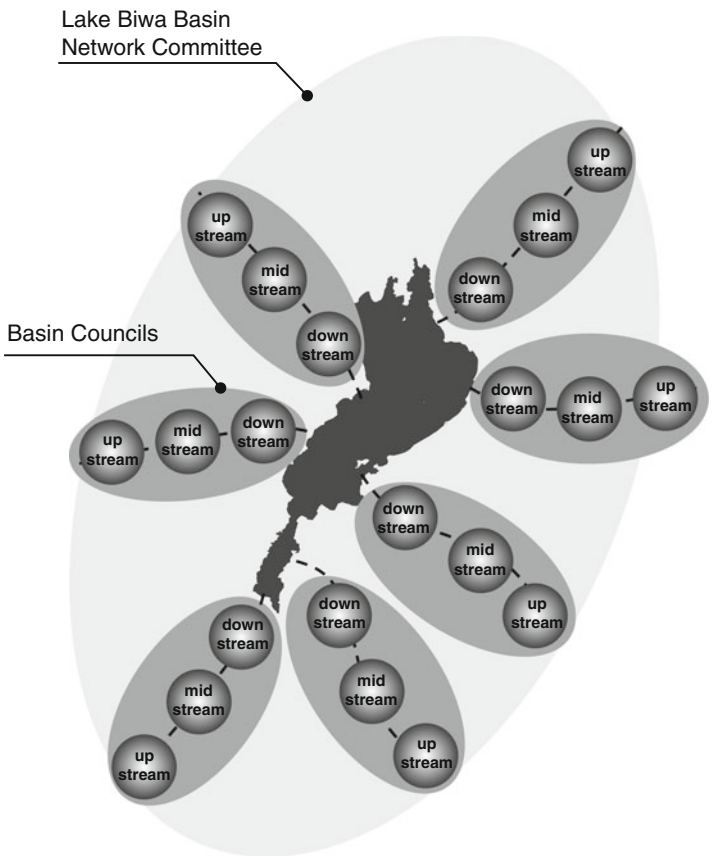

Fig. 1
Basin Workshops and Lake Biwa Basin Network Committee.

However, the results of an oral survey of all the Basin Councils conducted 6–9 years after their establishment revealed many practical problems. These councils played a certain role in offering opportunities for groups and individuals who worked independently in each region to build up a cooperative relationship with each other, or with the prefectural government. However, most of the groups were not able to implement their activities as initially envisioned. The reasons differed from group to group, but were mainly as follows:

1. Since these groups were organized by Shiga Prefecture, the objectives were not fully shared among the members who were developing voluntary initiatives.
2. Basin Councils were managed within the government jurisdiction and basin boundaries were not considered.
3. Bureaucratic divisions among departments and governments (municipality and prefecture) disturbed many activities.
4. Budget of the government for these groups was cut to a large degree.

Therefore, it was not necessarily an effective approach for the prefectural administration to establish a council in every region and try to organize government-led civic activities. Since the tight fiscal condition is expected to continue, we are faced with a big challenge, namely how to facilitate comprehensive conservation of Lake Biwa with the cooperation of citizens, experts, and the government.

New Approach for Citizen Participation: Drawing Up the Future Vision

Lake Biwa Basin Management Scenario Study Group

The evaluation by oral survey of the Basin Councils and the Lake Biwa Basin Network Committee highlights the importance of proactive activities of citizens. In the most typical example, the residents are guests invited to the conference that is held by the government, and no one finds the meaning of discussion. Therefore, the formulation of

plans and projects should directly involve the citizens instead of being initiated by the government.

Based on this concept, a project was conducted to let the citizens participate in drawing up the future vision of Lake Biwa, to be reflected in the Second Stage objectives of ML21. This project has been initiated by "the Lake Biwa Basin Management Scenario Study Group," involving residents, academic experts, and the government. The study group's aims are to review the future vision of Lake Biwa drawn up by citizen participation, and reflect it in the ML21 Second Stage objectives.

This study group consists of "the Academic Workshop" and "the Citizen Workshop." The former comprises 10 academic experts from various fields including water environments, ecosystems, landscape, cultures, and citizen participation. Its mission is to set up opportunities for the Citizen Workshop, and provide academic information to citizens. The latter comprises 15 citizens, namely the stakeholders, chosen from various regions and occupations such as fishermen, farmers, enterprise, and NPO. Its mission is to draw up the future vision of Lake Biwa toward 2020.

Framework of Citizen Workshop

The opinion leaders in each community were invited to the Citizen Workshop by the Academic Workshop members. Of course, it was also considered to hold workshops in various areas in the Lake Biwa basin, but the 15-member system was finally adopted, with an expectation that interactions in small groups would lead to expansion of civic activities in their own communities.

In addition, arrangements were made to have academic information that is objective and indispensable to the discussion provided to the citizens at each workshop. Water quality, diversity of animals and plants, land utilization, and people's lifestyles correlate with each other in the Lake Biwa basin, while it is difficult for most citizens to understand the whole system. Appropriate information gives them new viewpoints of the Lake Biwa basin, which would help them with drawing up the future vision.

Achievement of Citizen Workshop

Citizen Workshops were held seven times from June 2009 to March 2010, following the steps below:

1. Sharing each member's experience
2. On-site study
3. Extracting many ideas for the future vision
4. Arranging and summarizing the future vision

The achievement of the Citizen Workshops is shown in *Fig. 2*. This figure shows a comparison of the future vision toward 2020 between ML21 First Stage and the Citizen Workshops. The big difference between them is that the viewpoint of interaction between our lives and the lake is newly added to the future vision. Namely, it means that the citizens have noticed the changes in their livelihoods, and the importance of rebuilding close ties with Lake Biwa for its comprehensive preservation and improvement.

Adaptive Management of the Plan and the Role of Citizens

Of course, drawing up the future vision is not the goal. The actual implementation of projects to achieve the future vision may result in good outcome within our expectations, but it may also throw up various challenges. Therefore, it is necessary to promote the plan based on "adaptive management." Through making regular assessments on the achievements and challenges, activities within the plan should be reorganized or newly conducted if there are problems or better ways. In ML21 Second Stage, this management system will be actively adopted.

The evaluation results must reflect the citizens' opinions and scientific data. Therefore, it is necessary to incorporate process management into each project through the Plan-Do-Check-Action (PDCA) cycle, as well as into the whole ML21 plan. At the same time, for the citizens and enterprises to be able to judge and act independently, it is quite important to involve them into the information sharing system and decision-making process.

Especially in the next decade, citizen participation to the "Check" process is important for the adaptive management in the ML21 Second Stage. As you know by *Fig. 2*, people's opinions of the future, that is to say, their personal values have become diversified in recent years. In order to reflect different personal values in plans and projects, it is necessary to create opportunities for the citizens to be able to express their opinions. Based on this point of view, Shiga Prefecture is preparing to hold "Mother Lake 21 Forum (tentative name)," which includes "the Citizen Forum" and "the Academic Forum" (*Fig. 3*).

These two forums are future plans, but the contents are considered now like the following. The Citizen Forum offers opportunities for various stakeholders, including people engaged in agriculture, forestry, and fisheries industry, company representatives, experts, and the residents of the downstream basin, to gather about once a year. The participants will receive information from the administration regarding the current condition of Lake Biwa and the progress of the Second Stage ML21 Plan, and have a chance

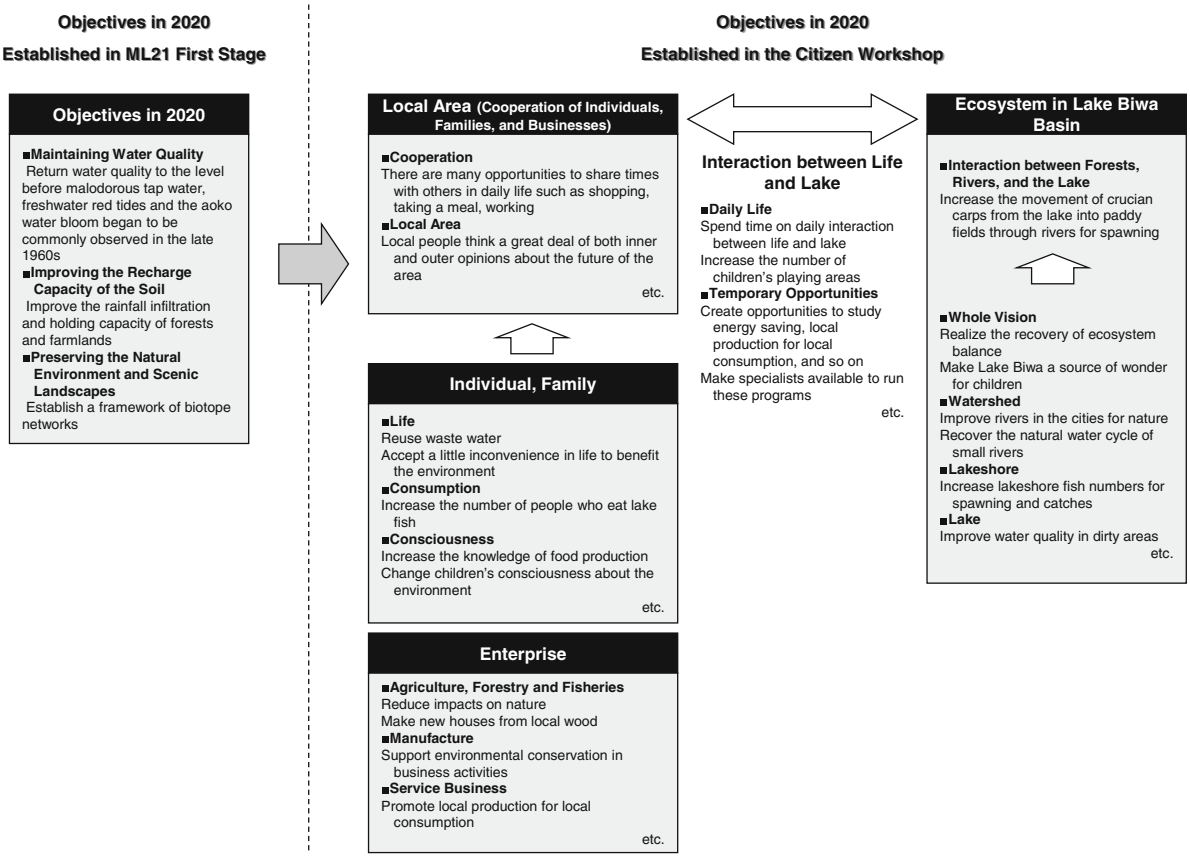

Fig. 2

The difference of the future vision of Lake Biwa between ML21 First Stage and Citizen Workshop.

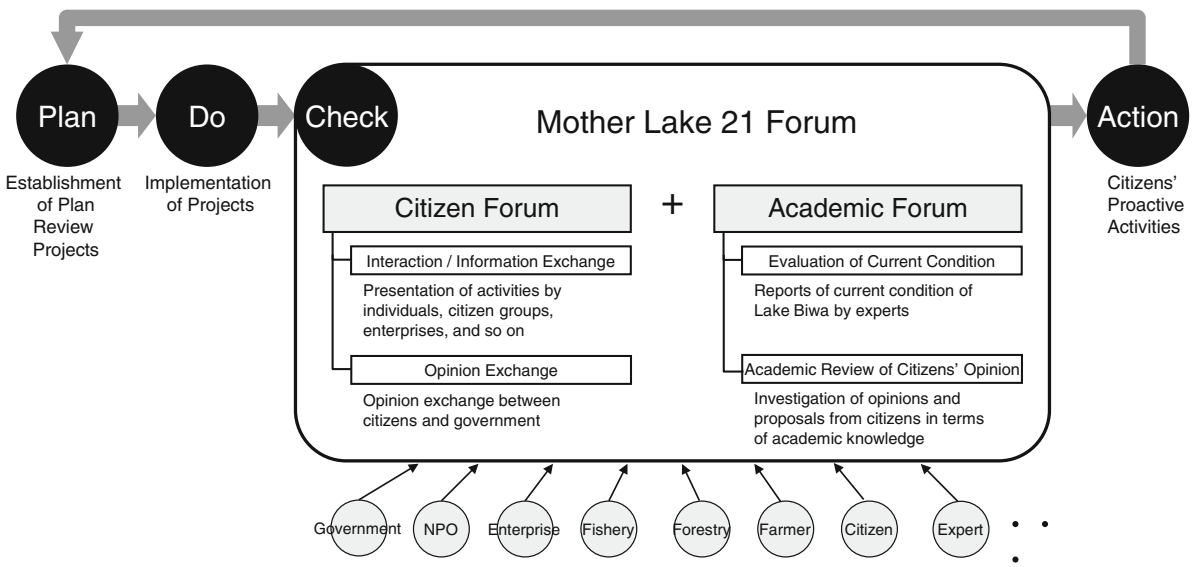

Fig. 3

Plan-Do-Check-Action cycle and Mother Lake 21 Forum.

to exchange opinions. In the Academic Forum, academic experts analyze the current conditions of Lake Biwa and make assessments on the status of achievements of the objectives. These results are presented to the Citizen Forum. The academic experts also review opinions and proposals from citizens from an academic viewpoint, and make suggestions to the government toward improvements of policies and projects.

This adaptive management process encourages citizens to proactively implement activities because they can reflect their achievements and challenges to plans and projects, and feel their activities worthwhile. The important thing for the government is not to organize citizens' activities, but to encourage citizens' participation to plans and projects.

Conclusions

In this paper, we intended to clarify the role of the government in expanding citizen activities and promoting citizen participation. According to the results of the oral survey of the regional network organizations that were established by Shiga Prefecture, it became clear that these government-led organizations were unable to initiate independent, proactive civic activities. Therefore, a project was held to involve the citizens in drawing up the future vision of Lake Biwa for the ML21 Second Stage, during which a new viewpoint of rebuilding close ties with the lake was developed. Moreover, through clearly placing citizen participation and academic assessments into the process management of the ML21 Second Stage, it will become possible to promote plans and projects based on various independent opinions. The incorporation of these study results into the actual Second Stage ML21 Plan is currently underway.

Acknowledgments

We would like to thank the members of Lake Biwa Basin Management Scenario Study Group and the commissioners of Lake Biwa Comprehensive Preservation and Improvement Academic Committee for valuable advice and discussions.

Topic 22 Project for Restoring Paddy Fields as Nursery Grounds for Fishes

Masayoshi Maehata · Akihiro Hori

In the past, crucian carp and common carp used to swim from Lake Biwa up to paddy fields for spawning through irrigation and drainage channels after rains during the rice-planting season in May and June. Paddy fields, thus, functioned as spawning and nursery grounds for lacustrine fishes. However, this function has been largely lost nowadays due to significant elevation gaps between the rice fields and their irrigation and drainage channels, resulting from the implementation during the past 30–40 years of land consolidation projects intended to increase rice production all over Japan, including the Lake Biwa area.

In short, the project, "Restoring Paddy Fields as Nursery Grounds for Fishes," is an administrative program to revive the old function of paddy fields as nursery grounds for fishes, and to revitalize deserted farming village communities.

In this project, various methods were implemented for the first time, such as directly stocking the paddy fields with larvae and/or adults of crucian carp (Nigoro-buna, *Carassius auratus grandoculis*), and making fishways in the drainage outlets of paddy fields to enable the adult fish to enter. However, each method poses certain problems. By a process of trial and error, the following method has been employed currently: by constructing a series of several small weirs, the water level of the drainage channel is gradually raised in a stepwise manner to reach the height of the paddy fields. By applying this method, fishes coming upstream can easily enter the paddy fields (*Fig. 1*).

In the paddy fields, used for this project, the usage of agricultural chemicals is kept to a minimum in order to allow the fishes to grow up safely; therefore, negative effects of the chemicals on other organisms besides fishes are also minimized. These paddy fields at first comprised 40 ha (in 2006) in area, which has been increased to 111 ha (in 2009) at present with the positive cooperation of various agriculture-associated organizations.

The background for this project's plan being started in the Lake Biwa area is related to changes in social circumstances in Japan. For example, consumers have been wishing to purchase safe agricultural products without agricultural pesticides and chemical fertilizers, and the majority of people have begun to recognize that the paddy fields occupying a large area in Japan serve an important function for the conservation of biodiversity. The amount of rice produced from the paddy fields used for this project is not yet substantial. It is, however, sold at a higher price than other brands in the market on account of its perceived safety under the brand name of Yurikago Suiden-mai (i.e., rice produced from paddy fields used as nursery grounds for fishes) (*Fig. 2*).

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Fig. 1
Fishway made in an irrigation drainage channel.

Fig. 2
Yurikago Suiden-mai (rice produced from paddy fields used as nursery grounds for fishes) on sale.

Topic 23 Ramsar Convention and Wintering Waterbirds in Lake Biwa

Hisashi Sugawa · Hiroshi Hashimoto

Ramsar Criteria for Waterbirds

The Ramsar Convention is an intergovernmental treaty, the purpose of which is in the conservation and wise use of all wetlands (Ramsar Convention Secretariat 2007). Lake Biwa was registered as a Ramsar sites in 1993. In 2008, the Lake Biwa site was expanded by the addition of its largest satellite lake, Nishino-ko. Although the Biwako Waterfowl Wetland Center and Ramsar committees involving local stakeholders were established at Lake Biwa after the registration, the Ramsar Convention has not been widely recognized by the local citizenry there, and thus has not become a strong driving force for conservation.

Lake Biwa was shown to be an internationally important wetland based on its population of wintering waterbirds. In this regard, Ramsar criteria were applied at the time of original registration, and are used in evaluating the present status of Lake Biwa as well (Sugawa 2005). One of the Ramsar criteria is that a wetland regularly supports 20,000 or more waterbirds. At Lake Biwa, 143,096 individuals of 43 species of waterbird were recorded by boat count along 220 km of the shore (out to 800 m from the shoreline) in the winter of 2007–2008 (Hashimoto and Sugawa 2008), and 85,596–132,179 individuals of 48 species were recorded by shoreline counts along 210 km of the shore of the lake in six successive winters, from 2004–2005 to 2009–2010 (Nihon Yacho-no-kai Shiga-shibu [Shiga Branch, Wild Bird Society of Japan] 2010). Another Ramsar criterion is that a wetland regularly supports more than 1% of the individuals of a regional population of a species or subspecies of waterbird, based on the latest estimates by Wetlands International (Wetlands International 2006). As shown in *Table 1*, for many species these are actually 1% of the estimated total for the respective East Asian population. In Lake Biwa, nine species exceeded this 1% level in at least one of the two above-mentioned counts, and seven species did so in both.

Characters of Lake Biwa Shown by Waterbirds

The wintering populations of Tufted ducks and Pochards in Lake Biwa, which dive for benthic prey such as mollusks in shallow lake waters, comprised more than 10% of the wintering population in East Asia (*Table 1*). Lake Biwa evidently has abundant benthic animals to support these species. The wintering populations of a group of dabbling ducks including Falcated Ducks, Wigeons, and Gadwalls, which mainly forage for water-weeds, somewhat exceeded or were at least close to the 1% level. This reflects the abundance of such aquatic plants in Lake Biwa. In contrast, the wintering populations of another group of dabbling ducks, including Mallards and Spot-billed Ducks, which mainly rest in the daytime along the lake shore and forage in agricultural lands at night, were considerably below the 1% level.

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Table 1

Wintering populations of waterbirds in Lake Biwa in 2007 relative to the Ramsar Convention's 1% criterion

English name	Species or Subspecies	Population	1% level	No. in Lake Biwa	% level	>1%	SB > 1%
Pochard	*Aythya ferina*	E Asia (nonbreeding)	3,000	36,385	12.1%	+	+
Tufted Duck	*Aythya fuligula*	E & SE Asia (non- breeding)	2,500	28,518	11.4%	+	+
Falcated Duck	*Anas falcata*	Central & E Asia	350	1,645	4.7%	+	+
Great Crested Grebe	*Podiceps cristatus cristatus*	E Asia (nonbreeding)	375	1,176	3.1%	+	+
Wigeon	*Anas penelope*	E Asia (nonbreeding)	7,500	18,520	2.5%	+	+
Black-necked Grebe	*Podiceps nigricollis nigricollis*	E Asia (nonbreeding)	1,000	2,282	2.3%	+	+
Great Cormorant	*Phalacrocorax carbo hanedae*		550	1,036	1.9%	+	+
Gadwall	*Anas strepera strepera*	E Asia (nonbreeding)	7,500	9,973	1.3%	+	–
Smew	*Mergellus albellus*	E Asia (nonbreeding)	250	202	0.8%	–	+
Mallard	*Anas platyrhynchos platyrhynchos*	E Asia (nonbreeding)	15,000	6,179	0.4%	–	–
Scaup	*Aythya marila mariloides*	E Asia	2,500	1,009	0.4%	–	–
Bean Goose	*Anser fabalis middendorffi*		800	294	0.4%	–	–
Common Merganser	*Mergus merganser orientalis*	E Asia (nonbreeding)	750	230	0.3%	–	–
Spot-billed Duck	*Anas poecilorhyncha zonorhyncha*		12,000	3,576	0.3%	–	–
Tundra Swan	*Cygnus columbianus jankowskii*		920	263	0.3%	–	–
Coot	*Fulica atra atra*	E & SE Asia (nonbreeding)	Unknown	26,444	?	?	?

1% level: Wetlands International (2006); no. in Lake Biwa: Hashimoto and Sugawa (2008); ***SB***: Shiga Branch, Wild Bird Society of Japan (2010)

Topic 24 Future Vision of a Sustainable Shiga and the Roadmap for Its Actualization by 2030

Jaegyu Kim · Takashi Iwakawa

Why Is a Sustainable Society Required Now?

The rapid economic development and consumption of resources since the twentieth century has brought great economic wealth and convenience. It is, however, also true that they have brought not only depletion of limited resources and aggravation of the natural environment, but also dire consequences for humanity and society, such as dissolution of communities, regional differences, extinction of traditions and cultures, and social unfairness.

These crises, which endanger even the continued existence of humanity, set the background for why "sustainable societies" are required throughout the world.

What Is a Sustainable Society?

So, what is a sustainable society like? In order to sustain humanity and ecosystems on earth for years to come, the first prerequisite is to reduce human activities to no more than the capacity of resources and the environment of the earth. To achieve this goal, the most important and the easiest-to-perceive target is to prevent global warming. This is because global warming is mainly caused by carbon dioxide from the consumption of fossil fuels, so it is easy to accurately determine the amount of emissions and specify the causes.

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However, a large reduction in carbon dioxide emissions would be immensely difficult since it would rock the foundations of modern society, which is often called "an oil civilization." If this challenge could be met, we could not only avoid these environmental and resource problems, but also their negative impacts on humanity and society. A sustainable society would also be possible.

From this standpoint, researchers in many parts of the world have begun searching for forms of sustainable societies that aim for large reductions in carbon dioxide emissions, to 50–80% of the levels in 1990, by 2050, and searching for ways to get there. As a goal of our research group since 2005, we have been working on the immense challenge in determining what a "sustainable Shiga" will be like and what is required to actualize it by 2030.

How Is a Future Vision of Society Created?

Such new social conditions cannot be actualized as an extension of current social conditions since they are naturally very different, thus a method called backcasting is widely used to forecast future visions for society. The term backcasting here means to first establish a long-term target for future society, and then investigate measures that are required to get there. This is thought to be the prevailing alternative method of forecasting to deal with the limits of the traditional method, which simply accumulates viable measurements (Gomi et al. 2009).

As a vision to target, we have been developing a method based on backcasting to quantitatively picture a society that has greatly reduced the emissions of greenhouse gases. With regard to the reduction of greenhouse gases, while many estimates focus on the kinds of technology to be used, giving consideration to changes in future social

conditions, our method also attempts to consider how people's lives and regional economies, in addition to technology, will change and how we should change them.

By using this method, we are able to project a future vision for Shiga (Shiga Prefecture Sustainable Society Research Team 2007) in which it is possible to achieve targets by changes in both society and technology. For example, a reduction of the greenhouse gas emissions in Shiga Prefecture to a half (compared with 1990 levels) in 2030, could be achieved by (a) improvements to the fundamental structure of energy consumption while keeping a moderate economic growth of 0.9% per year per capita and the current level of population, (b) by increases in energy efficiency through the spread of energy saving devices, etc., nationwide, and (c) by community-level efforts, such as urban improvements, to reduce the use of automobiles. By referring to such research outcomes, the "Shiga's Vision for Sustainable Society" was formulated in March 2008 in Shiga Prefecture (Shiga Prefectural Government, 2008).

What Is Required to Actualize the Vision?

The next step is to show the path to actualizing the vision formulated above. In general, many steps are required to implement a measure, such as development of plans, construction of infrastructure, and support systems (referred to as policies as a collective term). We have developed a method to create a "road map" in which these policies are mapped into a process flow. Taking as an example, the actualization of a 50% reduction of greenhouse gases in 2030 in Shiga Prefecture, as mentioned above, this method has enabled us to suggest a concrete road map (Shiga Prefecture Sustainable Society Research Team Roadmap Committee 2009) stating that all policies are actionable by 2030 and that almost 90% of the target reduction in greenhouse gases will be achieved in 2020, the half-way point, by focusing on (a) policies that accompany large social infrastructure development in the latter half of the road map, while focusing on (b) policies that are close to daily life and work proactively in the first half of the road map (Fig. 1).

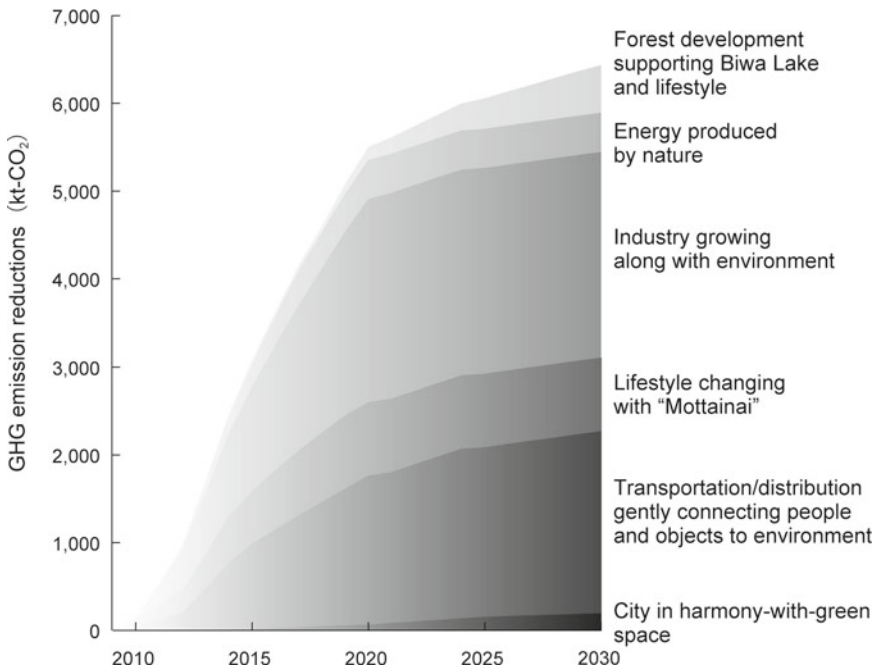

Fig. 1 **Changes in GHG emission reductions by policies (Shiga Prefecture Sustainable Society Research Team Roadmap Committee 2009).**

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Appendix

Machiko Nishino · Masaharu Yoda · Masayoshi Maehata

Appendix 1 Carbon and nitrogen stable isotopic signatures of fish, zoobenthos and zooplankton and their basal foods in Lake Biwa (N. Okuda)

Species	Origin[1]	Habitat type[2]	FFG[3]	*n*	δ^{13}C (‰)		δ^{15}N (‰)		Taxa code
					$\bar{X}$	SD	$\bar{X}$	SD	
Fish									
Pisces									
Hypomesus nipponensis	Ex	P	Pl	7	−21.9	0.6	11.8	0.5	1
Plecoglossus altivelis subsp. (adult)	N	P	Pl	108	−22.1	3.3	13.9	1.6	2
Plecoglossus altivelis subsp. (young)	N	P	Pl	32	−25.0	0.6	16.5	0.7	2′
Oncorhynchus masou subsp.	En	P	Pi	5	−22.4	0.8	16.0	0.2	3
Nipponocypris sieboldii	N	L	B	1	−23.2	–	9.3	–	4
Zacco platypus	N	L	B	78	−21.9	1.9	11.4	1.1	5
Opsariichthys uncirostris uncirostris (adult)	N	P	Pi	5	−20.3	0.2	15.2	0.2	6
Opsariichthys uncirostris uncirostris (young)	N	P	Pl	18	−23.4	0.2	13.8	0.4	6′
Tribolodon hakonensis	N	L	B	50	−20.8	2.6	10.7	1.2	7
Gnathopogon caerulescens	En	P	Pl	12	−22.5	3.6	12.4	2.3	8
Pseudorasbora parva	N	L	B	6	−19.6	2.0	11.8	0.9	9
Sarcocheilichthys variegatus microoculus	En	L	B	28	−16.2	4.9	12.6	0.9	10
Pseudogobio esocinus esocinus	N	L	B	9	−19.3	1.5	12.0	1.3	11
Biwia zezera	N	L	B	5	−23.9	1.3	14.0	0.6	12
Squalidus japonicus japonicus	N	L	B	1	−21.6	–	12.5	–	13
Hemibarbus barbus	N	L	B	4	−20.7	1.6	12.4	1.4	14
Cyprinus carpio	N	L	B	2	−20.6	1.3	10.8	1.9	15

(continued)

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Species	Origin[1]	Habitat type[2]	FFG[3]	*n*	$\delta^{13}C$ (‰)		$\delta^{15}N$ (‰)		Taxa code
					$\bar{X}$	SD	$\bar{X}$	SD	
Carassius sp. (adult)	N	L	B	2	–21.9	4.2	9.0	4.7	16
Carassius sp. (juvenile)	N	L	B	3	–23.9	1.4	5.5	0.4	16′
Acheilognathus rhombeus (adult)	N	L	B	54	–21.3	3.5	9.6	1.3	17
Acheilognathus sp. (juvenile)	N	L	B	6	–13.7	1.6	11.9	0.6	17′
Misgurnus anguillicaudatus	N	L	B	4	–21.7	2.8	8.5	2.1	18
Cobitis sp.	En	L	B	1	–24.2	–	12.2	–	19
Silurus asotus	N	L	Pi	2	–24.4	1.2	12.5	1.0	20
Silurus biwaensis	En	P	Pi	4	–20.6	0.5	16.5	0.3	21
Micropterus salmoides	Ex	L	Pi	70	–21.0	2.9	14.9	1.0	22
Lepomis macrochirus	Ex	L	B	51	–21.2	2.9	13.9	0.7	23
Odontobutis obscura obscura	N	L	B	1	–25.9	–	8.3	–	24
Rhinogobius sp. OR	N	L	B	131	–21.0	3.7	12.6	1.5	25
Tridentiger brevispinis	Ex	L	B	132	–18.9	3.0	13.2	1.0	26
Gymnogobius isaza	En	P	Pl	8	–24.3	1.5	15.3	0.6	27
Gymnogobius urotaenia	N	L	B	23	–21.4	1.5	12.7	1.1	28
Cottus reinii	En	L	B	9	–20.4	2.0	14.3	1.2	29
Zoobenthos									
Gastropoda									
Semisulcospira spp.	En	L	G	123	–15.7	4.3	9.8	1.8	30
Bivalvia									
Unio douglasiae biwae	En	L	F	68	–23.6	2.2	10.4	0.8	31
Lanceolaria oxyrhyncha	En	L	F	5	–23.8	1.6	9.8	1.4	32
Corbicula spp.	En*	L	F	11	–23.0	2.8	9.8	1.2	33
Crustacea									
Jesogammarus annandalei	En	P	D	11	–23.1	1.1	10.7	0.8	34
Jesogammarus naritai	En	L	G	12	–16.1	1.0	8.9	0.7	35
Palaemon paucidens	N	L	B	44	–20.6	1.7	12.9	1.4	36
Macrobrachium nipponense	N	L	B	13	–20.0	2.6	12.2	1.4	37
Zooplankton									
Crustacea									
Cladocera and Copepoda	N	P	F	4	–25.6	2.3	10.9	1.2	38
Basal food									
Phytoplankton				4	–25.5	2.4	7.6	3.6	39
Periphyton				71	–15.1	4.6	6.0	1.8	40
Terrigenous matter[a]				128	–26.4	1.9	5.1	1.7	41

[1] Origin: En=Endemic, Ex=Exotic and N=Native

[2] Habitat type: L=Littoral and P=Pelagic, according to Yuma et al. (1998)

[3] FFG (Functional feeding group): B=Benthivore, D=Detritivore, F=Filter feeder, G=Grazer, Pi=Piscivore and Pl=Planktivore

*Exotic corbicula may be included; [a] Data from Karube et al. (2010) and Kohzu et al. (2009)

Appendix 2 Lists of organisms in and around Lake Biwa (M. Nishino & M. Maehata (eds))

The taxa in the following article are not referred in this appendix, because it was published after this manuscript was submitted: Timoshkin O A et al. (2011) Biodiversity of Lake Biwa: New discoveries and future potential. In: Timoshkin O A (ed) Index of Animal Species inhabiting Lake Baikal and its Catchment Area. Volume II. Basins and Channels in the south of East Siberia and North Mongolia. Book 2. Limnological Institute, Siberian Divisions, Russian Academy of Sciences.

2-1 A list of Protozoa in Lake Biwa (Y. Kusuoka)
2-2 A list of Bacillariophyceae in Lake Biwa (T. Ohtsuka)
2-3 A list of phytoplankton in Lake Biwa (S. Ichise)
2-4 A list of submerged macrophytes in Lake Biwa and its adjacent waters (E. Hamabata)
2-5 A list of plants on the shore area of Lake Biwa (Y. Sasaki)
2-6 A list of Porifera in Lake Biwa and its adjacent waters (Y. Masuda)
2-7 A list of Cnidaria in Lake Biwa (M. Nishino)
2-8 A list of "Turbellaria" (Platyhelminthes) in Lake Biwa and its adjacent waters (M. Kawakatsu & M. Nishino)
2-9 A list of Trematoda and Cestoda (Platyhelminthes) in Lake Biwa (M. Nishino)
2-10 A list of Nemertea in Lake Biwa and its adjacent waters (M. Kawakatsu & M. Nishino)
2-11 A list of Acanthocephala in Lake Biwa (M. Nishino)
2-12 A list of Rotifera in Lake Biwa (T. Nagata and M. Maehata)
2-13 A list of Nematoda in Lake Biwa (E. Inoue and M. Nishino)
2-14 A list of Mollusca in Lake Biwa and its adjacent waters (M. Nishino)
2-15 A list of Oligochaeta (Annelida, Clitellata) in Lake Biwa and its adjacent waters (A. Ohtaka)
2-16 A list of Hirudinea in Lake Biwa and its adjacent waters (T. Itoh)
2-17 A list of Cladocera (Crustacea, Branchiopoda) in Lake Biwa and its adjacent waters (S. Tanaka)
2-18 A list of Copepoda (Crustacea, Maxillopoda) in Lake Biwa and its adjacent waters (K. Kawabata)
2-19 A list of Ostracoda (Crustacea) in Lake Biwa (R. J. Smith)
2-20 A list of Branchiura and Malacostraca (Crustacea) in Lake Biwa and its adjacent waters (M. Nishino)
2-21 A list of Odonata (Hexapoda) in Lake Biwa and its adjacent waters (K. Masunaga)
2-22 A list of Ephemeroptera (Hexapoda) in Lake Biwa and its adjacent waters (S. Ishiwata)
2-23 A list of Plecoptera, Hemiptera, Megaloptera, Neuroptera and Coleoptera (Hexapoda) in Lake Biwa (M. Nishino)
2-24 A list of Chironomidae (Hexapoda) in Lake Biwa and its adjacent waters (E. Inoue & T. Kobayashi)
2-25 A list of Trichoptera (Hexapoda) in Lake Biwa and its adjacent waters (M. Uenishi & K. Tanida)
2-26 A list of Bryozoa in Lake Biwa and its adjacent waters (M. Nishino)
2-27 A list of fishes (Agnatha and Gnathostomata) in Lake Biwa and its adjacent waters (M. Maehata)
2-28 A list of Amphibia in Lake Biwa and its adjacent waters (M. Matsui)
2-29 A list of Reptilia in and around Lake Biwa (M. Matsui)
2-30 A list of Aves in and around Lake Biwa (K. Kameda, J. Ueda, H. Hashimoto & H. Sugawa)

Appendix 2.1

A list of protozoa (non-photosynthetic protists) in Lake Biwa (by Y. Kusuoka)

Taxonomic level	Scientific name	Endemicity	Distribution in Lake Biwa	References
Phylum	Euglenozoa			
Class	Euglenoidea			
Order	Kinetoplastea			
Family	Bodonidae			
	Bodo caudatus		North basin	Takamura et al. (2000)
	Bodo sp.		South basin	Yamasaki et al. (1965)
	Pleuromonas jaculans		North basin, South basin	Takamura et al. (2000)

(continued)

Appendix 2.1
(continued)

Taxonomic level	Scientific name	Endemicity	Distribution in Lake Biwa	References
Phylum	Not assigned[a]			
Class	Not assigned			
Order	Euamoebida			
Family	Amoebidae			
	Amoeba sp.		North basin, South basin	Ichise et al. (1998), Miyamoto (1964), Mori and Miura (1990), Yamasaki et al. (1965), Wakabayashi and Ichise (1982)
	Amoeba spp.		North basin, South basin	Yamasaki et al. (1965)
Family	Vexilliferidae			
	Vexillifera ambulacralis			Mori and Miura (1990)
Phylum	Not assigned			
Class	Not assigned			
Order	Arcellinida			
Family	Microchlamyiidae			
	Microchlamys patella			Mori and Miura (1990)
Family	Arcellidae			
	Arcella discoides		North basin, South basin	Mori and Miura (1990), Negoro (1971), Okano (1991a, b)
	Arcella vulgaris			Ichise and Wakabayashi (1987), Mori and Miura (1990), Negoro (1971), Okano (1991a, b), Tuji and Ishigami (2000), Wakabayashi and Ichise (1982)
	Arcella sp.		North basin	Ichise and Wakabayashi (1987), Iima (1963)
	Arcella spp.		North basin, South basin	Yamasaki et al. (1965)
	Pyxidicula operculata			Mori and Miura (1990)
Family	Difflugiidae			
	Difflugia acuminata			Mori and Miura (1990), Negoro (1971), Okano (1974, 1991a)
	Difflugia biwae		North basin, South basin	Miura (1991), Mori and Miura (1990), Negoro (1971), Okano (1974), Okano (1992a), Wakabayashi and Ichise (1982)
	Difflugia brevicolla		South basin	Ichise and Wakabayashi (1987), Ichise et al. (1998), Mori and Miura (1990), Negoro (1971), Okano (1991a), Wakabayashi and Ichise (1982)
	Difflugia corona		South basin	Ichise and Wakabayashi (1987), Ichise et al. (1998), Mori and Miura (1990), Negoro (1971), Okano (1974, 1991a, b), Tuji and Ishigami (2000), Wakabayashi and Ichise (1982)
	Difflugia globulosa		South basin	Takamura et al. (2000)
	Difflugia globulus			Mori and Miura (1990)

(continued)

Appendix 2.1
(continued)

Taxonomic level	Scientific name	Endemicity	Distribution in Lake Biwa	References
	Difflugia gramen			Mori and Miura (1990)
	Difflugia lanceolata			Mori and Miura (1990)
	Difflugia lobostoma		North basin, South basin	Mori and Miura (1990), Yamasaki et al. (1965)
	Difflugia manicata			Mori and Miura (1990)
	Difflugia oblonga			Ichise and Wakabayashi (1987), Mori and Miura (1990)
	Difflugia pyriformis			Mori and Miura (1990)
	Difflugia tuberculata			Mori and Miura (1990)
	Difflugia urceolata			Okano (1974, 1991a)
	Difflugia sp.		North basin, South basin	Ichise and Wakabayashi (1987), Ichise et al. (1998), Iima (1963), Miyamoto (1964), Okano (1991b, 1993), Yamasaki et al. (1965)
Family	Centropyxidae			
	Centropyxis aculeata		North basin, South basin	Ichise and Wakabayashi (1987), Mori and Miura (1990), Negoro (1971), Okano (1991a, b), Wakabayashi and Ichise (1982), Yamasaki et al. (1965)
	Centropyxis constricta			Mori and Miura (1990)
	Centropyxis sp.		North basin, South basin	Iima (1963), Mori and Miura (1990)
Family	Lesquereusiidae			
	Lesquereusia spiralis			Mori and Miura (1990)
Family	Nebelidae			
	Nebela caudata		South basin	Wakabayashi and Ichise (1982)
	Nebela sp.		North basin, South basin	Mori and Miura (1990), Wakabayashi and Ichise (1982), Yamasaki et al. (1965)
Phylum	Not assigned			
Class	Not assigned			
Order	Not assigned			
Family	Pseudodifflugiidae			
	Pseudodifflugia horrida			Mori and Miura (1990)
Order	Euglyphida			
Family	Euglyphidae			
	Euglypha acanthophora		North basin	Mori and Miura (1990), Wakabayashi and Ichise (1982)
	Euglypha alveolata			Mori and Miura (1990)
	Euglypha ampulla		South basin	Yamasaki et al. (1965)
	Euglypha ciliata		South basin	Mori and Miura (1990), Okano (1991b), Wakabayashi and Ichise (1982)
	Euglypha tuberculata		North basin, South basin	Yamasaki et al. (1965)
	Euglypha sp.		North basin, South basin	Ichise and Wakabayashi (1987), Iima (1963)

(continued)

Appendix 2.1

(continued)

Taxonomic level	Scientific name	Endemicity	Distribution in Lake Biwa	References
Family	Trinematidae			
	Trinema sp.		North basin, South basin	Yamasaki et al. (1965)
Family	Cyphoderiidae			
	Cyphoderia ampulla		North basin	Mori and Miura (1990), Okano (1991b), Yamasaki et al. (1965)
Family	Paulinellidae			
	Paulinella sp.		North basin, South basin	Ichise and Wakabayashi (1987), Mori and Miura (1990), Wakabayashi and Ichise (1982), Yamasaki et al. (1965)
Phylum	Heliozoa			
Class	Not assigned			
Order	Not assigned			
Family	Actinophryidae			
	Actinophrys sol		South basin	Ichise et al. (1998), Mori and Miura (1990), Negoro (1971), Okano (1974, 1991a, b), Takamura et al. (2000)
	Actinophrys sp.			Ichise and Wakabayashi (1987), Tuji and Ishigami (2000), Wakabayashi and Ichise (1982)
	Actinophrys spp.		North basin, South basin	Yamasaki et al. (1965)
	Actinosphaerium eichhorni			Ichise and Wakabayashi (1987), Mori and Miura (1990), Wakabayashi and Ichise (1982), Yamasaki et al. (1965)
Order	Not assigned			
Family	Clathrulinidae			
	Clathrulina sp.			Mori and Miura (1990)
Order	Centrohelida			
Family	Acanthocystidae			
	Acanthocystis chaetophora		South basin	Ichise and Wakabayashi (1987), Ichise et al. (1998), Mori and Miura (1990), Negoro (1971), Okano (1974, 1991a), Wakabayashi and Ichise (1982, 1995)
	Acanthocystis erinaceoides		South basin	Takamura et al. (2000)
	Acanthocystis sp.		South basin	Ichise and Wakabayashi (1987)
Family	Raphidiophryidae			
	Raphidiophrys viridis		South basin	Mori and Miura (1990), Wakabayashi and Ichise (1982)
	Raphidiophrys sp.			Ichise and Wakabayashi (1987), Tuji and Ishigami (2000)
Phylum	Ciliophora			
Class	Heterotrichea			
Order	Heterotrichida			

(continued)

Appendix 2.1

(continued)

Taxonomic level	Scientific name	Endemicity	Distribution in Lake Biwa	References
Family	Stentoridae			
	Stentor sp.		South basin	Ichise and Wakabayashi (1987), Iima (1963), Mori and Miura (1990), Okano (1974, 1991a, b), Tuji and Ishigami (2000), Wakabayashi and Ichise (1982)
Family	Blepharismidae			
	Blepharisma sp.		North basin	Yamasaki et al. (1965)
Class	Spirotrichea			
Order	Euplotida			
Family	Aspidiscidae			
	Aspidisca sp.		North basin, South basin	Yamasaki et al. (1965)
Family	Euplotidae			
	Euplotes sp.		South basin	Yamasaki et al. (1965)
Order	Tintinnida			
Family	Tintinnidiidae			
	Tinntinnidium fluviatile		North basin, South basin	Ichise and Wakabayashi (1987), Ichise et al. (1998), Mori and Miura (1990), Negoro (1971), Okano (1991a), Wakabayashi and Ichise (1982, 1991, 1993, 1995), Wakabayashi et al. (1999)
	Tinntinnidium sp.		North basin, South basin	Ichise and Wakabayashi (1987), Mori and Miura (1990), Wakabayashi and Ichise (1990, 1991, 1993, 1995), Wakabayashi et al. (2001), Yamasaki et al. (1965)
	Tinntinnidium sp. 1		South basin	Ichise et al. (1998)
	Tinntinnidium sp. 2		South basin	Ichise et al. (1998)
Family	Codonellidae			
	Tintinnopsis conus		South basin	Takamura et al. (2000)
	Tintinnopsis sp.		South basin	Ichise et al. (1998), Okano (1991b)
	Codonella (*Tintinnopsis*) *cratera*		North basin, South basin	Ichise and Wakabayashi (1987), Ichise et al. (1998), Mori and Miura (1990), Negoro (1971), Okano (1991a, b), Wakabayashi and Ichise (1982, 1991, 1993), Wakabayashi et al. (1999, 2001)
	Codonella sp.			Tuji and Ishigami (2000)
Order	Choreotrichida			
Family	Strobilidiina			
	Strobilidium gyrans			Mori and Miura (1990)
	Strobilidium sp.		North basin	Tuji and Ishigami (2000), Wakabayashi and Ichise (1982), Wakabayashi et al. (1998)
	Strobilidium sp. 1		South basin	Ichise and Wakabayashi (1987), Ichise et al. (1998)

(continued)

Appendix 2.1

(continued)

Taxonomic level	Scientific name	Endemicity	Distribution in Lake Biwa	References
	Strobilidium sp. 2		South basin	Ichise and Wakabayashi (1987), Ichise et al. (1999)
	Strobilidium sp. 3		South basin	Ichise and Wakabayashi (1987), Ichise et al. (2000)
Order	Stichotrichida			
Family	Amphisiellidae			
	Balladyna parvula			Mori and Miura (1990)
Order	Sporadotrichida			
Family	Halteriidae			
	Halteria grandinella		North basin, South basin	Ichise and Wakabayashi (1987), Ichise et al. (1998), Mori and Miura (1990), Wakabayashi and Ichise (1982, 1990, 1991, 1996)
Family	Oxytrichidae			
	Oxytricha sp.		North basin, South basin	Yamasaki et al. (1965)
Order	Urostylida			
Family	Pseudourostylidae			
	Pseudourostyla cristata		South basin	Chen et al. (2010)
Order	Strombidiidae			
Family	Strombidiidae			
	Strombidium viride		North basin, South basin	Ichise and Wakabayashi (1987), Mori and Miura (1990), Wakabayashi and Ichise (1982, 1990, 1991, 1993, 1995, 1996), Wakabayashi et al. (1999, 2000)
	Strombidium sp.		North basin	Mori and Miura (1990), Wakabayashi and Ichise (1990, 1991, 1993, 1994, 1995, 1996), Wakabayashi et al. (1999, 2000, 2001)
Class	Litostomatea			
Order	Haptorida			
Family	Actinobolinidae			
	Actinobolina radians		South basin	Ichise and Wakabayashi (1987), Ichise et al. (1998), Mori and Miura (1990)
Family	Didiniidae			
	Monodinium (*Didinium*) *balbianii*		South basin	Ichise and Wakabayashi (1987), Ichise et al. (1998), Mori and Miura (1990), Wakabayashi and Ichise (1982)
	Didinium nasutum		South basin	Ichise and Wakabayashi (1987), Ichise et al. (1998), Mori and Miura (1990), Wakabayashi and Ichise (1982)
	Didinium sp.		South basin	Wakabayashi and Ichise (1996)
Family	Enchelyidae			
	Enchelydium sp.		South basin	Wakabayashi and Ichise (1982)
Family	Homalozoonidae			

(continued)

Appendix 2.1

(continued)

Taxonomic level	Scientific name	Endemicity	Distribution in Lake Biwa	References
Family	Lacrymariidae			
	Lacrymaria sp.			Ichise and Wakabayashi (1987)
Family	Spathidiidae			
	Spathidium sp.		North basin, South basin	Ichise and Wakabayashi (1987), Ichise et al. (1998), Mori and Miura (1990), Wakabayashi and Ichise (1982, 1991, 1994, 1995), Wakabayashi et al. (2000)
Family	Tracheliidae			
	Pelagodileptus trachelioides			Kusuoka (2011)
	Paradileptus robustus		North basin, South basin	Ichise and Wakabayashi (1987), Ichise et al. (1998), Mori and Miura (1990), Okano (1991b), Wakabayashi and Ichise (1982)
	Paradileptus sp.			Tuji and Ishigami (2000), Wakabayashi et al. (1999)
	Dileptus sp.		North basin, South basin	Ichise and Wakabayashi (1987), Ichise et al. (1998), Mori and Miura (1990), Wakabayashi and Ichise (1982)
Family	Trachelophyllidae			
	Lagynophrya simplex		South basin	Takamura et al. (2000)
Order	Pleurostomatida			
Family	Amphileptidae			
	Amphileptus sp.?			Tuji and Ishigami (2000)
Order	Cyclotrichiida			
Family	Mesodiniidae			
	Askenasia volvox		North basin, South basin	Ichise and Wakabayashi (1987), Ichise et al. (1998), Mori and Miura (1990), Wakabayashi and Ichise (1982, 1996)
	Askenasia sp.		North basin, South basin	Mori and Miura (1990), Okano (1991b), Wakabayashi and Ichise (1982, 1990, 1991)
	Mesodinium pulex		North basin	Wakabayashi et al. (2000)
	Mesodinium sp.			Wakabayashi and Ichise (1990), Wakabayashi and Ichise (1991)
Class	Phyllopharyngea			
Order	Chlamydodontida			
Family	Chilodonellidae			
	Chilodonella uncinata		North basin	Takamura et al. (2000)
Order	Endogenida			
Family	Acinetidae			
	Acineta sp.			Tuji and Ishigami (2000)

(continued)

Appendix 2.1

(continued)

Taxonomic level	Scientific name	Endemicity	Distribution in Lake Biwa	References
	Squalorophyra sp.		South basin	Ichise and Wakabayashi (1987), Ichise et al. (1998), Okano (1993), Wakabayashi and Ichise (1982)
Family	Tokophryidae			
	Tokophrya quadrupartita		South basin	Mori and Miura (1990), Wakabayashi and Ichise (1982)
	Tokophrya sp.		South basin	Ichise and Wakabayashi (1987), Ichise et al. (1998)
Family	Trichophryidae			
	Staurophrya elegans		North basin, South basin	Ichise and Wakabayashi (1987), Ichise et al. (1998), Mori and Miura (1990), Wakabayashi and Ichise (1982)
	Staurophrya sp.			Ichise and Wakabayashi (1987), Tuji and Ishigami (2000)
Class	Nassophorea			
Order	Nassulida			
Family	Nassulidae			
	Nassula sp.			Mori and Miura (1990)
Class	Colpodea			
Order	Bryophryida			
Family	Bursariidae			
	Bursaria sp.		South basin	Ichise and Wakabayashi (1987), Ichise et al. (1998), Mori and Miura (1990), Okano (1991b), Wakabayashi and Ichise (1982)
Class	Prostomatea			
Order	Prorodontida			
Family	Colepidae			
	Coleps hirtus		South basin	Ichise and Wakabayashi (1987), Ichise et al. (1998), Mori and Miura (1990), Wakabayashi and Ichise (1982)
	Levicoleps biwae	[b]	South basin	Foissner et al. (2008)
Class	Oligohymenophorea			
Order	Peniculida			
Family	Parameciidae			
	Paramecium sp.		South basin	Ichise and Wakabayashi (1987), Ichise et al. (1998), Mori and Miura (1990), Okano (1991b), Tuji and Ishigami (2000), Wakabayashi and Ichise (1982)
Family	Stokesiidae			
	Stokesia vernalis		South basin	Ichise et al. (1998), Wakabayashi et al. (2000)
	Stokesia sp.			Tuji and Ishigami (2000)
Order	Philasterida			

(continued)

Appendix 2.1

(continued)

Taxonomic level	Scientific name	Endemicity	Distribution in Lake Biwa	References
Family	Cinetochilidae			
	Cinetochilum margaritaceum		South basin	Takamura et al. (2000)
Family	Uromenatidae			
	Uronema sp.		North basin, South basin	Miyamoto (1964), Wakabayashi et al. (2001), Yamasaki et al. (1965)
Order	Pleuronematida			
Family	Cyclidiidae			
	Cyclidium sp.		North basin, South basin	Miyamoto (1964), Yamasaki et al. (1965)
Family	Histiobalantiidae			
	Histiobalantium natans		South basin	Foissner et al. (2009)
Family	Pleuronematidae			
	Pleuronema sp.		North basin, South basin	Mori and Miura (1990), Wakabayashi and Ichise (1982), Wakabayashi and Ichise (1990)
Order	Tetrahymenida			
Family	Glaucomidae			
	Glaucoma sp.		South basin	Miyamoto (1964), Yamasaki et al. (1965)
Family	Turaniellidae			
	Colpidium sp.		North basin	Miyamoto (1964)
Order	Sessilida			
Family	Epistylididae			
	Epistylis plicatylis		South basin	Ichise et al. (1998), Wakabayashi and Ichise (1991)
	Epistylis sp.		North basin, South basin	Ichise and Wakabayashi (1987), Iima (1963), Miura (1991), Miyamoto (1964), Mori and Miura (1990), Tuji and Ishigami (2000), Wakabayashi and Ichise (1982), Yamasaki et al. (1965)
Family	Lagenophryidae			
	Lagenophrys sp.			Okano (1991a)
Family	Ophrydiidae			
	Ophrydium eichornii		South basin	Ji and Kusuoka (2009)
Family	Vaginicolidae			
	Cothurnia annulata		South basin	Okano (1991b)
	Cothurnia sp.			Tuji and Ishigami (2000)
Family	Vorticellidae			
	Apocarchesium rosettum		South basin	Ji and Kusuoka (2009)
	Vorticella campanula			Mori and Miura (1990)
	Vorticella campanulata			Okano (1974, 1991a)

(continued)

Appendix 2.1
(continued)

Taxonomic level	Scientific name	Endemicity	Distribution in Lake Biwa	References
	Vorticella sp.		North basin, South basin	Ichise and Wakabayashi (1987), Ichise et al. (1998), Iima (1963), Miyamoto (1964), Okano (1993), Tuji and Ishigami (2000), Wakabayashi and Ichise (1982), Yamasaki et al. (1965)
	Vorticella spp.			Mori and Miura (1990)
	Carchesium polypinum		South basin	Okano (1974, 1991a, b)
	Carchesium sp.			Ichise and Wakabayashi (1987), Mori and Miura (1990)
Family	Zoothamniidae			
	Zoothamnium limneticum		South basin	Ichise et al. (1998), Miyamoto (1964)
	Zoothamnium sp.		South basin	Ichise et al. (1998)
Order	Mobilida			
Family	Trichodinidae			
	Trichodina sp.		North basin, South basin	Ichise and Wakabayashi (1987), Ichise et al. (1998), Mori and Miura (1990), Wakabayashi and Ichise (1982, 1991)
Phylum	Apicomplexa			
Class	Conoidasida			
Order	Eucoccidiorida			
Family	Eimeriidae			
	Goussia biwaensis	[b]	Mano (type locality)	Molar and Ogawa (2000)
	Goussia grygieri	[b]	Mano (type locality)	Molar and Ogawa (2000)
	Goussia sp. I		Mano (type locality)	Molar and Ogawa (2000)
	Goussia nippinica	[b]	Mano (type locality)	Molar and Ogawa (2000)
	Goussia wakabayashii	[b]	Mano (type locality)	Molar and Ogawa (2000)
	Goussia sp. II		Mano (type locality)	Molar and Ogawa (2000)
	Goussia sp. III		Mano (type locality)	Molar and Ogawa (2000)

This list is not complete. A thorough compilation of all the literature awaits, and many species whose existance in Lake Biwa has been confirmed by personal observation but not published have been omitted from this list
The higher level classification of the ciliates follows Lynn (2007)
The higher level classification of the other protozoa follows Lee et al. (2000)
Many species in this list were taken from ecological literature so the validity of the identification could not be confirmed
Apparent mistakes such as spelling in the scientific names have been corrected
[a]Not assigned means that the higher level classification of this taxon is still in consideration among specialists
[b]Not found other than Lake Biwa, but further study is required to ensure the endemicity

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Appendix 2.2

A list of Bacillariophyceae newly described from Lake Biwa (by T. Ohtsuka)

Scientific name	References
Achnanthes hauciana var. *nipponica* Skvortsov	Skvortzow (1936)
Achnanthes linearis var. *minuta* Skvortsov	Skvortzow (1936)
Aulacoseira nipponica (Skvortsov) Tuji	Tuji (2002)
Basionym: *Melosira solida* var. *nipponica* Skvortsov	Skvortzow (1936)
Caloneis punctata Skvortsov	Skvortzow (1936)

(continued)

Appendix 2.2

(continued)

Scientific name	References
Caloneis nipponica Skvortsov	Skvortzow (1936)
Cocconeis disculus var. *nipponica* Skvortsov	Skvortzow (1936)
Coscinodiscus lacustris var. *nipponica* Skvortsov	Skvortzow (1936)
Cymbella lata var. *nipponica* Skvortsov	Skvortzow (1936)
Cymbella nipponica Skvortsov	Skvortzow (1936)
Cymbella rheophila Ohtsuka in Ohtsuka et Tuji	Ohtsuka and Tuji (2002)
Basionym: *Cymbella turgidula* var. *nipponica* Skvortsov	Skvortzow (1936)
Diploneis marginestriata var. *nipponica* Skvortsov	Skvortzow (1936)
Diploneis ovalis var. *bipunctata* Skvortsov	Skvortzow (1936)
Diploneis ovalis var. *nipponica* Skvortsov	Skvortzow (1936)
Diploneis ovalis var. *oblongella* fo. *nipponica* Skvortsov	Skvortzow (1936)
Eunotia sudetica var. *nipponica* Skvortsov	Skvortzow (1936)
Frustulia rhomboides var. *saxonica* fo. *nipponica* Skvortsov	Skvortzow (1936)
Gomphonema lingulatum var. *elongatum* Skvortsov	Skvortzow (1936)
Gomphonema lingulatum var. *pumila* Skvortsov	Skvortzow (1936)
Gomphonema vastum var. *maxima* Skvortsov	Skvortzow (1936)
Gyrosigma attenuatum var. *nipponica* Skvortsov	Skvortzow (1936)
Luticola nipponica (Skvortsov) Tuji	Tuji (2003)
Basionym: *Navicula mutica* var. *nipponica* Skvortsov	Skvortzow (1936)
Melosira americana var. *nipponica* Skvortsov	Skvortzow (1936)
Navicula achnanthoides Skvortsov	Skvortzow (1936)
Navicula biwaensis (Skvortsov) Ohtsuka in Ohtsuka et Tuji	Ohtsuka and Tuji (2002)
Basionym: *Navicula rostellata* var. *biwaensis* Skvortsov	Skvortzow (1936)
Navicula costulata fo. *curta* Skvortsov	Skvortzow (1936)
Navicula costulata var. *nipponica* Skvortsov	Skvortzow (1936)
Navicula costulata var. *tenuirostris* Skvortsov	Skvortzow (1936)
Navicula gastrum fo. *nipponica* Skvortsov	Skvortzow (1936)
[Synonym]: *Placoneis elliptica* (Hust.) Ohtsuka	Ohtsuka (2002)
Navicula hasta var. *undulata* (Skvortsov) H. Kobayasi in H. Kobayasi et al.	Mayama et al. (2002)
Basionym: *Navicula undulata* Skvortsov	Skvortzow (1936)
Navicula kawamurae Skvortsov	Skvortzow (1936)
Navicula lanceolata var. *nipponica* Skvortsov	Skvortzow (1936)
[Synonym]: *Navicula angustissima* Hust	Schmidt et al (1874–1959)
Navicula minuta Skvortsov	Skvortzow (1936)
Navicula nippon Skvortsov	Skvortzow (1936)
Navicula nipponica (Skvortsov) Lange-Bert.	Lange-Bertalot (1993)
Basionym: *Navicula radiosa* fo. *nipponica* Skvortsov	Skvortzow (1936)
Navicula peregrina var. *nipponica* Skvortsov	Skvortzow (1936)

(continued)

Appendix 2.2

(continued)

Scientific name	References
Navicula pseudobrasiliana Tuji	Tuji (2003)
Navicula pusio fo. *minuta* Skvortsov	Skvortzow (1936)
Navicula similis var. *nipponica* Skvortsov	Skvortzow (1936)
[Synonym]: *Placoneis abundans* Metzeltin et al.	Metzeltin et al. (2005)
Navicula subhamulata var. *parallela* Skvortsov	Skvortzow (1936)
Navicula subhasta Ohtsuka in Ohtsuka et Tuji	Ohtsuka and Tuji (2002)
Basionym: *Navicula hasta* var. *gracilis* Skvortsov	Skvortzow (1936)
Navicula tuscula var. *densistriata* Skvortsov	Skvortzow (1936)
Navicula subtrophicatrix Tuji	Tuji (2003)
Neidium obliquestriatum var. *elongata* Skvortsov	Skvortzow (1936)
Pinnularia braunii var. *amphicephala* fo. *nipponica* Skvortsov	Skvortzow (1936)
Pinnularia braunii var. *nipponica* Skvortsov	Skvortzow (1936)
Pinnularia cucumis Skvortsov	Skvortzow (1936)
Pinnularia gibba var. *biwaensis* Skvortsov	Skvortzow (1936)
Pinnularia kawamurae Skvortsov	Skvortzow (1936)
Pinnularia lacus-biwa Skvortsov	Skvortzow (1936)
Pinnularia major var. *nipponica* Skvortsov	Skvortzow (1936)
Pinnularia nakaii Skvortsov	Skvortzow (1936)
Pinnularia platycephala var. *hattoriana* fo. *angustior* Skvortsov	Skvortzow (1936)
Pinnularia polyonca var. *nipponica* Skvortsov	Skvortzow (1936)
Pinnularia striatula Skvortsov	Skvortzow (1936)
Pinnularia undulata var. *nipponica* Skvortsov	Skvortzow (1936)
Sellaphora lambda var. *nipponica* (Skvortsov) Ohtsuka in Ohtsuka et Tuji	Ohtsuka and Tuji (2002)
Basionym: *Navicula lambda* var. *nipponica* Skvortsov	Skvortzow (1936)
Stephanodiscus biwaensis Skvortsov	Skvortzow (1936)
Stephanodiscus pseudosuzukii Tuji et Kociolek	Tuji and Kociolek (2000)
Stephanodiscus suzukii Tuji et Kociolek	Tuji and Kociolek (2000)
Surirella biwaensis Skvortsov	Skvortzow (1936)
Surirella gracilis fo. *curvata* Skvortsov	Skvortzow (1936)
Surirella robusta var. *nipponica* Skvortsov	Skvortzow (1936)
Surirella tenera var. *nipponica* Skvortsov	Skvortzow (1936)
Synedra minuscula var. *capitata* Skvortsov	Skvortzow (1936)
Synedra rumpens var. *fragilarioides* fo. *nipponica* Skvortsov	Skvortzow (1936)

[a]The above is a checklist of diatoms whose type locality is Lake Biwa; 66 diatom taxa are listed. Three of them have been already synonymized with the others whose type localties are outside Lake Biwa

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Appendix 2.3

A list of phytoplankton in Lake Biwa and its adjacent waters recorded by the long-term monitoring data of Lake Biwa Environmental Research Institute (former the Shiga Prefectural Institute of Public Health and Environmental Science) since 1978 (by S. Ichise)

Taxonomic level	Scientific name	Endemicity	Biomass +: common, ++: abundant	Planktonic	Benthic	Habitat	
						Pelagic	Littoral areas and attached lakes
Phylum	Cyanophyta						
Class	Cyanophyceae						
Order	Chroococcales						
	Microcystis aeruginosa (Kützing) Kützing		++	+		+	+
	Microcystis wesenbergii Komarek in Kondrateva		++	+		+	+
	Microcystis incerta Lemmermann		+	+		+	+
	Microcystis viridis (Broun) Lemmermann		+	+			+
	Microcystis novacekii (Komárek) Compère		+	+			+
	Microcystis ichthyoblabe Kützing		+	+			+
	Aphanocapsa elachista West et G. S. West		+	+		+	+
	Aphanocapsa elachista var. *conferta* West. et G. S. West		++	+		+	+
	Aphanothece clathrata West et G. S. West		++	+		+	+
	Aphanothece nidulans P. Richter		+	+	+		+
	Aphanothece saxicola Nägeli			+	+		+
	Dactylococcopsis sp.			+	+		+
	Chroococcus dispersus (Keissler) Lemmermann		++	+	+	+	+
	Chroococcus dispersus (Keissl) Lemmermann var. *minor* G. M. Smith		++	+	+	+	+

(continued)

Appendix 2.3
(continued)

Taxonomic level	Scientific name	Endemicity	Biomass +: common, ++: abundant	Planktonic	Benthic	Habitat	
						Pelagic	Littoral areas and attached lakes
	Chroococcus minutus (Kützing) Nägeli		+	+	+		+
	Chroococcus limneticus Lemmermann		+	+	+	+	+
	Gloeocapsa sp.			+	+		+
	Gloeothece sp.			+	+		+
	Rhabdoderma lineare Schmidle et Lauterborn			+	+		+
	Merismopedia tenuissima Lemmermann		+	+	+	+	+
	Merismopedia punctata Meyen			+	+		+
	Merismopedia elegans A. Braun ex Kützing			+	+		+
	Woronichinia naegeliana (Unger) Elenkin		+	+			+
	Coelosphaerium kuetzingianum Nägeli		+	+		+	+
	Gomphosphaeria lacustris Chod		++	+	+	+	+
	Gomphosphaeria aponina Kutzing		+	+	+	+	+
	Marssoniella elegans Lemmermann			+	+		+
	Chamaesiphon sp.			+	+		+
Order	Nostocales						
	Aphanizomenon flos-aquae Ralfs ex Bornet et Flahault		+	+		+	+
	Anabaena spiroides Klebahn		+	+			+
	Anabaena spiroides var. *crassa* Klebahn		+	+		+	+
	Anabaena macrospora Klebahn		+	+		+	+
	Anabaena macrospora var. *crassa* Lemmermann		+	+		+	+
	Anabaena affinis Lemmermann		+	+			+
	Anabaena planctonica Brunnth.			+			+
	Anabaena smithii (Komárek) M. Watanabe			+			+
	Anabaena circinalis Rabenh. ex Bornet et Flahault			+			+
	Anabaena oumiana M. Watanabe		+	+			+
	Anabaena flos-aquae Bréb. ex Bornet et Flahault		+	+			+
	Anabaena aphanizomenoides Forti			+			+
	Anabaenopsis sp.			+			+

(continued)

Appendix 2.3

(continued)

Taxonomic level	Scientific name	Endemicity	**Biomass +: common, ++: abundant**	Planktonic	Benthic	Habitat	
						Pelagic	Littoral areas and attached lakes
	Nostoc sp.			+	+		+
	Oscillatoria tenuis Gomont		+	+	+		+
	Oscillatoria kawamurae Negoro		+	+	+		+
	Phormidium tenue Gomont		+	+	+	+	+
	Phormidium mucicola Huber-Pestalozzi et Naumann		+	+	+	+	+
	Lyngbya limnetica Lemmermann		+	+	+	+	+
	Raphidiopsis curvata F. E. Fritsch et M. F. Rich			+	+		+
	Homoeothrix janthina (Born. and Flah.) Starmach			+	+		+
Phyllum	Heterokontophyta						
Class	Xanthophyceae						
Order	Mischococcales						
	Botryococcus braunii Kutzing		++	+		+	+
	Chlorocloster sp.		++	+	+	+	+
	Peroniella sp.			+	+		+
	Centritractus belanophorus Lemmermann			+	+		+
	Ophiocytium sp.			+	+		+
Class	Chrysophyceae						
Order	Chrysamoebales						
	Chrysidiastrum catenatum Lauterborn		+	+			+
	Lagynion ampullaceum Pascher			+			+
Order	Chromulinales						
	Chromulina sp.		++	+	+	+	+
	Kephyrion sp.		+	+	+		+
	Chrysamoeba radians G. A. Klebs		++	+		+	+
	Chrysococcus rufescens G. A. Klebs			+			+
	Chrysocapsa planktonica Pascher		+	+		+	+
	Pseudopedinella sp.		+	+	+	+	+
Order	Ochromonadales						
	Chrysosphaerella longispina Lauterborn		+	+		+	+
	Mallomonas tonsurata Teiling		++	+		+	+
	Mallomonas reginae Teiling		+	+		+	+
	Mallomonas fastigata Zacharias		++	+		+	+

(continued)

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(continued)

Taxonomic level	Scientific name	Endemicity	**Biomass +: common, ++: abundant**	Planktonic	Benthic	Habitat	
						Pelagic	Littoral areas and attached lakes
	Mallomonas akrokomos Ruttner in Pascher		++	+		+	+
	Mallomonas elongata Reverdin			+			+
	Mallomonas papillosa K. Harris et W. H. Bradley			+			+
	Mallomonas eoa Takahashi			+			+
	Mallomonas elliptica Matvienko			+			+
	Uroglena americana G.N.Calkins		++	+		+	+
	Uroglena volvox C. G. Ehrenberg		+	+			+
	Dinobryon divergens O.E.Imhof		+	+		+	+
	Dinobryon cylindricum O.E.Imhof		+	+		+	+
	Dinobryon bavaricum O.E.Imhof		++	+		+	+
	Dinobryon sertularia Ehrenberg			+			+
	Dinobryon sociale Ehrenberg			+			+
	Dinobryon sociale var. *americanum* (Brunnth.) Bachmann			+			+
	Pseudokephyrion conicum Schiller		+	+		+	+
	Pseudokephyrion pseudospirale Bourrelly			+			+
	Ochromonas mutabilis Klebs		+	+	+	+	+
	Ochromonas crenata Klebs		+	+	+	+	+
	Synura uvella Ehrenberg emend. F.Stein		+	+			+
	Synura petersenii Korshikov		+	+		+	+
	Synura echinulata Korshikov			+			+
Class	Raphidophyceae						
Order	Chloromonadales						
	Gonyostomum semen Diesing		+	+			+
Order	Vaucheriales						
	Vacuolaria sp.			+	+		+
Class	Bacillariophyceae						
	Melosira varians Agardh		+	+	+	+	+
	Aulacoseira nipponica (Skvortzow) Tuji	+	++	+		+	+
	Aulacoseira granulata (Ehr.) Simonsen		++	+	+	+	+
	Aulacoseira granulata var. *angustissima* (O.Muller) Simonsen		++	+	+	+	+
	Aulacoseira italica (Ehrenberg) Simonsen		++	+	+	+	+

(continued)

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(continued)

Taxonomic level	Scientific name	Endemicity	Biomass +: common, ++: abundant	Planktonic	Benthic	Habitat	
						Pelagic	Littoral areas and attached lakes
	Aulacoseira italica var. *tenuissima* (Grunow) Simonsen			+	+		+
	Aulacoseira distans (Ehrenberg) Simonsen		++	+	+	+	+
	Aulacoseira ambigua (Grunow) Simonsen		+	+	+		+
	Cyclotella kuetzingiana Thwaites			+			+
	Cyclotella stelligera (Cleve et Grunow) Van Heurck		++	+		+	+
	Cyclotella comta (Ehrenberg) Kuetzing			+			+
	Cyclotella meneghiniana Kuetzing		+	+			+
	Cyclotella glomerata Bachmann		++	+		+	+
	Cyclotella atomus Hustedt			+			+
	Cyclotella meduanae Germain			+			+
	Cyclotella bodanica Grunow			+			+
	Discostella pseudostelligera (Husted) Houk et Klee		+	+			+
	Stephanodiscus suzukii Tuji et Kociolek	+	++	+		+	+
	Stephanodiscus pseudosuzukii Tuji et Kociolek	+	++	+		+	+
	Stephanodiscus dubius Hustedt			+			+
	Stephanodiscus astraea var. *minutula* (Kutzing) Grunow		++	+		+	+
	Stephanodiscus alpinus Hustedt			+			+
	Stephanodiscus minutulus (Kützing) Cleve et Möller			+			+
	Stephanodiscus parvus Stoermer et Håk.		+	+		+	+
	Cyclostephanos tholiformis Stoermer, Hakansson et Theriot			+			+
	Cyclostephanos dubius (Fricke) Round			+			+
	Cyclostephanos invisitatus (Hohn et Hellermann) Theriot, Stoermer et Håk.			+			+
	Coscinodiscus sp.			+			+
	Thalassiosira bramaputrae (Ehrenberg) Håk. et Locker			+			+
	Skeletonema potamos (Weber) Hasle		+	+		+	+

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(continued)

Taxonomic level	Scientific name	Endemicity	**Biomass +: common, ++: abundant**	Planktonic	Benthic	Habitat	
						Pelagic	Littoral areas and attached lakes
	Urosolenia longiseta (O.Zacharias) Edlund et Stoermer			+			+
	Acanthoceras zachariasii (Brun) Simonsen		+	+		+	+
	Meridion sp.			+	+		+
	Tabellaria fenestrata (Lyngbye) Kuetzing			+	+		+
	Diatoma vulgaris Bory		+	+	+		+
	Diatoma elongatum (Lyngbye) Agardh			+	+		+
	Fragilaria crotonensis Kitton		++	+		+	+
	Fragilaria capucina Desmazieres		+	+	+	+	+
	Staurosirella pinnata (Ehrenberg) Williams et Round			+	+		+
	Asterionella formosa Hassall		++	+		+	+
	Asterionella gracillima (Hantzsch) Heiberg		+	+			+
	Synedra ulna (Nitzsch) Ehrenberg		+	+	+	+	+
	Synedra ulna var. *ramesi* (Herib.) Hustedt			+	+		+
	Synedra acus Kutzing		++	+	+	+	+
	Synedra acus var. *radians* (Kutzing) Hustedt		+	+	+	+	+
	Synedra rumpens Kutzing		+	+	+	+	+
	Synedra rumpens var. *familiaris* (Kützing) Grunov			+	+		+
	Synedra rumpens var. *meneghiniana* Grunow			+	+		+
	Rhoicosphaenia curvata (KUTZ.) GRUN.			+	+		+
	Cocconeis placentula Ehrenberg		++	+	+	+	+
	Cocconeis euglypta Ehrenberg		+	+	+		+
	Achnanthidium minutissimum Kutzing		+	+	+	+	+
	Eunotia sp.			+	+		+
	Frustulia rhomboides (Ehrenberg) De Toni			+	+		+
	Gyrosigma acuminatum (Kützing) Rabenhorst		+	+	+		+
	Gyrosigma distortum (W. Smith) Cleve			+	+		+

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(continued)

Taxonomic level	Scientific name	Endemicity	**Biomass +: common, ++: abundant**	Planktonic	Benthic	Habitat	
						Pelagic	Littoral areas and attached lakes
	Neidium iridis (Ehrenberg) Cleve			+	+		+
	Neidium iridis var. *ampilata* (Ehrenberg) Cleve			+	+		+
	Diploneis ovalis (Hilse) Cleve			+	+		+
	Cymbella tumida (Brébisson) Van Heurck		+	+	+		+
	Encyonema ventricosum (C. Agardh) Grunow		+	+	+	+	+
	Navicula hasta var. *undulata* (Skvortzov) H. Kobayasi		+	+	+		+
	Navicula cryptocephala Kützing		+	+	+	+	+
	Navicula veneta Kützing			+	+		+
	Navicula lanceolata (Agardh) Kützing			+	+		+
	Navicula minima Grunow			+	+		+
	Navicula pupula Kützing		+	+	+	+	+
	Navicula nipponica (Skvortzov) Lange-Bert.			+	+		+
	Navicula viridula (Kuetzing) Ehrenberg			+	+		+
	Navicula gregaria Donkin			+	+		+
	Stauroneis phoenicenteron Ehrenberg			+	+		+
	Pinnularia braunii (Grunow) Cleve			+	+		+
	Amphora pediculus (Kützing) Grunow			+	+		+
	Gomphonema angustatum (Kützing) Rabenhorst			+	+		+
	Gomphonema parvulum (Kuetzing) Kuetzing			+	+		+
	Gomphonema acuminatum Ehrenberg			+	+		+
	Gomphonema tetrastigmatum Horikawa et Okuno			+	+		+
	Gomphonema intricatum Kuetzing			+	+		+
	Gomphonema olivaceum (Lyngbye) Kuetzing			+	+		+
	Epithemia sorex Kuetzing			+	+		+
	Bacillaria paxillifer (O.F.Müll.) Hendey			+	+		+
	Nitzschia holsatica Hustedt		+	+	+	+	+

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(continued)

Taxonomic level	Scientific name	Endemicity	Biomass +: common, ++: abundant	Planktonic	Benthic	Habitat	
						Pelagic	Littoral areas and attached lakes
	Nitzschia acicularis W. Smith		++	+	+	+	+
	Nitzschia amphibia Grunow			+	+		+
	Nitzschia kuetzingiana Hilse ex Rabenhorst			+	+		+
	Nitzschia palea W. Smith		+	+	+	+	+
	Nitzschia paleacea Grunow in Van Heurck			+	+		+
	Nitzschia romana (Grunow) Mayer			+	+		+
	Nitzschia tryblionella Hantzsch			+	+		+
	Nitzschia fonticola Grunow in Van Heurck			+	+		+
	Nitzschia dissipata (Kuetzing) Grunow		+	+	+	+	+
	Nitzschia obtusa W. Smith			+	+		+
	Nitzschia lorenziana Grunow			+	+		+
	Nitzschia closterium W. Smith			+	+		+
	Cymatopleura solea (Brébisson) W. Smith			+	+		+
	Cymatopleura elliptica (Brébisson) W. Smith			+	+		+
	Surirella robusta Ehrenberg			+	+		+
	Surirella ovata Kuetzing			+	+		+
	Surirella ovata var. pinnata W. Smith			+	+		+
	Surirella biseriata Brebisson in Brebisson et Godey			+	+		+
Phyllum	Dinophyta						
Class	Dinophyceae						
Order	Gymnodiniales						
	Gymnodinium helveticum Penard		++	+		+	+
	Gymnodinium mirabile Penard			+			+
	Gymnodinium uberrimum (G.J.Allman) Kofoid et Swezy		+	+		+	+
	Gymnodinium aeruginosum F. Stein			+			+
	Glenodinium pulvisculus (Ehrenberg) F. Stein		++	+		+	+
Order	Peridiniales						
	Peridinium tabulatum Ehrenberg			+			+
	Peridinium volzii Woloszynska		+	+			+
	Peridinium cunnigtonii Lemmermann			+			+

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(continued)

Taxonomic level	Scientific name	Endemicity	Biomass +: common, ++: abundant	Planktonic	Benthic	Habitat	
						Pelagic	Littoral areas and attached lakes
	Peridinium africanum Lemmermann			+			+
	Peridinium penardii (Lemmermann) Lemmermann		+	+			+
	Peridinium penardiforme Lindemann		+	+		+	+
	Peridinium inconspicuum Lemmermann			+			+
	Peridinium berolinense Lemmermann		++	+		+	+
	Peridinium berolinense var. *apiculatum* (Lemmermann) Calado, Craveiro			+			+
	Peridinium elpatiewskyi (Ostenfeld) Lemmermann		+	+		+	+
	Ceratium hirundinella (O.F.Muller) Dujardin		++	+		+	+
Phyllum	Cryptophyta						
Class	Cryptophyceae						
Order	Cryptomonadales						
	Cryptomonas erosa Ehrenberg		++	+		+	+
	Cryptomonas erosa var. *reflexa* M. Marsson		+	+		+	+
	Cryptomonas ovata Ehrenberg			+			+
	Cryptomonas curvata Ehrenberg			+			+
	Cryptomonas sp.		++	+		+	+
	Rhodomonas lens Pascher et Ruttner		+	+		+	+
	Rhodomonas sp.		++	+		+	+
Phyllum	Euglenophyta						
Class	Euglenophyceae						
Order	Euglenales						
	Euglena acus Ehrenberg			+	+		+
	Euglena proxima P.A.Dangeard		+	+	+		+
	Euglena gracilis Klebs			+	+		+
	Euglena oxyuris Schmarda		+	+	+		+
	Euglena tripteris (Dujardin) Klebs			+	+		+
	Phacus longicauda (Ehrenberg) Dujardin			+	+		+
	Phacus caudatus Hübner			+	+		+
	Trachelomonas volvocina Ehrenberg			+	+		+

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Taxonomic level	Scientific name	Endemicity	**Biomass +: common, ++: abundant**	Planktonic	Benthic	Habitat	
						Pelagic	Littoral areas and attached lakes
	Trachelomonas hispida (Perty) F. Stein ex Deflandre			+	+		+
	Trachelomonas oblonga Lemmermann		+	+	+	+	+
	Trachelomonas granulosa Playfair			+	+		+
Phyllum	Chlorophyta						
Class	Chlorophyceae						
Order	Volvocales						
	Chlamydomonas epibiotica Ettl			+			+
	Chlamydomonas conferta Korshikov			+			+
	Chlamydomonas parisii P.Bourrelly			+			+
	Chlamydomonas similis Korshikov			+			+
	Chlamydomonas debaryana Goroschankin			+			+
	Chlamydomonas penium Pascher			+			+
	Chlamydomonas gerloffii Ettl			+			+
	Chlamydomonas asymmetrica var. *gallica* Bourrelly			+			+
	Chlamydomonas cingulata Pascher			+			+
	Chlamydomonas cingulata var. *seligeriensis* A.A.Korshikov			+			+
	Chlamydomonas callosa var. *bipapillata* H.Ettl			+			+
	Chlamydomonas angulosa O. Dill			+			+
	Chlamydomonas gloeophila Skuja			+			+
	Chlamydomonas altera Skuja			+			+
	Chlamydomonas passiva Skuja			+			+
	Chlamydomonas proboscigera Korshikov			+			+
	Chlamydomonas sp.		++	+		+	+
	Sphaerellopsis sp.			+			+
	Lobomonas sp.			+			+
	Pteromonas sp.			+			+
	Thoracomonas sp.			+			+
	Coccomonas sp.			+			+
	Dysmorphococcus sp.			+			+
	Carteria globosa Korshikov			+			+
	Carteria stellifera Nygaard			+			+
	Carteria peterhofiensis Kisselev			+			+

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(continued)

Taxonomic level	Scientific name	Endemicity	Biomass +: common, ++: abundant	Planktonic	Benthic	Habitat	
						Pelagic	Littoral areas and attached lakes
	Carteria radiosa Korshikov			+			+
	Chlorogonium elongatum (P.A. Dangeard) Francé			+			+
	Chlorogonium minimum Playfair		+	+			+
	Gonium pectorale (O.F.Muller)		+	+			+
	Pandorina morum (O.F.Muller) Bory		+	+			+
	Pandorina morum var. major Iyengar		+	+			+
	Eudorina elegans Ehrenberg		++	+		+	+
	Eudorina unicocca G. M. Smith		+	+			+
	Pleodorina californica Shaw		+	+			+
	Volvox aureus Ehrenberg		+	+			+
	Volvox globator Linnaeus		+	+			+
	Volvox carteri F. Stein			+			+
	Volvox tertius Meyer			+			+
Order	Sphaeropleales						
	Sphaerocystis schroeteri Chodat		+	+			+
	Asterococcus superbus (Cienkowski) Scherffel			+			+
	Tetraspora lacustris Lemmermann		++	+		+	+
	Apiocystis sp.			+			+
	Paulschulzia pseudovolvox (Schulz) Skuja		+	+			+
	Ourococcus sp.			+			+
	Dactylothece sp.			+			+
	Coccomyxa dispar W. Schmidle			+			+
	Elakatothrix gelatinosa Wille		++	+		+	+
	Elakatothrix viridis (J. Snow) Printz			+			+
	Gloeocystis gigas (Kützing) Lagerheim		++	+		+	+
	Gloeocystis ampla Kützing			+			+
	Gloeocystis vesiculosa Nageli		++	+		+	+
Order	Ulotrichaceae						
	Klebsormidium sp.		+	+			+
	Ulothrix sp.			+			+
Order	Chaetophorales						
	Stigeoclonium sp.			+			+
Order	Cladophorales						
	Cladophora sp.			+			+

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Taxonomic level	Scientific name	Endemicity	Biomass +: common, ++: abundant	Planktonic	Benthic	Habitat	
						Pelagic	Littoral areas and attached lakes
Order	Chlorococcales						
	Chlorococcum sp.			+			+
	Golenkinia radiata Chodat 1894 emend. Korshikov		+	+			+
	Micractinium pusillum Fresenius		++	+		+	+
	Micractinium quadrisetum (Lemmermann) G. M. Smith			+			+
	Errerella bornhemiensis Conrad		+	+			+
	Dictyosphaerium pulchellum H.C.Wood		++	+		+	+
	Dictyosphaerium ehrenbergianum Nageli			+			+
	Dictyosphaerium subsolitarium Van Goor		++	+		+	+
	Dictyosphaerium tetrachotomum Printz			+			+
	Dictyosphaerium tetrachotomum var. *minutum* Komárek			+			+
	Dictyosphaerium botrytella Komárek et Perman			+			+
	Pseudodictyospharium sp.			+			+
	Quadricoccus sp.			+			+
	Dichotomococcus curvatus Korshikov			+			+
	Dichotomococcus lunatus Fott		++	+			+
	Kirchneriella lunaris (Kirchner) K. Möbius			+			+
	Kirchneriella contorta (Schmidle) Bohlin		++	+		+	+
	Kirchneriella obesa (G. S. West) Schmidle			+			+
	Kirchneriella aperta Teiling			+			+
	Quadrigula chodatii (Tanner-Fullman) G.M.Smith		+	+			+
	Quadrigula lacustris (Chodat) G.M.Smith		++	+		+	+
	Quadrigula korshikovii Komarek		+	+			+
	Quadrigula closterioides (Bohlin) Printz			+			+
	Quadrigula pfitzeri (Schroder) G.M.Smith		+	+			+

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(continued)

Taxonomic level	Scientific name	Endemicity	Biomass +: common, ++: abundant	Planktonic	Benthic	Habitat	
						Pelagic	Littoral areas and attached lakes
	Planktosphaeria gelatinosa G.M.Smith		++	+		+	+
	Eutetramorus planktonicus (Kors.) Bourr.			+			+
	Coenochloris sp.		+	+			+
	Coenocystis sp.		++	+		+	+
	Thorakochloris sp.			+			+
	Schizochlamydella sp.			+			+
	Radiococcus sp.			+			+
	Tetraedron gracile (Reinsch)		+	+			+
	Tetraedron limneticum Borge			+			+
	Tetraedron planctonicum G. M. Smith			+			+
	Tetraedron triangulare Kors			+			+
	Tetraedron trigonum (Nägeli) Hansgirg			+			+
	Westella botryoides (W. West) De Wildeman			+			+
	Scotiella sp.			+			+
	Treubaria setigerum (Archer) G. M. Smith		+	+			+
	Treubaria triappendiculata C. Bernard			+			+
	Oocystis borgei J.Snow			+			+
	Oocystis parva West et G.S.West		+	+			+
	Oocystis lacustris Chodat		++	+		+	+
	Oocystis lacustris var. *natans* (Lemmermann) Playfair			+			+
	Oocystis natans (Lemmermann) Lemmermann			+			+
	Oocystis solitaria Wittrock in Wittrock et Nordstedt		++	+		+	+
	Oocystis pusilla Hansgirg			+			+
	Oocystis submarina Lagerheim		++	+		+	+
	Oocystis sp.		++	+		+	+
	Eremosphaera sp.			+			+
	Amphikrikos sp.			+			+
	Polyedriopsis sp.			+			+
	Siderocelis sp.			+			+
	Pachycladon sp.			+			+

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(continued)

Taxonomic level	Scientific name	Endemicity	**Biomass +: common, ++: abundant**	Planktonic	Benthic	Habitat	
						Pelagic	Littoral areas and attached lakes
	Lobocystis planctonica (Tiffany et Ahlstrom) Fott			+			+
	Chodatella subsalsa Lemmermann			+			+
	Chodatella citriformis (Snow) G. M. Smith		++	+		+	+
	Chodatella genevensis (Chod.)			+			+
	Chodatella longiseta (Lemm.) Printz			+			+
	Nephrocytium sp.			+			+
	Nephrochlamys sp.			+			+
	Ankistrodesmus falcatus (Corda) Ralfs		++	+		+	+
	Ankistrodesmus falcatus var. *mirabile* W.et G.		++	+		+	+
	Ankistrodesmus falcatus var. *biplex* (Reinsch) G.S. West			+			+
	Ankistrodesmus fusiformis Corda ex Korshikov			+			+
	Ankistrodesmus spiralis (W.B.Turner) Lemmermann		+	+			+
	Monoraphidium tortile (West et G.S.West) Komarkova-Legnerova		++	+		+	+
	Monoraphidium contortum (Thuret) Komàrková-Legnerová			+			+
	Monoraphidium griffithii (Berkeley) Komárková-Legnerová			+			+
	Monoraphidium pusillum (Printz) Komárková-Legnorová			+			+
	Monoraphidium minutum (Nägeli) Komárková-legnerová			+			+
	Hyaloraphidium sp.			+			+
	Choricystis sp.			+			+
	Raphidocelis sp.			+			+
	Chlorella vulgaris M. Beijerinck			+	+		+
	Characium sp.			+	+		+
	Selenastrum gracile Reinsch		+	+			+
	Schroederia setigera (Schroder) Lemmermann		++	+		+	+
	Schroederia judayi G.M.Smith		++	+		+	+
	Ankyra ancora (G. M. Smith) Fott			+			+
	Pediastrum tetras (Ehrenberg) Ralfs			+			+

(continued)

Appendix 2.3

(continued)

Taxonomic level	Scientific name	Endemicity	Biomass +: common, ++: abundant	Planktonic	Benthic	Habitat	
						Pelagic	Littoral areas and attached lakes
	Pediastrum deplex Meyen		+	+			+
	Pediastrum duplex var. *gracillimum* W. et G. S. West		+	+			+
	Pediastrum duplex var. *reticulatum* Lagerheim			+			+
	Pediastrum boryanum (Turpin) Meneghini		+	+			+
	Pediastrum biwae Negoro		++	+		+	+
	Pediastrum biwae var. triangulatum Negoro		+	+		+	+
	Pediastrum biwae var. ovatum Negoro		+	+		+	+
	Hydrodictyon sp.			+	+		+
	Coelastrum microporum Nageli in A.Braun		++	+		+	+
	Coelastrum cambricum Archer		++	+		+	+
	Didymogenes sp.			+			+
	Crucigenia rectangularis (Nageli) Gay		+	+			+
	Crucigenia irregularis (Wille) Tsarenko et D. M. John		++	+		+	+
	Crucigenia lauterbornii (Schmidle) Schmidle		+	+			+
	Crucigenia fenestrata (Schmidle) Schmidle			+			+
	Crucigenia crucifera (Wolle) Collins			+			+
	Crucigenia apiculata (Lemmermann) Schmidle			+			+
	Crucigenia tetrapedia (Kirchner) W. West et G. S. West			+			+
	Crucigenia quadrata Morren			+			+
	Crucigenia pulchra (West et G.S.West) Komárek			+			+
	Crucigenia mucronata (G.M.Smith) Kom.			+			+
	Actinastrum hantzschii Lagerheim		+	+			+
	Actinastrum hantzschii var. *fluviatile* Schroed		++	+		+	+
	Actinastrum gracillimum Smith			+			+
	Tetrastrum glabrum (Y. V. Roll) Ahlstrom et Tiffany			+			+

(continued)

Appendix 2.3
(continued)

Taxonomic level	Scientific name	Endemicity	Biomass +: common, ++: abundant	Planktonic	Benthic	Habitat	
						Pelagic	Littoral areas and attached lakes
	Tetrastrum heteracanthum (Nordstedt) Chodat			+			+
	Tetrastrum staurogeniaeforme (Schröder) Lemmermann			+			+
	Tetrastrum sp.			+			+
	Didymocystis sp.			+			+
	Tetrachlorella sp.			+	+		+
	Schroederiella sp.			+	+		+
	Dicloster sp.			+	+		+
	Neodesmus sp.			+			+
	Scenedesmus acutus Meyen		+	+			+
	Scenedesmus acuminatus (Lagerheim) Chodat		+	+			+
	Scenedesmus armatus (Chodat) G. M. Smith			+			+
	Scenedesmus denticulatus Lagerheim		+	+			+
	Scenedesmus denticulatus var. *lunatus* W. West et G.S. West		+	+			+
	Scenedesmus circumfusus Hortobágyi		+	+			+
	Scenedesmus bijuga var. *disciformis* (Chodat) C. R. Leite		+	+			+
	Scenedesmus spinosus Chodat		+	+			+
	Scenedesmus ovalternus Chodat			+			+
	Scenedesmus abundans (O. Kirchner) Chodat (Kirchner) Chodat		+	+			+
	Scenedesmus abundans var. *longicauda* G.M. Smith		+	+			+
	Scenedesmus quadricauda (Turpin) Breb.		+	+			+
	Scenedesmus protuberans F. E. Fritsch et M. F. Rich			+			+
	Scenedesmus opoliensis P.G.Richter		+	+			+
	Scenedesmus perforatus Lemmermann		+	+			+
	Scenedesmus bicaudatus Dedusenko			+			+
	Scenedesmus brasiliensis Bohlin			+			+
	Scenedesmus intermedius Chodat			+			+

(continued)

Appendix 2.3

(continued)

Taxonomic level	Scientific name	Endemicity	**Biomass +: common, ++: abundant**	Planktonic	Benthic	Habitat	
						Pelagic	Littoral areas and attached lakes
	Scenedesmus grahneisii (Heynig) Fott			+			+
	Scenedesmus helveticus Cod			+			+
	Scenedesmus disciformis (Chodat) Ahlstrom			+			+
	Scenedesmus granulatus West et G.S.West			+			+
	Scenedesmus quadrispina Chodat		+	+			+
	Scenedesmus verrucosus P. González			+			+
	Scenedesmus armatus var. *bicaudatus* (Guglielmetti) Chodat			+			+
	Scenedesmus spinulatus K. Biswas			+			+
	Scenedesmus ecornis (Ehrenberg) Chodat			+			+
Order	Oedogoniales						
	Oedogonium sp.		+	+	+		+
	Bulbochaete sp.			+	+		+
Order	Zygnematales				+		
	Zygnema sp.			+	+		+
	Mougeotia sp.		++	+	+	+	+
	Spirogyra sp.		+	+	+		+
	Gonatozygon sp.		+	+	+		+
	Mesotaenium sp.			+	+		+
	Netrium sp.			+	+		+
Order	Desmidiales						
	Closterium aciculare var. *subpronum* W.et G.		++	+		+	+
	Closterium gracile Brebisson ex Ralfs			+			+
	Closterium acerosum (Schrank) Ehrenberg		+	+	+		+
	Closterium parvulum Nägeli			+			+
	Closterium acutum var. *variabile* (Lemmermann) Willi Krieger		++	+		+	+
	Closterium sp.		++	+		+	+
	Pleurotaenium sp.			+			+
	Cosmarium sp.		+	+			+
	Arthrodesmus sp.			+			+
	Xanthidium hastiferum var. *javanicum* (Nordst.) Turner		++	+		+	+

(continued)

Appendix 2.3
(continued)

Taxonomic level	Scientific name	Endemicity	**Biomass +: common, ++: abundant**	Planktonic	Benthic	Habitat	
						Pelagic	Littoral areas and attached lakes
	Xanthidium antilopaeum (Brébisson) Kützing			+			+
	Euastrum sp.		+	+			+
	Micrasterias sp.			+			+
	Staurastrum dorsidentiferum var. *ornatum* Gronbl		++	+		+	+
	Staurastrum longiradiatum W. West et G. S. West			+			+
	Staurastrum sebaldi var. *productum* W.et G.S.West		++	+		+	+
	Staurastrum pingue Teiling		++	+		+	+
	Staurastrum limneticum var. *burmense* W. West et G. S. West			+			+
	Staurastrum biwaensis Hirano			+			+
	Staurastrum submanfeldtii W.et G. S. West		++	+		+	+
	Staurastrum chaetoceras (Shrod.) G. M. Smith			+			+
	Staurastrum arctiscon (Ehrenberg) P. Lundell		++	+		+	+
	Staurastrum gracile Ralfs		+	+			+
	Staurastrum paradoxum Meyen ex Ralfs			+			+
	Staurastrum anatinum Cooke and Wills			+			+
	Staurastrum asterias Nygaard		+	+			+
	Spondylosium moniliforme P. Lundell		++	+		+	+
	Hyalotheca dissiliens Brébisson ex Ralfs			+			+
	Sphaerozoma sp.			+			+
	Cosmocladium constrictum (Archer) Joshua		++	+		+	+
Order	Prasinophyceae						
	Tetraselmis cordiformis (N. Carter) S. F. N. Stein			+			+

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Appendix 2.4

A list of submerged macrophytes in Lake Biwa and its adjacent waters (by E. Hamabata)

Taxonomic level	Scientific name	Japanese name	Habitat			Alien	Category in the Red List (RL) by the Ministry of Environment of Japan[a]	References
			Lake Biwa	Attached lakes	Endemicty			
	Chara spp.	Shajikumo spp.	+					Maeda (1910), Yamaguchi (1943), Ikusima et. al. (1962)
	Chara braunii	Shajikumo	+				CR+EN	Japan Water Agency (2009)
	Chara corallina var. *corallina*	Oushajikumo	+				CR+EN	Japan Water Agency (2009)
	Nitella spp.	Furasukomo spp.	+					Yamaguchi (1943), Ikusima et al. (1962), Hamabata (1991), Japan Water Agency (2009)
	Nitella flexilis var. *flexilis*	Himefurasukomo	+				CR+EN	Japan Water Agency (2009)
	Nitella hyalina	Otomefurasukomo	+				CR+EN	Japan Water Agency (2009)
	Nitella gracillima var. *robusta*	Onihinafurasukomo	+					Japan Water Agency (2009)
	Nitella mucronata	Sakibosofurasukomo	+					Japan Water Agency (2009)
	Nitella rigida var. *rigida*	Onifurasukomo	+					Japan Water Agency (2009)
	Potamogeton natans	Ohirumushiro		+				Hamabata and Yabuuchi (in this survery)
	Potamogeton fryeri	Futohirumushiro		+				Yamaguchi (1943)

(continued)

Appendix 2.4

(continued)

Taxonomic level	Scientific name	Japanese name	Habitat			Alien	Category in the Red List (RL) by the Ministry of Environment of Japan[a]	References
			Lake Biwa	Attached lakes	Endemicty			
	Potamogeton distinctus	Hirumushiro	+	+				Maeda (1910), Yamaguchi (1943), Kunii et al. (1985), Hamabata and Yabuuchi (in this survery)
	Potamogeton malainoides	Ainokohirumushiro	+					Yamaguchi (1943)
	Potamogeton nipponicus	Sasaebimo	+	+			EN	Yamaguchi (1943), Nagai (1975)
	Potamogeton octandrus	Hosobamizuhikimo	+	+				Yamaguchi (1943), Hamabata (1991), Japan Water Agency (2009)
	Potamogeton octandrus var. *miduhikimo*	Mizuhikimo		+				Yamaguchi (1943)
	Potamogeton perfoliatus	Hirohanoebimo	+	+				Maeda (1910), Yamaguchi (1943), Ikusima et al. (1962), Ikusima (1966), Nagai (1975); Hamabata (1991), Japan Water Agency (2009)
	Potamogeton dentatus	Gashamoku	+	+			CR	Yamaguchi (1943), Ikusima (1962)
	Potamogeton malaianus	Sasabamo	+	+				Yamaguchi (1943), Ikusima et al. (1962), Ikusima (1966), Nagai (1975), Kunii et al. (1985), Hamabata (1991), Japan Water Agency (2009)
	Potamogeton crispus	Ebimo	+	+				Maeda (1910), Yamaguchi (1943), Ikusima et al. (1962), Ikusima (1966), Nagai (1975), Kunii et al. (1985), Hamabata (1991), Japan Water Agency (2009)
	Potamogeton oxyphyllus	Yanagimo	+	+				Maeda (1910), Yamaguchi (1943), Kunii et al. (1985), Japan Water Agency (2009)
	Potamogeton maackianus	Senninmo	+	+				Yamaguchi (1943), Ikusima et al. (1962), Ikusima (1966), Nagai (1975), Kunii et al. (1985), Hamabata (1991), Japan Water Agency (2009)

(continued)

Appendix 2.4

(continued)

Taxonomic level	Scientific name	Japanese name	Habitat			Alien	Category in the Red List (RL) by the Ministry of Environment of Japan[a]	References
			Lake Biwa	Attached lakes	Endemicty			
	Potamogeton oxyphyllus × *Potamogeton maackianus*	Yanagimo × Senninmo	+					Hamabata (1991)
	Potamogeton leptocephalus	Hirohanosenninmo	+					Hamabata (1991), Japan Water Agency (2009)
	Potamogeton biwaensis	Sannenmo	+		+			Yamaguchi (1943), Ikusima et al. (1962), Ikusima (1966), Hamabata (1991), Japan Water Agency (2009)
	Potamogeton panormitanus	Tsutsuitomo	+				CR	Hamabata and Yabuuchi (in this survery)
	Potamogeton pectinatus	Ryunohigemo		+			VU	Yamaguchi (1943)
	Potamogeton anguillanus	Oosasaebimo	+					Yamaguchi (1943), Kunii et al. (1985), Hamabata (1991), Japan Water Agency (2009)
	Najas marina	Ibaramo	+	+				Maeda (1910), Yamaguchi (1943), Ikusima et al. (1962), Ikusima (1966), Nagai (1975), Kunii et al. (1985), Hamabata (1991), Japan Water Agency (2009)
	Najas oguraensis	Ootorigemo	+	+				Yamaguchi (1943), Hamabata (1991), Japan Water Agency (2009)
	Najas minor	Torigemo	+	+			EN	Maeda (1910), Yamaguchi (1943), Ikusima (1966)
	Najas foveolata	Hirohatorigemo		+				Yamaguchi (1943)
	Najas graminea	Hossumo	+	+				Yamaguchi (1943), Ikusima et al. (1962)
	Blyxa japonica	Yanagisubuta	+					Nagai (1975)
	Blyxa echinosperma	Subuta	+				VU	Maeda (1910)
	Vallisneria denseserrulata	Kougaimo	+	+				Maeda (1910), Yamaguchi (1943), Ikusima et al. (1962), Ikusima (1966), Nagai (1975), Kunii et al. (1985), Hamabata (1991), Japan Water Agency (2009)
	Vallisneria asiatica	Sekishoumo	+	+				Maeda (1910), Yamaguchi (1943), Ikusima et al. (1962), Nagai (1975)

(continued)

Appendix 2.4

(continued)

Taxonomic level	Scientific name	Japanese name	Habitat			Alien	Category in the Red List (RL) by the Ministry of Environment of Japan[a]	References
			Lake Biwa	Attached lakes	Endemicty			
	Vallisneria asiatica var. *biwaensis*	Nejiremo	+		+			Yamaguchi (1943), Ikusima et al. (1962), Ikusima (1966), Nagai (1975), Kunii et al. (1985), Hamabata (1991a), Japan Water Agency (2009)
	Hydrilla verticillata	Kuromo	+	+				Maeda (1910), Yamaguchi (1943), Ikusima et al. (1962), Ikusima (1966), Nagai (1975), Kunii et al. (1985), Hamabata (1991), Japan Water Agency (2009)
	Elodea nuttallii	Kokanadamo	+	+		+		Ikusima (1966), Nagai (1975), Kunii et al. (1985), Hamabata (1991), Japan Water Agency (2009)
	Egeria densa	Ookanadamo	+	+		+		Nagai (1975), Kunii et al. (1985), Hamabata (1991), Japan Water Agency (2009)
	Ottelia alismoides	Mizuoobako	+	+				Maeda (1910), Yamaguchi (1943), Japan Water Agency (2009)
	Schoenoplectus lineolatus	Himehotarui	+					Japan Water Agency (2009)
	Cabomba caroliniana	Hagoromomo	+	+		+		Nagai (1975), Kunii et al. (1985), Hamabata (1991), Japan Water Agency (2009)
	Ceratophyllum demersum	Matsumo	+	+				Maeda (1910), Yamaguchi (1943), Ikusima et al. (1962), Ikusima (1966), Nagai (1975), Kunii et al. (1985), Hamabata (1991), Japan Water Agency (2009)
	Ceratophyllum demersum var. *quadrispinum*	Goharimatsumo	+	+				Yamaguchi (1943), Hamabata and Yabuuchi (in this survery)
	Ranunculus nipponicus var. *submersus*	Baikamo	+	+				Maeda (1910), Yamaguchi (1943)
	Elatine triandra	Mizohakobe		+				Yamaguchi (1943)
	Myriophyllum verticillatum	Fusamo	+	+				Maeda (1910), Yamaguchi (1943), Ikusima et al. (1962), Nagai (1975)

(continued)

Appendix 2.4

(continued)

Taxonomic level	Scientific name	Japanese name	Habitat			Alien	Category in the Red List (RL) by the Ministry of Environment of Japan[a]	References
			Lake Biwa	Attached lakes	Endemicty			
	Myriophyllum spicatum	Hozakinofusamo	+	+				Maeda (1910), Yamaguchi (1943), Ikusima et al. (1962), Ikusima (1966), Kunii et al. (1985), Hamabata (1991), Japan Water Agency (2009)
	Myriophyllum oguraense	Oguranofusamo		+			VU	Yamaguchi (1943)
	Myriophyllum ussuriense	Tachimo		+			NT	Yamaguchi (1943)
	Myriophyllum aquaticum	Oofusamo	+	+		+		Yamaguchi (1943), Nagai (1975), Kunii et al. (1985)

[a] *CR* criticall endangered, *EN* endangered, *VU* vulnerable, *NT* near threatened, *DD* data deficient

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Appendix 2.5

A list of plants on the shore area of Lake Biwa (without submerged plants) (by Y. Sasaki)

Taxonomic level	Scientific name	Japanese name	
Infraphylum	Moniliformopses		
Family	Equisetaceae		
	Equisetum arvense	Sugina	
	Equisetum ramasissimum	Inudokusa	
Family	Osmundaceae		
	Osmunda japonica	Zenmai	
Family	Pteridaceae		
	Pteridium aquilinum var. *latiusculum*	Warabi	
	Pteris cretica	Obano-inomotoso	
	Pteris multifida	Inomotoso	
Family	Aspleniaceae		
	Asplenium incisum	Torano-oshida	
Family	Dryopteridaceae		
	Arachniodes standishii	Ryomenshida	
	Cyrtomium fortunei var. *clivicola*	Yama-yabusotetsu	
	Dryopteris bissetiana	Yama-itachishida	
	Dryopteris erythrosora	Benishida	
	Dryopteris erythrosora var. *dilatata*	Togokushida	
	Dryopteris hikonensis	Oitachishida	
	Dryopteris lacera	Kumawarabi	
	Dryopteris tokyoensis	Tanihego	
	Matteuccia struthiopteris	Kusasotetsu	
	Polystichum polyblepharum	Inode	
Family	Thelypteridaceae		
	Cyclogramma acuminatus	Hoshida	
	Phegopteris decursive-pinnata	Gejigejishida	
	Thelypteris palustris	Himeshida	
Family	Woodsiaceae		
	Athyrium niponicum	Inuwarabi	
	Onoclea sensibilis var. *interrupta*	Koyawarabi	
Family	Polypodiaceae		
	Lepisorus thunbergianus	Nokishinobu	
Family	Azollaceae		
	Azolla japonica	Oakaukikusa	
	Azolla cristata	Azora-kurisutata	Alien
Class	Gymnospermae		
Family	Pinaceae		
	Pinus densiflora	Akamatsu	Planted
	Pinus thunbergii	Kuromatsu	Planted
	Pinus densi-thunbergii	Akakuromatsu	

(continued)

Appendix 2.5

(continued)

Taxonomic level	Scientific name	Japanese name	
Class	Angiosperms		
Subclass	Choripetalae		
Family	Juglandaceae		
	Juglans ailanthifolia	Onigurumi	
Family	Salicaceae		
	Salix babylonica var. *lavalle*	Shidareyanagi	Escape
	Salix babylonica f. seiko	Seikoyanagi	Escape
	Salix chaenomeloides	Akameyanagi	
	Salix eriocarpa	Jayanagi	
	Salix gilgiana	Kawayanagi	
	Salix gracilistyla	Nekoyanagi	
	Salix integra	Inukoriyanagi	
	Salix matsudana	Unryuyanagi	Escape
	Salix pierotii	Otachiyanagi	
	Salix sachalinensis	Onoeyanagi	
	Salix serissaefolia	Kogomeyanagi	
	Salix subfragilis	Tachiyanagi	
Family	Betulaceae		
	Alnus japonica	Hannoki	
Family	Fagaceae		
	Castanea crenata	Kuri	
	Quercus glauca	Arakashi	
	Quercus serrata	Konara	
	Quercus myrsinaefolia	Shirakashi	
	Quercus variabilis	Abemaki	
Family	Ulmaceae		
	Aphananthe aspera	Mukunoki	
	Celtis sinensis	Enoki	
	Ulmus parvifolia	Akinire	
Family	Moraceae		
	Fatoua villosa	Kuwakusa	
	Humulus japonicus	Kanamugura	
	Morus alba	Maguwa	Escape
	Morus australis	Yamaguwa	
Family	Urticaceae		
	Boehmeria dura	Marubayabumao	
	Boehmeria holosericea	Oniyabumao	
	Boehmeria japonica var. *longispica*	Yabumao	
	Boehmeria nipononivea	Karamushi	
	Laportea bulbifera	Mukagoirakusa	

(continued)

Appendix 2.5
(continued)

Taxonomic level	Scientific name	Japanese name	
	Nanocnide japonica	Katenso	
	Pilea pseudopetiolaris	Komiyamamizu	
	Pilea hamaoi	Mizu	
	Pilea pumila	Aomizu	
Family	Polygonaceae		
	Fagopyrum cymnosum	Shakuchirisoba	Alien
	Persicaria conspicua	Sakuratade	
	Persicaria foliosa var. *paludicola*	Yanaginukabo	
	Persicaria hastatosagittata	Nagabano-unagitsukami	
	Persicaria hydropiper	Yanagitade	
	Persicaria lapathifolia	Oinutade	
	Persicaria lapathifolia f. *albiflora*	Shirobana-oinutade	
	Persicaria longiseta	Inutade	
	Persicaria maackiana	Sadekusa	
	Persicaria perfoliata	Ishimikawa	
	Persicaria scabra	Sanaetade	
	Persicaria senticosa	Mamakono-shirinugui	
	Persicaria praetermissa	Hosobano-unagitsukami	
	Persicaria sieboldii	Akino-unagitsukami	
	Persicaria thunbergii	Mizosoba	
	Persicaria thunbergii var. *hastatotriloba*	Omizosoba	
	Polygonum arenastrum	Haimichiyanagi	
	Reynoutria japonica	Itadori	
	Rumex acetosa	Suiba	
	Rumex acetosella	Himesuiba	Alien
	Rumex congiomeratus	Arechi-gishigishi	Alien
	Rumex crispus	Nagaba-gishigishi	Alien
	Rumex japonicus	Gishigishi	
	Rumex obtusifolius	Ezono-gishigishi	Alien
	Persicaria lapathifolia var. *salicifolius*	Urajiro-sanaetade	
	Persicaria pubescens	Bontokutade	
	Persicaria japonica	Shirobana-sakuratade	
Family	Phytolaccaceae		
	Phytolacca americana	Yoshuyamagobo	Alien
Family	Molluginaceae		
	Mollugo pentaphylla	Zakuroso	
	Mollugo verticilliata	Kumaba-zakuroso	Alien
Family	Aizoaceae		
	Tetragonia tetragonoides	Tsuruna	

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Taxonomic level	Scientific name	Japanese name	
Family	Portulacaceae		
	Portulaca oleracea	Suberihiyu	
Family	Caryophyllaceae		
	Arenaria serpyllifolia	Nominotsuzuri	
	Cerastium gromeratum	Orandamiminagusa	Alien
	Dianthus superbus var. *longicalycinus*	Kawaranadeshiko	
	Petrorhagia prolifera	Komochinadeshiko	Alien
	Silene armeria	Mushitorinadeshiko	Alien
	Silene firma	Fushiguro	
	Silene firma f. *pubescens*	Kefushiguro	
	Silene gallica var. *quinquevulnera*	Mantema	Alien
	Silene gallica	Shirobana-mantema	Alien
	Stellaria aquatica	Ushihakobe	
	Stellaria media	Kohakobe	Alien
Family	Chenopodiaceae		
	Chenopodium album	Shiroza	
	Chenopodium ambrosioides var. *anthelminticum*	Aritaso	Alien
Family	Amaranthaceae		
	Achyranthes bidentata var. *japonica*	Hikage-inokozuchi	
	Achyranthes bidentata var. *tomentosa*	Hinata-inokozuchi	
	Alternanthera nodiflora	Hosoba-tsurunogeito	Alien
	Alternanthera philoxeroides	Nagae-tsurunogeito	Alien
	Amaranthus patulus	Hosoaogeito	Alien
	Amaranthus viridis	Honagainubiyu	Alien
	Amaranthus lividus	Inubiyu	Alien
	Celosia argentea	Nogeito	Alien
Family	Magnoliaceae		
	Magnolia praecocissima	Kobushi	
Family	Schisandraceae		
	Kadsura japonica	Sanekazura	
Family	Lauraceae		
	Cinnamomum japonicum	yabunikkei	
	Neolitsea sericea	Shirodamo	
Family	Ranunculaceae		
	Aquilegia adoxoides	Himeuzu	
	Clematis apiifolia	Botanzuru	
	Clematis ternifora	Senninso	
	Ranunculus quelpaertensis var. *glaber*	Kitsunenobotan	
	Ranunculus japonicus	Umanoashigata	
	Ranunculus sceleratus	Tagarashi	
	Thalictrum komense var. *hypoleucum*	Akikaramatsu	

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Taxonomic level	Scientific name	Japanese name	
Family	Lardizabalaceae		
	Akebia quinata	Akebi	
	Akebia trifoliata	Mitsuba-akebi	
	Stauntonia hexaphylla	Mube	
Family	Menispermaceae		
	Cocculus trilobus	Aotsuzurafuji	
Family	Nymphaeaceae		
	Nuphar japonicum	Kohone	
Family	Saururaceae		
	Houttuynia cordata	Dokudami	
	Saururus chinensis	Hangesho	
Family	Theaceae		
	Camellia japonica	Yabutsubaki	
Family	Hypericaceae		
	Hypericum perforatum var. *angustifolium*	Kogomebaotogiri	Alien
Family	Papaveraceae		
	Corydalis incisa	Murasakikeman	
	Papaver dubium	Nagamihinageshi	Alien
Family	Brassicaceae		
	Arabis glabra	hatazao	
	Arabis kawasakiana	Tachisuzushiroso	
	Brassica juncea	Seiyokarashina	Alien
	Cardamine flexuosa	Tanetsukebana	
	Draba nemorosa	Inunazuna	
	Lepidium virginicum	Mamegunbainazuna	Alien
	Lunaria annua	Godaso	Alien
	Raphanus sativus var. *raphanistroides*	Hamadaikon	Alien
	Rorippa indica	Inugarashi	
	Rorippa islandica	Sukashitagobo	
	Rorippa obtusa	Kogomeinugarashi	Alien
Family	Crassulaceae		
	Sedum aizoon var. *floribundum*	Kirinso	
	Sedum bulbiferum	Komochi-mannengusa	
	Sedum japonicum	Meno-mannengusa	
	Sedum makinoi	Maruba-mannengusa	
Family	Saxifragaceae		
	Penthorum chinense	Takonoashi	
Family	Pittosporaceae		
	Pittosporum tobira	Tobera	Escape

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Taxonomic level	Scientific name	Japanese name	
Family	Rosaceae		
	Agrimonia japonica	Kinmizuhiki	
	Duchesnea chrysantha	Hebiichigo	
	Malus toringo	Zumi	
	Photinia glabra	Kanamemochi	
	Potentilla chinensis	Kawarasaiko	
	Potentilla sundaica var. *robusta*	Ohebiichigo	
	Prunus buergeriana	Inuzakura	
	Prunus grayana	Uwamizuzakura	
	Prunus jamasakura	Yamazakura	Planted
	Rhaphiolepis umbellata	Sharinbai	Planted
	Rosa multiflora	Noibara	
	Rosa wichuraiana	Terihanoibara	
	Rubus buergeri	Fuyuichigo	
	Rubus hirsutus	Kusaichigo	
	Rubus parvifolius	Nawashiroichigo	
Family	Fabaceae		
	Aeschynomene indica	Kusanemu	
	Albizia julibrissin	Nemunoki	
	Amorpha fruticosa	Itachihagi	Alien
	Amphicarpaea bracteata var. *japonica*	Yabumame	
	Cassia minosoides ssp. *nomame*	Kawaraketsumei	
	Cassia obtusifolia	Ebisugusa	Alien
	Desmodium paniculatum	Arechinusubitohagi	Alien
	Glycine max ssp. *soja*	Tsurumame	
	Indigofera pseudotinctoria	Komatsunagi	
	Indigofera tinctoria	Taiwankomatsunagi	Alien
	Kummerowia stipulacea	Marubayahazuso	
	Kummerowia striata	Yahazuso	
	Lathyrus japonics	Hamaendo	
	Lespedeza bicolor	Yamahagi	
	Lespedeza cuneata	Medohagi	
	Lespedeza japonica f. *angustifolia*	Nishikihagi	Ornamental
	Medicago arabica	Montsukiumagoyashi	Alien
	Pueraria lobata	Kuzu	
	Trifolium campestre	Kusudamatsumekusa	Alien
	Pterocarya stenoptera	Shinasawagurumi	Ornamental
	Gleditsia japonica	Saikachi	
	Rhynchosia volubilis	Tankirimame	
	Robinia pseudoacacia	Harienju	Alien

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Taxonomic level	Scientific name	Japanese name	
	Trifolium arvense	Shagumahagi	Alien
	Trifolium dubium	Kometsubu-tsumekusa	Alien
	Trifolium pratense	Murasaki-tsumekusa	Alien
	Trifolium repens	Shiro-tsumekusa	Alien
	Vicia hirsuta	Suzumenoendo	
	Vicia sepium	Karasunoendo	
	Vicia tetrasperma	Kasumagusa	
	Vigna angularis var. *nipponensis*	Yabutsuruazuki	
	Wisteria floribunda	Fuji	
Family	Oxalidaceae		
	Oxalis articulata	Imokatabami	Alien
	Oxalis corniculata	Katabami	
	Oxalis corniculata f. rubrifolia	Akakatabami	
	Oxalis corniculata f. tropaeoloides	Usuakakatabami	
	Oxalis corymbosa	Murasakikatabami	Alien
	Oxalis stricta	Ottachikatabami	Alien
Family	Geraniaceae		
	Geranium carolinianum	Amerikafuro	Alien
	Geranium thunbergii	Gennoshoko	
Family	Euphorbiaceae		
	Acalypha australia	Enokigusa	
	Euphorbia adenochlora	Nourushi	
	Euphorbia pseudochamaesyce	Nishikiso	
	Euphorbia supina	Konishikiso	Alien
	Mallotus japonicus	Akamegashiwa	
	Sapium sebiferum	Nankinhaze	Escape
Family	Rutaceae		
	Fagara ailanthoides	Karasuzansho	
	Fagara mantchurica	Inuzansho	
Family	Simaroubaceae		
	Ailanthus altissima	Niwaurushi	Alien
	Picrasma quassioides	Nigaki	
Family	Meliaceae		
	Melia azedarach	Sendan	Planted/ escape
Family	Anacardiaceae		
	Rhus javanica var. *roxburgii*	Nurude	
	Rhus sylvestris	Yamahaze	
	Rhus trichocarpa	Yamaurushi	
Family	Sapindaceae		
	Cardiospermum halicacabum	Fusenkazura	Alien

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Taxonomic level	Scientific name	Japanese name	
Family	Aquifoliaceae		
	Ilex rotunda	Kuroganemochi	Planted
	Ilex chinensis	Nanaminoki	
Family	Celastraceae		
	Celastrus orbiculatus	Tsuruumemodoki	
	Euonymus alatus f. *ciliato-dentatus*	Komayumi	
	Euonymus japonicus	Masaki	Planted
	Euonymus oxyphyllus	Tsuribana	
	Euonymus sieboldianus	Mayumi	
	Euonymus sieboldianus var. *sanguineus*	Kantomayumi	
Family	Vitaceae		
	Ampelopsis glandulosa var. *heterophylla*	Nobudo	
	Cayratia japonica	Yabugarashi	
	Parthenocissus tricuspidata	Tsuta	
	Vitis coignetiae	Yamabudo	
	Vitis ficifolia var. *lobata*	Ebizuru	
	Vitis flexuosa	Sankakuzuru	
Family	Sterculiaceae		
	Firmiana simplex	Aogiri	Ornamental
Family	Elaeagnaceae		
	Elaeagunus multiflora var. *gigantea*	Daiogumi	Ornamental
Family	Violaceae		
	Viola mandshurica	Sumire	
	Viola kusanoana	Otachitsubosumire	
Family	Cucurbitaceae		
	Actinostemma lobatum	Gokizuru	
	Gynostemma pentaphyllum	Amachazuru	
	Melothria japonica	Suzumeuri	
	Sicyos angulatus	Arechiuri	Alien
Family	Lythraceae		
	Lythrum anceps	Misohagi	
Family	Trapaceae		
	Trapa incisa	Himebishi	
	Trapa japonica	Hishi	
Family	Onagraceae		
	Circaea mollis	Mizutamaso	
	Gaura lindheimeri	Yamamomoso	Alien
	Ludwigia decurrens	Hiretagobo	Alien
	Ludwigia prostrata	Chojitade	
	Ludwigia ovalis	Mizuyukinoshita	

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Taxonomic level	Scientific name	Japanese name	
	Ludwigia stipulacea	Mizukinbai	Escape
	Oenothera biennis	Mematsu-yoigusa	Alien
	Oenothera laciniata	Komatsu-yoigusa	Alien
	Oenothera stricta	Matsuyoigusa	Alien
Family	Haloragaceae		
	Myriophyllum brasilense	Ofusamo	Alien
Family	Cornaceae		
	Aucuba japonica	Aoki	
	Cornus macrophylla	Kumanomizuki	
Family	Araliaceae		
	Aralia cordata	Udo	
	Hedera rhombea	Kizuta	
Family	Apiaceae		
	Apium leptophyllum	Matsubazeri	Alien
	Cicuta virosa	Dokuzeri	
	Cryptotaenia japonica	Mitsuba	
	Daucus carota	Noraninjin	Alien
	Hydrocotyle maritima	Nochidome	
	Hydrocotyle javanica	Obachidome	
	Hydrocotyle ramiflora	Ochidome	
	Oenanthe javanica	Seri	
	Sanicula chinensis	Umanomitsuba	
	Torilis scabra	Oyabujirami	
Subclass	Sympetalae		
Family	Ericaceae		
	Rhododendron x *omurasaki*	Omurasaki	Ornamental
	Pieris japonica	Asebi	
Family	Primulaceae		
	Lysimachia japonica f. *subsessilis*	Konasubi	
Family	Oleaceae		
	Ligutrum japonicum	Nezumimochi	
	Ligutrum lucidum	Tonezumimochi	Ornamental
Family	Apocynaceae		
	Trachelospermum asiaticum f. *intermedium*	Teikakazura	
	Vinca major	Tsurunichinichiso	Ornamental
Family	Asclepiadaceae		
	Metaplexis japonica	Gagaimo	
Family	Rubiaceae		
	Diodia teres	Ofutabamugura	Alien
	Diodia virginiana	Merikenmugura	Alien

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Taxonomic level	Scientific name	Japanese name	
	Hydyotis diffusa	Futabamugura	
	Hedyotis lindleyana var. *hirsuta*	Hashikagusa	
	Galium spurium var. *echinospermon*	Yaemugura	
	Galium trachyspermum var. *trachysperum*	Yotsubamugura	
	Galium trifidum var. *brevipedunculatum*	Hosobanoyotsubamugura	
	Galium verum f. *nikkoense*	Kawaramatsuba	
	Galium verum f. *album*	Chosenkawaramatsuba	
	Paederia scandens	Hekusokazura	
	Rubia akane	Akane	
Family	Convolvulaceae		
	Calystegia hederacea	Kohirugao	
	Calystegia japonica	Hirugao	
	Calystegia soldanella	Hamahirugao	
	Cuscuta pentagona	Amerikanenashikazura	Alien
	Ipomoea coccinea	Marubaruko	Alien
	Ipomoea lacunosa	Mameasagao	Alien
Family	Boraginaceae		
	Bothriospermum tenellum	Hanaibana	
	Trigonotis peduncularis	Kyurigusa	
Family	Verbenaceae		
	Callicarpa japonica	Murasakishikibu	
	Clerodendrum trichotomum	Kusagi	
	Lippia nodiflora	Iwadareso	
	Verbera brasiliensis	Arechihanagasa	Alien
	Verbena incompta	Dakibaarechihanagasa	Alien
	Vitex rotundifolia	Hamago	
Family	Lamiaceae		
	Clinopodium gracile	Tobana	
	Glechoma hederacea var. *grandis*	Kakidoshi	
	Lamium amplexicaule	Hotokenoza	
	Lamium purpureum	Himeodorikoso	Alien
	Leonurus japonica	Mehajiki	
	Lycopus lucidus	Shirone	
	Lycopus ramosissmus var. *japonicus*	Koshirone	
	Lycopus ramosissmus	Himesarudahiko	
	Mentha arvensis var. *piperascens*	Hakka	
	Mentha rotundifolia	Marubahakka	Alien
	Mentha spicata var. *crispa*	Orandahakka	Alien
	Mosla dianthera	Himejiso	
	Mosla punctulata	Inukoju	

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Taxonomic level	Scientific name	Japanese name	
	Salvia plebeia	Mizokoju	
	Scutellaria dependens	Himenamiki	
	Scutellaria strigillosa	Namikiso	
	Stachys riederi var. *intermedia*	Inugoma	
	Teucrium japonicum	Nigakusa	
Family	Solanaceae		
	Lycium rhombifolium	Kuko	Escape
	Solanum lyratum	Hiyodorijogo	
	Solanum americanum	Amerikainuhozuki	Alien
	Solanum megacarpum	Omarubanohoroshi	
	Solanum nigrescens	Oinuhozuki	Alien
	Solanum nigrum	Inuhozuki	Alien
Family	Scrophulariaceae		
	Linaria canadensis	Matsubaunran	Alien
	Lindernia dubia	Taketoazena	Alien
	Lindernia dubia var. *major*	Amerikaazena	Alien
	Lindernia procumbens	Azena	
	Mazus pumilus	Tokiwahaze	
	Parentucellia viscosa	Seiyohikiyomogi	Alien
	Verbascum thapsus	Birodomozuika	Alien
	Veronica anagallis-aquatica	Okawajisha	Alien
	Veronica arvensis	Tachiinunofuguri	Alien
	Veronica persica	Oinunofuguri	Alien
	Veronica undulata	Kawajisha	
Family	Bignoniaceae		
	Paulownia tomentosa	Kiri	Escape
Family	Acanthaceae		
	Justicia procumbens var. *parvifolius*	Kitsunenogoma	
	Hygrophila salicifolia	Oginotsume	
Family	Plantaginaceae		
	Plantago asiatica	Obako	
	Plantago lanceolata	Hera-obako	Alien
	Plantago virginica	Tsubomi-obako	Alien
Family	Caprifoliaceae		
	Lonicera japonica	Suikazura	
Family	Valerianaceae		
	Valerianella olitoria	Nojisha	Alien
Family	Campanulaceae		
	Campanula punctata	Hotarubukuro	
	Lobelia chinensis	Mizokakushi	

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Taxonomic level	Scientific name	Japanese name	
	Specularia perfoliata	Kikyoso	Alien
	Wahlenbergia marginata	Hinagikyo	
Family	Asteraceae		
	Ambrosia artemisiifolia var. *elatior*	Butakusa	Alien
	Ambrosia trifida	Obutakusa	Alien
	Artemisia capillaris	Kawarayomogi	
	Artemisia princeps	Yomogi	
	Aster ageratoides ssp. *amplexifolius*	Inakagiku	
	Aster ageratoides ssp. *leiophyllus*	Shiroyomena	
	Aster ageratoides ssp. *ovatus*	Nokongiku	
	Aster exlis	Ohokigiku	Alien
	Aster rugulosus	Sawashirogiku	
	Bidens frondosa	Amerika-sendangusa	Alien
	Bidens pilosa	Ko-sendangusa	Alien
	Bidens pilosa var. *minor*	Shirobana-sendangusa	
	Bidens pilosa var. *radiata*	Awayuki-sendangusa	Alien
	Cirsium buergeri	Himeazami	
	Cirsium kagamontanum	Kaganoazami	
	Cirsium pendulum	Takaazami	
	Cirsium yezoense	Sawaazami	
	Conyza sumatrensis	Oarechinogiku	Alien
	Coreopsis lanceolata	Okinkeigiku	Alien
	Crassocephalum crepidioides	Benibanaborogiku	Alien
	Eclipta alba	Amerikatakasaburo	Alien
	Eclipta thermalis	Takasaburo	
	Erechtites hieracifolia	Dandoborogiku	Alien
	Erigeron annuus	Himejon	Alien
	Erigeron canadensis	Himemukashiyomogi	Alien
	Erigeron canadensis var. *levis*	Kenashi-himemukashiyomogi	Alien
	Galinsoga ciliata	Hakidamegiku	Alien
	Gnaphalium affine	Hahakogusa	
	Gnaphalium japonicum	Chichikogusa	
	Gnaphalium pensylvanicum	Chichikogusamodoki	Alien
	Gnaphalium purpureum	Usubeni-chichikogusa	Alien
	Gymnocoronis spilanthoides	Mizuhimawari	Alien
	Helianthus tuberosus	Kikuimo	Alien
	Hypochoeris radicata	Butana	Alien
	Kalimeris pinnatifida	Yugagiku	
	Lactuca indica var. *indica*	Akinonogeshi	
	Lactuca serriola	Togechisha	Alien

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Taxonomic level	Scientific name	Japanese name	
	Lapsana humilis	Yabutabirako	
	Petasites japonicus	Fuki	
	Senecio vulgaris	Noborogiku	Alien
	Solidago altissima	Seitakaawadachiso	Alien
	Solidago virgaurea var. *asiatica*	Akinokirinso	
	Sonchus asper	Oninogeshi	Alien
	Sonchus oleraceus	Nogeshi	
	Taraxacum japonicum	Kansaitanpopo	
	Taraxacum officinale	Seiyotanpopo	Alien
	Xanthium canadense	Oonamomi	Alien
	Youngia japonica	Onitabirako	
Class	Monocotyledons		
Family	Alismataceae		
	Sagittaria trifolia var. *edulis*	Kuwai	Escape
	Sagittaria trifolia	Omodaka	
Family	Hydrocharitaceae		
	Hydrocharis dubia	Tochikagami	
Family	Liliaceae		
	Allium grayi	Nobiru	
	Hemerocallis fulva var. *kwanso*	Yabukanzo	
	Hemerocallis fulva var. *longituba*	Nokanzo	
	Ophiopogon japonicus	Janohige	
	Ophiopogon ohwii	Nagabajanohige	
	Ornithogalum umbellatum	Oamana	Ornamental
	Liriope minor	Himeyaburan	
	Liriope platyphylla	Yaburan	
	Liriope spicata	Koyaburan	
	Smilax china	Sarutoriibara	
	Smilax riparia var. *ussuriensis*	Shiode	
Family	Amaryllidaceae		
	Lycoris radiata	Higanbana	
Family	Dioscoreaceae		
	Dioscorea bulbifera	Nigagashu	
	Dioscorea japonica	Yamanoimo	
	Dioscorea tenuipes	Himedokoro	
	Dioscorea tokoro	Onidokoro	
Family	Pontederiaceae		
	Eichhornia crassipes	Hoteiaoi	Alien

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Taxonomic level	Scientific name	Japanese name	
Family	Iridaceae		
	Iris japonica	Shaga	Escape
	Iris pseudacorus	Kishobu	Alien
	Sisyrinchium atlanticum	Niwazekisho	Alien
Family	Juncaceae		
	Fimbristylis diphylloides	Kurotentsuki	
	Fimbristylis complanata f. *exalata*	Notentsuki	
	Juncus alatus	Hanabizekisho	
	Juncus effusus var. *decipiens*	I	
	Juncus leschenaultii	Kogaizekisho	
	Juncus setchuwnsis	Hosoi	
	Juncus tenuis	Kusai	
	Juncus wallichianus	Harikogaizekisho	
Family	Commelinaceae		
	Aneilema keisak	Ibokusa	
	Commelina communis	Tsuyukusa	
	Tradescantia fluminensis	Nohakatakarakusa	Alien
	Tradescantia reflexa	Murasakitsuyukusa	Alien
Family	Marantaceae		
	Thalia dealbata	Mizukanna	Escape
Family	Poaceae		
	Agropyron racemiferum	Aokamojigusa	
	Agropyron tsukushiense var. *transiens*	Kamojigusa	
	Agrostis clavata ssp. *matsumurae*	Nukabo	
	Agrostis canina	Himenukabo	
	Aira elegans	Hananukasusuki	Alien
	Aira elegans ssp. *ambiqua*	Himenukasusuki	Alien
	Alopecurus aequalis	Suzumenoteppo	
	Andropogon virginicus	Merikenkarukaya	Alien
	Anthoxanthum odoratum	Harugaya	Alien
	Arundinella hirta	Todashiba	
	Arundinella hirta var. *ciliata*	Usuge-todashiba	
	Arundo donax	Danchiku	Planted?
	Avena fatua	Karasumugi	Alien
	Avena fatua var. *glabrata*	Ko-karasumugi	Alien
	Beckmannia syzigachne	Kazunokogusa	
	Briza maxima	Kobanso	Alien
	Briza minor	Hime-kobanso	Alien
	Bromus catharticus	Inumugi	Alien
	Bromus commutatus	Mukugechahiki	Alien

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Taxonomic level	Scientific name	Japanese name	
	Bromus rigidus	Higenaga-suzumenochahiki	Alien
	Calamagrostis epigeios	Yamaawa	
	Coix lacryma-jobi	Juzudama	Alien
	Cynodon dactylon	Gyogishiba	
	Digitaria ciliaris	Mehishiba	
	Digitaria violascens	Akimehishiba	
	Echinochloa crus-galli	Inubie	
	Echinochloa crus-galli var. *echinata*	Keinubie	
	Echinochloa crus-galli var. *praticola*	Himeinubie	
	Eleusine indica	Ohishiba	
	Eragrostis curvula	Shinadaresuzumegaya	Alien
	Eragrostis ferruginea	Kazekusa	
	Eragrostis intermedia	Noharakazekusa	
	Eragrostis minor	Kosuzumegaya	
	Festuca arundinacea	Oniushinokegusa	Alien
	Festuca myuros	Naginatagaya	Alien
	Festuca ovina var. *coreana*	Aoushinokegusa	
	Glyceria × *tokitana*	Nangokudojotsunagi	
	Imperata cylindrica var. *cylindrica*	Kenashichigaya	
	Imperata cylindrica var. *koenigii*	Fushigechigaya	
	Lolium × *hybridum*	Nezumihosomugi	Alien
	Lolium multiflorum	Nezumimugi	Alien
	Lolium perenne	Hosomugi	Alien
	Lolium rigidum ssp. *lepturoides*	Bomugi	
	Melica nutana	Komegaya	
	Microstegium vimineum	Himeashiboso	
	Microstegium vimineum var. *polystachyum*	Ashiboso	
	Milium effusus	Ibukinukabo	
	Miscanthus sacchariforus	Ogi	
	Miscanthus sinensis	Susuki	
	Oplismenus undulatifolius var. *japonicus*	Kochijimizasa	
	Oplismenus undulatifolius	Kechijimizasa	
	Panicum bisulacatum	Nukakibi	
	Panicum dichotomiflorum	Okusakibi	Alien
	Paspalum dilatatum	Shima-suzumenohie	Alien
	Paspalum distichum	Kisyu-suzumenohie	Alien
	Paspalum distichum var. *indutum*	Chikugo-suzumenohie	Alien
	Paspalum urvillei	Tachi-suzumenohie	Alien
	Pennisetum alopecuroides f. *purpurascens*	Chikarashiba	
	Phararis arundinacea	Kusayoshi	

(continued)

Appendix 2.5

(continued)

Taxonomic level	Scientific name	Japanese name	
	Phragmites australis	Yoshi	
	Phragmites japonica	Tsuruyoshi	
	Phragmites karka	Seitakayoshi	
	Phyllostachys bambusoides	Madake	Escape
	Phyllostachys nigra var. *henonis*	Hachiku	Escape
	Pleioblastus chino var. *viridis*	Nezasa	
	Pleioblastus simonii	Medake	
	Poa annua	Suzumenokatabira	
	Poa hisauchii	Yamamizoichigotsunagi	
	Poa trivialis	Osuzumenokatabira	Alien
	Polypogon fugax	Hiegaeri	
	Setaria faberi	Akinoenokorogusa	
	Setaria pallide-fusca	Kotsubukinenokoro	
	Sorghum halepense	Seibanmorokoshi	Alien
	Sorghum halepense f. *muticum*	Himemorokoshi	Alien
	Sporobolus fertilis	Nezumino-o	
	Trisetum bifidum	Kanitsurigusa	
	Zizania latifolia	Makomo	
	Microstegium japonicum	Sasagaya	
	Zoysia japonica	Shiba	
Family	Arecaceae		
	Trachycarpus fortunei	Shuro	Ornamental
Family	Araceae		
	Acorus calamus	Shobu	
	Acorus gramineus	Sekisho	
	Pinellia ternata	Karasubishaku	
	Pistia stratiotes	Botan-ukikusa	Alien
Family	Lemnaceae		
	Lemna minor	Ko-ukikusa	
	Lemna paucicostata	Ao-ukikusa	
	Spirodela polyrhiza	Ukikusa	
Family	Sparganiaceae		
	Sparganium japonicum	Nagaemikuri	
	Sparganium stoloniferum	Mikuri	
Family	Typhaceae		
	Typha angustata	Himegama	
Family	Cyperaceae		
	Bulbostylis barbata	Hatagaya	
	Carex albata	Minoborosuge	
	Carex aphanolepis	Enashihigogusa	

(continued)

Appendix 2.5
(continued)

Taxonomic level	Scientific name	Japanese name	
	Carex arenicola	Kurokawazusuge	
	Carex brunnea	Kogomesuge	
	Carex dimorpholepis	Azenaruko	
	Carex dispalata	Kasasuge	
	Carex fedia var. *miyabei*	Birodosuge	
	Carex idzuroei	Umasuge	
	Carex nervata	Shibasuge	
	Carex thunbergii	Azesuge	
	Carex transversa	Yawarasuge	
	Carex vescaria	Oninarukosuge	
	Carex persistens	Kinkikasasuge	
	Carex doniana	Shirasuge	
	Carex kiotensis	Tekirisuge	
	Carex japonica	Higokusa	
	Carex gibba	Masukusa	
	Carex breviculmis	Aosuge	
	Cyperus alternifolius	Shurogayatsuri	Alien
	Cyperus pacificus	Shirogayatsuri	
	Cyperus odoratus	Kingayatsuri	
	Cyperus brevifolius	Aidakugu	
	Cyperus difformis	Tamagayatsuri	
	Cyperus engelmannii	Hosomikingayatsuri	Alien
	Cyperus eragrostis	Merikengayatsuri	Alien
	Cyperus iria	Kogomegayatsuri	
	Cyperus microiria	Kayatsurigusa	
	Cyperus x *mihashi*	Hirabogayatsuri	
	Cyperus nipponicus	Aogayatsuri	
	Cyperus rotundus	Hamasuge	
	Kyllinga gracillima	Himekugu	
	Scirpus tabernaemontani	Futoi	
	Scirpus triqueter	Sankakui	
	Scirpus yagara	Ukiyagara	
	Scirpus juncoides	Hotarui	
Family	Orchidaceae		
	Cremastra appendiculata	Saihairan	
	Spiranthes sinensis var. *amoena*	Nejibana	

Appendix 2.6

A list of Porifera in Lake Biwa and its adjacent waters (by Y. Masuda)

Taxonomic level	Scientific name	Endemicity	Distribution outside Lake Biwa	Life form	Lake Biwa	
				B: benthic, PA: planktonic, PE: pleuston, PR: parasitic	Littoral (0–10 m deep)	Sublittoral (10–30 m deep)
Family	Spongillidae					
	Spongilla lacustris (Linnaeus 1758)	–	Northern Hemisphere	Sessile	+	+
	Spongilla inarmata Annandale 1918	+		Sessile	+	?
	Stratospongilla clementis (Annandale 1909)	–	Philippines, China, Japan, tropical west coast of Africa	Sessile	+	+
	Eunapius fragilis (Leidy 1851)	–	Cosmopolitan	Sessile	+	?
	Eunapius coniferus (Annandale 1916)	–	China	Sessile	?	
	Radiospongilla cerebellata (Bowerbank 1863)	–	Tropical and subtropical regions of Africa, Indonesia, Philippines, New Guinea, China, Russia, South-eastern Europe	Sessile	+	
	Radiospongilla sendai (Sasaki 1936)	–	Japan, Korean Peninsula	Sessile	+	
	Radiospongilla crateriformis (Potts 1882)	–	The United States, Mexico, China, Japan, South-eastern Asia	Sessile	+	
	Ephydatia muelleri (Lieberkühn 1855)	–	Northern Hemisphere	sessile	+	
	Ephydatia fluviatilis (Linnaeus 1758)	–	cosmopolitan	sessile	+	
	Trochospongilla latouchiana Annandale 1907	–	India, South eastern Asia, China, Australia	sessile	+	
	Trochospongilla phillottiana (Annandale 1907)	–	tropical region of Asia, Africa	sessile	+	
	Heteromeyenia stepanowii (Dybowsky 1884)	–	Russia, Germany, China, Japan, Australia	sessile	+	
	Heterorotula multidentata (Weltner 1895)	–	Australia	sessile	+	

Lake Biwa			Attached lakes or lagoons, creek	Paddy fields, small stream, ditches	Rivers flowing into Lake Biwa	Notes (Ecology)	References
Profundal (30 m deep-)	Pelagic	Unknown				Hosts (intermediate, additional) (if parasitic)	
			+		+		Mizuno and Tesukawa (1965), Masuda (2009), Nishino (1991)
							Annandale and Kawamura (1916)
+							Annandale and Kawamura (1916), Mizuno and Tesukawa (1965), Nishino (1991)
			+		+		Annandale and Kawamura (1916), Nishino (1991)
			+		+		
			+		+		Annandale and Kawamura (1916), Mizuno and Tesukawa (1965), Nishino (1991)
			+		?		Sasaki (1936)
			+		+		
			+		?		Annandale and Kawamura (1916), Mizuno and Tesukawa (1965), Nishino (1991)
			+		+		Nishino (1991)
			+		+		Nishino (1991)
			+		?		Gee (1928), Nishino (1991)
			+		?		Annandale and Kawamura (1916), Mizuno and Tesukawa (1965), Nishino (1991)
			+		+		Nishino (1991)

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Appendix 2.7

A list of Cnidaria in Lake Biwa (by M. Nishino)

Taxonomic level	Scientific name	Endemicity	Benthic	Littoral	References
Order	Anthomedusae				
Family	Hydridae				
	Pelmatohydra oligactis Pallas 1766	–	B	+	Stepanjants et al. (2006)
Family	Clavidae (Atecata)				
	Pachycordyle kubotai Stepanjants, Timoshkin, Anokhin et Napara 2000	a	B	+	Stepanjants et al. (2000, 2006)

[a] Not found other than Lake Biwa but further study is required to ensure the endemicity

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Appendix 2.8

A list of "Turbellaria" (Platyhelminthes) in Lake Biwa and its adjacent waters (by M. Kawakatsu and M. Nishino)

Taxonomic level	Scientific name	Endemicity	Distribution outside Lake Biwa	Origin (introduced species)	Habitat				Category in the Red List (RL) by the Ministry of Environment of Japan	References
					Lake Biwa			Around the Lake		
			EJ: endemic to Japan		Littral zone, and attached Lakes	Sublittoral	Profundal	Inlet river, waterway, ditches		
Family	Catenulidae									
	Catenula lemnae Dugès 1832		Japan, Europe, North America							Kawakatsu and Nishino (1994)
Family	Stenostomidae									
	Stenostomum leucops (Dugès 1828)		Japan, Southeast Asia, Europe, South Africa							Kawakatsu and Nishino (1994)
	Stenostomum unicolor Schmidt 1848		Japan, Southeast Asia, Europe							Kawakatsu and Nishino (1994)
	Stenostomum ignatum Vejdovský 1880		Japan, Europe							Kawakatsu and Nishino (1994)
	Rhynchoscolex simples Leydy 1851		Hokkaido, Europe, North America							Kawakatsu and Nishino (1994)
Family	Macrostomidae									
	Microstomum lineare (Müller 1774)		Japan, Southeast Asia, Europe, North America							Kawakatsu and Nishino (1994)
	Macrostomum gigas Okugawa 1930		Japan, Europe, North America							Kawakatsu and Nishino (1994)
	Macrostomum hystricinum Beklemischev 1951		Japan, Southeast Asia, Siberia, Europe		+			+		Kawakatsu and Nishino (1994)

(continued)

Appendix 2.8
(continued)

Taxonomic level	Scientific name	Endemicity	Distribution outside Lake Biwa	Origin (introduced species)	Habitat				Category in the Red List (RL) by the Ministry of Environment of Japan	References
					Lake Biwa			Around the Lake		
			EJ: endemic to Japan		Littral zone, and attached Lakes	Sublittoral	Profundal	Inlet river, waterway, ditches		
	Macrostomum japonicum Okugawa 1930		Central Japan (EJ)		+			+		Kawakatsu and Nishino (1994)
	Macrostomum kawamurai Okugawa 1930	+			+					Kawakatsu and Nishino (1994)
	Macrostomum saifunicum Nassonov 1929		Japan (EJ)		+			+		Kawakatsu and Nishino (1994)
Family	Prorhynchidae									
	Prorhynchus stagnalis biwaensis Timoshkin, Grygier et Kawakatsu 2001		Central Japan		+					Kawakatsu and Nishino (1994)
Family	Plagiostomidae									
	Plagiostomum lemani (Du Plessis 1874)		Japan, Siberia, Europe, North America		+					Kawakatsu and Nishino (1994)
Family	Dalyelliidae									
	Microdalyellia armiger (Schmidt 1861)		Japan, Siberia, Europe, North America							Kawakatsu and Nishino (1994)
	Microdalyellia biwae (Okugawa 1930)		Central Japan		+			+		Kawakatsu and Nishino (1994)

Family	Typhloplanidae									
	Typhloplana viridata (Abildgaard 1789)		Japan, Europe, North America							Kawakatsu and Nishino (1994)
	Strongylostoma radiatum (Ørsted 1843)		Central Japan, Southeast Asia, Siberia, Europe							Kawakatsu and Nishino (1994)
	Castrada hofmanni Braun 1858		Central Japan, Siberia, Europe, North America							Kawakatsu and Nishino (1994)
	Rhynchomesostoma rostratum (Müller 1774)		Central Japan, Southeast Asia, Siberia, Europe, North America							Kawakatsu and Nishino (1994)
	Mesostoma productum (Schmidt 1848)		Japan, Southeast Asia, Siberia, Europe							Kawakatsu and Nishino (1994)
Family	Polycystididae									
	Gyratrix hermaphrodites Ehrenberg 1831		Japan, Southeast Asia, Europe, North America, South Africa							Kawakatsu and Nishino (1994)
Family	Scutariellidae									
	Scutariella japonica (Matjašič 1990)		Japan, China, Taiwan, Korea							Kawakatsu and Nishino (1994), Kawakatsu et al. (1967), Kawakatsu et al. (2007), Kawakatsu et al. (2009)
Family	Planariidae									
	Phagocata kawakatsui Okugawa 1956		Central Japan (EJ)			+	(+)			Kawakatsu and Nishino (1994), Kawakatsu and Ohtaka (2008), Kawakatsu et al. (2009)

(continued)

Appendix 2.8
(continued)

Taxonomic level	Scientific name	Endemicity	Distribution outside Lake Biwa: EJ: endemic to Japan	Origin (introduced species)	Habitat: Lake Biwa: Littral zone, and attached Lakes	Habitat: Lake Biwa: Sublittoral	Habitat: Lake Biwa: Profundal	Habitat: Around the Lake: Inlet river, waterway, ditches	Category in the Red List (RL) by the Ministry of Environment of Japan	References
	Phagocata vivida (Ijima et Kaburaki 1916)		Japan (except for Southwest Kyushu and N Hokkaido), Northeast Asia							Kawakatsu and Nishino (1994), Kawakatsu et al. (1967, 2009)
Family	Dendrocoelidae									
	Bdellocephala annandalei Ijima et Kaburaki 1916	+				+	+		CR+EN	Kawakatsu and Nishino (1994), Kawakatsu and Ohtaka (2008), Kawakatsu et al. (1967, 2000, 2009)
	Bdellocephala brunnea Ijima et Kaburaki 1916		Central Japan (EJ)					(+)		Kawakatsu et al. (1967, 2009)
Family	Dugesiidae									
	Girardia tigrina (Girard 1850)		Central Japan (EJ)	North America (cosmopolitan)	+					Kawakatsu et al. (2007, 2009)
	Girardia dorotocephala (Woodworth 1897)		Central Japan (EJ)	North America	+					Kawakatsu et al. (2007, 2009)
	Dugesia japonica Ichikawa et Kawakatsu 1964		Japan, China, Taiwan, Korea		+			+		Kawakatsu and Nishino (1994), Kawakatsu et al. (1967, 2009), Kawakatsu and Ohtaka (2008)

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Appendix 2.9

A list of Trematoda and Cestoda (Platyhelminthes) in Lake Biwa (by M. Nishino)

Taxonomic level	Scientific name	Endemicity	Benthic	Host species	Origin (introduced)	References
Class	Trematoda					
	Parabucephalopsis parasiluri Wang 1985			*Silurus biwaensis*	Middle South China	Urabe et al. (2008)
Class	Cestoda					
Family	Proteocephalidae					
	Gangesia margolisi Shimazu 1994		P	*Sirulus biwaensis*		Shimazu (1994)
	Proteocephalus plecoglossi Yamaguti 1934			*Plecoglossus altivelis, Chaenogobius isaza, Cottus reinii, Hemibarbus barbus, Lepomis macrochirus*		Shimazu (1993)
	Paraproteocephalus parasiluri (Yamaguti 1934)			*Silurus asotus, Chaenogobius isaza, Chaenogobius urotaenia*		Shimazu (1993)

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Appendix 2.10

A list of Nemertea in Lake Biwa and its adjacent waters (by M. Kawakatsu and M. Nishino)

Taxonomic level	Scientific name	Endemicity	Distribution outside Lake Biwa	Origin (introduced species)	Habitat				Category in the Red List (RL) by the Ministry of Environment of Japan	References
					Lake Biwa			Around the Lake		
			EJ: endemic to Japan		Littral zone, and attached Lakes	Sublittoral	Profundal	Inlet river, waterway, ditches		
Family	Tetrastemmatidae									
	Prostoma ohmiense Chernyshev, Timoshkin et Kawakatsu 1998	?			+					Chernyshev et al. (1998)

References

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Appendix 2.11

A list of Acanthocephala in Lake Biwa (by M. Nishino). All acanthocephalan species are parasitic

Taxonomic level	Scientific name	Endemicity	Distribution	References	Remarks or known host species
Class	Palaeacanthocephala				
Order	Echinorhynchida				
Family	Echinorhynchidae				
	Acanthocephalus aculeatus Van Cleave 1931	*	Lake Biwa and its basin	Kataoka and Momma (1933, 1934)	*Plecoglossus altivelis* subsp.
	Sen. Syn. *Acanthocephala echigoensis* Fujita 1920				Nagasawa et al. (2007) claimed that this synonymy needs reassessment.
	Acanthocephalus gotoi Van Cleave 1925	*		Yamaguti (1939)	*Gymnogobius urotaenia*
	Acanthocephalus opsariichthydis Yamaguti 1935	–	Lake Biwa, Lake Ogura (since drained), Yodo River, Lake Biwa and Yodo River basin	Yamaguti (1935), Nagasawa et al. (1987), Amin et al. (2007)	*Cyprinus carpio*, *Hemibarbus barbus*, *Parabotia curta*, *Opsariichthys uncirostris uncirostris*, *Silurus asotus*, *Pseudorasbora parva*, *Zacco platypus*, *Gymnogobius urotaenia*, *Gnathopogon elongatus elongatus*, *Triborodon hakonensis*, *Misgurnus anguillicaudatus*, *Rhynchocypris lagowskii steindachneri*, *Plecoglossus altivelis* subsp., *Oncorhynchus nerka*, *Oncorhynchus masou* subsp., *Oncorhynchus mykiss*, *Salvelinus fontinalis*, *Cobitis* spp., *Hemibarbus labeo*, *Hemibarbus longirostris*, *Phoxinus oxycephalus jouyi*, *Pseudogobio esocinus esocinus*, *Pungtungia herzi*, *Gasterosteus microcephalus*, *Oncorhynchus masou ishikawae*
	Invalid name: *Acanthocephala opsarichthydis* Yamaguti 1935				

(continued)

Appendix 2.11
(continued)

Taxonomic level	Scientific name	Endemicity	Distribution	References	Remarks or known host species
	Echinorhynchus cotti Yamaguti 1935	–	Lake Biwa and its basin, Kanita River (Aomori Pref., Japan)	Kataoka and Momma (1934), Yamaguti (1935, 1939), Fukui and Morishita (1937), Amin et al. (2007), Shimazu (1999)	*Cottus pollux*, *Cottus reinii*, *Gnathopogon caerulescens*, *Gymnogobius isaza*, *Hemibarbus barbus*, *Plecoglossus altivelis* subsp., *Pelteobagrus nudiceps*, *Sarcocheilichthys variegatus microoculus*, *Silurus biwaensis*, *Tridentiger brevispinis*, *Oncorhynchus masou masou*, *Oncorhynchus mykiss*, *Salvelinus leucomaenis leucomaenis*, *Anguilla japonica*, *Channa argus*, *Cyprinus carpio*, *Opsariichthys uncirostris uncirostris*, *Tanakia limbata*, *Rhinogobius* sp., *Hypomesus nipponensis*
	Syn. *Echinorhynchus oblitus* Golvan 1969				
	Syn. *Echinorhynchus* sp. sensu Kataoka and Momma (1933, 1934)				
	Echinorhynchus parasiluri Fukui 1929	*		Fukui (1929)	*Silurus* sp. (*Silurus asotus*?)
Family	Illiosentidae				
	Pseudorhadinorhynchus samegaiensis Nakajima et Egusa 1975	*	Lake Biwa basin (Samegai Trout Experimental Station)	Amin et al. (2007), Nakajima et al. (1975), Nakajima and Egusa (1975)	*Oncorhynchus mykiss*, *Anguilla japonica*, *Hemibarbus barbus*, *Opsariichthys uncirostris uncirostris*, *Triborodon hakonensis*, *Gasterosteus microcephalus*, *Gymnogobius isaza*, *Oncorhynchus masou ishikawae*
Order	Polymorphida				
Family	Polymorphidae				
	Southwellina hispida (Van Cleave 1925)	–	Japan, United States, Russia	Amin et al. (2007)	*Coreoperca kawamebari*, *Odontobutis obscura obscura*, *Rhinogobius* sp., *Carassius* sp. (or *Cyprinus carpio*?), *Micropterus salmoides*, *Tanakia lanceolata*, *Tanakia limbata*, *Nipponocypris sieboldii*, *Lefua echigonia*, *Nycticorax nycticorax nycticorax*
Class	Eoacanthocephala				
Order	Gyracanthocephala				

(continued)

Appendix 2.11

(continued)

Taxonomic level	Scientific name	Endemicity	Distribution	References	Remarks or known host species
Family	Quadrigyrida				
	Acanthogyrus (*Acanthosentis*) *alternatspinus* Amin 2005	*	Katata-naiko (Lake Biwa basin)	Amin (2005)	*Rhodeus ocellatus ocellatus*
	Acanthogyrus (*Acanthosentis*) *parareceptaclis* Amin 2005	*	Daido River (a tributary of Seta River, Lake Biwa's outflow)	Amin (2005)	*Cobitis* spp.
	Acanthogyrus (*Acanthosentis*) spp.	?	Kusano River (Lake Biwa basin)	Amin et al. (2007)	*Cobitis* spp.

[a]Not found other than Lake Biwa, but further study is required to ensure the endemicity

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Appendix 2.12

A list of Rotifera in Lake Biwa (by M. Maehata and T. Nagata)

Taxonomic level	Scientific name	Japanese name
Family	Habrotrochidae	
	Habrotrocha sp.	
Family	Philodinidae	
	Rotaria elongata (Weber 1888)	
	Rotaria neptunia (Ehrenberg 1882)	Neptune-hirugata-wamushi
	Rotaria rotatoria (Pallas 1766)	
	Rotaria socialis (Kellicott 1888)	
	Philodina roseola Ehrenberg 1832	Beni-hirugata-wamushi
	Philodina sp.	
	Dissotrocha aculeata (Ehrenberg 1832)	Toge-hirugata-wamushi
Family	Epiphanidae	
	Epiphanes senta (Müller 1723)	
Family	Brachionidae	
	Platyias quadricornis (Ehrenberg 1832)	
	Brachionus patulus (Müller 1786)	
	Brachionus leydigi Cohn 1862	Shirimitsu-toge-tsubo-wamushi
	Brachionus quadridentatus (Hermann 1783)	Kado-tsuno-wamushi
	Brachionus quadridentatus var. *cluniorbicularis* (Skorikov 1894)	
	Brachionus urceolaris Müller 1773	Kame-gata-tsubo-wamushi
	Brachionus urceolaris var. *rubens* (Ehrenberg 1838)	Aka-tsubo-wamushi
	Syn. *Brachionus rubens*	
	Brachionus falcatus Zacharias 1898	Kama-gata-tsubo-wamushi
	Brachionus diversicornis Daday 1883	Tsuno-wamushi
	Brachionus calyciflorus Pallas 1766	Tsubo-wamushi
	Brachionus calyciflorus fo. *anuraeiformis* (Brehm 1909)	
	Brachionus calyciflorus fo. *amphiceros* (Ehrenberg 1838)	
	Brachionus calyciflorus fo. *dorcas* (Gosse 1851)	
	Brachionus dimidiatus (Bryce 1931)	
	Brachionus angularis Gosse 1851	Kogata-tsubo-wamushi
	Brachionus angularis var. *bidens* (Plate 1886)	Kadonashi-kogata-tsubo-wamushi
	Brachionus budapestinensis Daday 1885	Butapesto-tsubo-wamushi
	Brachionus caudatus Barrois et Daday 1894	
	Brachionus forficula Wierzejski 1891	Ushirozuno-tsubo-wamushi
	Brachionus forficula fo. *minor* (Voronkov 1891)	
	Keratella quadrata (Müller 1786)	Koshibuto-kamenokou-wamushi
	Keratella valga (Ehrenberg 1834)	Koshiboso-kamenokou-wamushi

(continued)

Appendix 2.12
(continued)

Taxonomic level	Scientific name	Japanese name
	Keratella valga var. *tropica* fo. *reducta* (Fadeew 1927)	
	Syn. *Keratella valga* var. *tropica* fo. *monstrosa*	
	Keratella cochlearis (Gosse 1851)	Kamenokou-wamushi
	Keratella cochlearis var. *micracantha* (Lauterborn 1898)	
	Keratella cochlearis var. *tecta* (Gosse 1886)	
	Keratella cochlearis var. *macracantha* (Lauterborn 1898)	
	Notholca striata (Müller 1786)	Toge-wamushi
	Notholca acuminata (Ehrenberg 1832)	Suji-toge-wamushi
	Notholca labis Gosse 1887	Shirikire-shima-wamushi
	Notholca foliacea (Ehrenberg 1838)	Tongarishima-wamushi
	Kellicottia longispina (Kellicott 1879)	Togenaga-wamushi
	Anuraeopsis fissa Gosse 1851	Nise-kamenokou-wamushi
Family	Euchlanidae	
	Euchlanis dilatata Ehrenberg 1832	Haori-wamushi
	Euchlanis incisa Carlin 1939	
	Dipleuchlanis propatula Gosse 1886	Ashinaga-hario-wamushi
Family	Mytilinidae	
	Mytilina mucronata (Müller 1776)	Yotsuzuno-sayagata-wamushi
	Mytilina ventralis (Ehrenberg 1832)	Sayagata-wamushi
	Mytilina ventralis var. *brevispina* Ehrenberg 1832	
	Lophocharis salpina (Ehrenberg 1834)	
Family	Trichotriidae	
	Trichotria pocillum (Müller 1776)	Onaga-oni-wamushi
	Trichotria tetractis (Ehrenberg 1830)	Shiritoge-oni-wamushi
Family	Colurellidae	
	Colurella adriatica Ehrenberg 1831	
	Syn. *Colurella leptus*	
	Colurella obtusa Gosse 1886	Maru-chibi-wamushi
	Colurella uncinata (Müller 1773)	
	Colurella uncinata fo. *bicuspidata* (Ehrenberg 1832)	
	Syn. *Colurella bicuspidata*	
	Squatinella mutica Ehrenberg 1832	
	Squatinella longispinata (Tatem 1826)	
	Lepadella ovalis (Müller 1786)	
	Lepadella patella (Müller 1786)	

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Taxonomic level	Scientific name	Japanese name
	Lepadella patella fo. *oblonga* (Ehrenberg 1934)	Usagi-wamushi
	Syn. *Lepadella oblonga*	
	Lepadella acuminata Ehrenberg 1834	Tongari-usagi-wamushi
	Lepadella rhomboides (Gosse 1886)	
	Syn. *Lepadella imbricata*	
Family	Lecanidae	
	Lecane ludwigi (Eckstein 1893)	
	Lecane ludwigi fo. *laniculata* (Hauer 1938)	
	Lecane ohioensis (Herrick 1885)	
	Lecane elegans (Harring 1914)	
	Lecane luna (Müller 1776)	Tsukigata-wamushi
	Lecane ungulata (Gosse 1887)	
	Lecane flexilis (Gosse 1889)	
	Lecane stichaea Harring 1913	
	Lecane aculeata (Jakubski 1912)	
	Lecane galeata (Bryce 1892)	
	Syn. *Lecane* (*Monostyla*) *pygmaea*	
	Lecane murrayi (Hauer 1965)	
	Lecane stenroosi Meissner 1908	Tsubo-enaga-wamushi
	Lecane lunaris (Ehrenberg 1832)	Tsukigata-enaga-wamushi
	Lecane lunaris crenata (Harring 1913)	
	Lecane bulla (Gosse 1886)	Tamago-enaga-wamushi
	Lecane quadridentata (Ehrenberg 1832)	Kado-enaga-wamushi
	Lecane closterocerca Schmarda 1859	Marugata-enaga-wamushi
	Lecane hamata (Stoke 1896)	Kagi-enaga-wamushi
	Lecane hamata var. *thienemanni* (Hauer1937)	
	Lecane (*Monostyla*) sp.	
Family	Proalidae	
	Proales sigmoidea (Skorikov 1896)	
	Proales decipiens (Ehrenberg 1831)	
	Proales micropus (Gosse 1886)	
	Proales adenoides (Myers 1933)	
Family	Lindiidae	
	Lindia truncata (Jennings 1894)	
	Lindia pallida (Harring et Myers 1922)	
	Lindia tecusa Harring et Myers 1922	

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Taxonomic level	Scientific name	Japanese name
Family	Notommatidae	
	Scaridium longicaudum (Müller 1786)	Onaga-wamushi
	Monommata dentata (Wuleert 1940)	
	Monommata grandis Tessin 1890	Katao-wamushi
	Eosphora sp.	
	Notommata haueri Wulfert 1939	
	Notommata omentata Wulfert1939	
	Notommata cyrtopus Gosse 1886	
	Notommata paracyrtopus De Beauchamp 1932	
	Cephalodella gibba (Ehrenberg 1838)	
	Cephalodella pachydactyla Wulfert1937	
	Cephalodella sterea (Gosse 1887)	
	Cephalodella sterea var. *serrata* (Wulfert 1937)	
	Syn. *Cephalodella serrata*	
	Cephalodella oxydactyla (Wulfert 1937)	
	Cephalodella cyclops (Wulfert 1937)	
	Cephalodella catellina (Müller 1786)	
	Cephalodella rotunda (Wulfert 1937)	
Family	Trichocercidae	
	Trichocerca collaris (Rousselet 1896)	Erigata-futao-wamushi
	Trichocerca brachyura (Gosse 1851)	Futo-futao-wamushi
	Trichocerca cavia (Gosse 1886)	
	Trichocerca dixon-nuttalli Jennings 1903	Futo-nezumi-wamushi
	Trichocerca weberi Jennings 1903	
	Trichocerca tenuior (Gosse 1886)	
	Trichocerca tigris (Müller 1786)	
	Trichocerca porcellus (Gosse 1851)	
	Trichocerca musculus (Hauer 1936)	
	Trichocerca insignis Herrick 1885	Yubinaga-futao-wamushi
	Trichocerca bidens (Lucks 1912)	
	Trichocerca similis (Wierzejski 1893)	
	Trichocerca birostris (Minkiewicz 1900)	
	Trichocerca bicristata (Gosse 1887)	Futasuji-nezumi-wamushi
	Trichocerca elongata (Gosse 1886)	Onaga-nezumi-wamushi (Nagagata-nezumi-wamushi)
	Trichocerca rattus (Müller 1776)	Nekoze-nezumi-wamushi
	Syn. *Trichocerca cristata*	
	Trichocerca pusilla (Jennings 1903)	

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(continued)

Taxonomic level	Scientific name	Japanese name
	Trichocerca stylata (Gosse 1851)	
	Trichocerca iernis (Gosse 1887)	
	Trichocerca cylindrica (Imhof 1891)	Tsumenaga-nezumi-wamushi
	Trichocerca cylindrica chattoni (De Beauchamp 1907)	
	Trichocerca longiseta (Schrank 1802)	Nagatsuno-nezumi-wamushi
	Trichocerca capucina (Wierzejski et Zacharias 1893)	Nezumi-wamushi
Family	Gastropodidae	
	Ascomorpha ovalis (Carlin1943)	
	Syn. *Ascomorpha testudo*	
Family	Synchaetidae	
	Synchaeta tremula (Müller 1786)	Hoso-doro-wamushi
	Synchaeta oblonga (Ehrenberg 1832)	Nagamaru-doro-wamushi
	Synchaeta stylata Wierzejski 1893	Doro-wamushi
	Synchaeta pectinata Ehrenberg 1832	
	Polyarthra vulgaris Carlin 1943	Haneude-wamushi
	Syn. *Polyarthra trigla*	
	Syn. *Polyarthra trigla vulgaris*	
	Syn. *Polyarthra platyptera*	
	Polyarthra vulgaris var. *longirermis* (Carlin 1943)	
	Polyarthra dolichoptera Idelson 1925	
	Polyarthra major Burckhardt 1900	
	Polyarthra euryptera Wierzejski 1893	Hirohane-ude-wamushi
	Polyarthra minor Voigt 1904	
	Ploesoma hudsoni (Imhof 1891)	Ibo-suji-wamushi
	Ploesoma truncatum (Levander 1894)	Suji-wamushi
	Ploesoma lenticulare Herrick 1885	
Family	Asplanchnidae	
	Asplanchnopus multiceps (Schrank 1793)	
	Syn. *Asplanchna multiceps*	
	Asplanchna priodonta Gosse 1850	Fukuro-wamushi
	Asplanchna sieboldi (Leydig 1854)	Siebold-fukuro-wamushi
Family	Dicranophoridae	
	Dicranophorus grandis (Ehrenberg 1832)	
	Dicranophorus hercules Wiszniewski 1934	
	Encentrum pachidum (Gosse 1887)	
	Encentrum lutetiae (Harring et Myers 1928)	

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Taxonomic level	Scientific name	Japanese name
Family	Testudinellidae	
	Testudinella patina (Hermann 1783)	Hirata-wamushi
	Testudinella parva (Terentz 1892)	
	Testudinella brycei Hauer 1937/38	
	Testudinella dicella (Myers 1934)	
	Pompholyx complanata Gosse 1851	Awa-wamushi
	Pompholyx sulcata Hudson 1885	
Family	Floscullariidae	
	Limnias melicerta nymphea (Stenroos 1898)	
	Syn. *Limias nymphea*	
	Floscularia ringens (Linnaeus 1785)	Marusaya-wamushi
	Floscularia conifera (Hudson 1886)	
	Ptygura brevis (Rousselet 1893)	
	Sinantherina socialis (Linne 1758)	
	Lacinularia flosculosa (Müller 1758)	
Family	Conochilidae	
	Conochilus unicornis Rousselet 1892	Tsuno-temari-wamushi
	Conochilus hippocrepis Schrank 1830	Temari-wamushi
	Conochilus natans (Seligo 1900)	
	Syn. *Conochiloides natans*	
	Conochilus dossuarius (Hudson 1875)	
	Conochilus coenobasis (Skorikow 1914)	
Family	Hexarthidae	
	Hexarthra mira Hudson 1871	Mijinko-wamushi
	Syn. *Pedalia mira*	
Family	Filinidae	
	Filinia longiseta (Ehrenberg 1834)	Naga-mitsuude-wamushi
	Filinia longiseta var. *passa* (Müller 1786)	
	Filinia terminalis (Plate 1886)	
	Filinia opoliensis Zacharias1898	Yotsuude-wamushi
Family	Collothecidae	
	Collotheca pelagica (Rousselet 1893)	
	Collotheca mutabilis (Hudson 1885)	
	Collotheca campanulata Dobie 1849	

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(continued)

Taxonomic level	Scientific name	Japanese name
	Collotheca ornata (Ehrenberg 1835)	
	Collotheca ornata var. *cornuta* (Dobie 1849)	
	Collotheca uncinata (Müller 1773)	
Family	Atrochidae	
	Cupelopagis vorax (Leidy 1857)	

[a]This list is cited from Matsubara (1996). Some scientific names have been corrected according to Jersabek et al. (2012).

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Appendix 2.13

A list of Nematoda in Lake Biwa (by E. Inoue and M. Nishino)

Taxonomic level	Scientific name	Endemicity	Distribution	Benthic (B) or Parasitic (P)	Littoral	References	Remarks (habitat or host species)
Class	Adenophorea						
Order	Araeolaimida						
Family	Leptolaimidae						
	Leptolaimus primitivus Gagarin 2001	a	Lake Biwa	B	Littoral	Gagarin (2001a, 2003)	Kita-komatsu depth 1-1.2m, ground sand, boulders, macrophytes
	Monhystera amabilis Gagarin 1997	–	Japan, Russia	B	Upper littoral	Gagarin (2001a, 2003)	ground sand
Order	Chromadorida						
Family	Ethmolaimidae						
	Ethmolaimus pratensis de Man 1880	–	Lake Biwa, Lake Baikal, Lake Hovsgol	B	Littoral	Gagarin (2000, 2003)	
Family	Achromadoridae						
	Achromadora terricola (de Man 1880)	?	Lake Biwa	B	Littoral	Gagarin (2000, 2003)	
Order	Desmodorida						
Family	Desmodoridae						
	Prodesmodora circulata (Micoletzky 1913)	?	Lake Biwa	B	Littoral	Gagarin (2000, 2003)	
Order	Dorylaimida						
Family	Actinolaimidae						
	Paractinolaimus macrolaimus (de Man 1880)	?	Lake Biwa	B	Littoral	Gagarin (2000, 2003)	
	Parastomachoglossa japonica Tsalolikhin 1999	a	Lake Biwa	B	Littoral	Tsalolikhin (1999), Gagarin (2003)	
Family	Aporcelaimidae						
	Aporcelaimellus obtusicaudatus (Bastian 1865)	–	Worldwide	B	Littoral	Tsalolikhin (2002)	

(continued)

Appendix 2.13
(continued)

Taxonomic level	Scientific name	Endemicity	Distribution	Benthic (B) or Parasitic (P)	Littoral	References	Remarks (habitat or host species)
Family	Dorylaimidae						
	Dorylaimus stagnalis Dujardin 1845	–	Lake Biwa, Lake Baikal, Lake Hovsgol	B	Littoral	Gagarin (2000, 2003)	
	Laimydorus sp.	?	Lake Biwa	B	Littoral	Gagarin (2000)	
	Mesodorylaimus subtiliformis (Andrassy 1959)	?	Lake Biwa	B	Littoral	Gagarin (2000, 2003)	
Family	Qudsianematidae						
	Labronema sp.	?	Lake Biwa	B	Littoral	Gagarin (2000)	
Order	Enoplida						
Family	Alaimidae						
	Alaimus psammophilus Gagarin 2000	?	Lake Biwa	B	Littoral	Gagarin (2000, 2003)	
Family	Bastianidae						
	Bastiania exilis Cobb 1914	?	Lake Biwa	B	Littoral	Gagarin (2000, 2003)	
Family	Cryptonchidae						
	Cryptonchus sp.	?	Lake Biwa	B	Littoral	Gagarin (2000)	
Family	Ironidae						
	Ironus ignavus Bastian 1865	–	Holarctic	B	Littoral	Gagarin (2000, 2003), Tsalolikhin (2002)	
	Ironus longicaudatus de Man 1884	?	Lake Biwa	B	Littoral	Gagarin (2000, 2003)	
Family	Prismatolaimidae						
	Prismatolaimus intermedius (Bütschli 1873)	?	Lake Biwa	B	Littoral	Gagarin (2000, 2003)	
Family	Rhabdolaimidae						
	Rhabdolaimus directistomus Gagarin 2000	?	Lake Biwa	B	Littoral	Gagarin (2000, 2003)	

Family	Tobrilidae						
	Brevitobrilus stefanskii (Micoletzky 1925)	–	Widespread (Japan, Mongolia, Singapore, Kazakhstan, Azerbaijan, Ethiopia, Spain, Denmark, etc.)	B	littoral	Gagarin (2000, 2003), Tsalolikhin (2001a)	sand, 0.2-3m deep
	Epitobrilus parvipapillatus (Kreis 1932)	–	Central Asia and Lake Biwa	B	littoral	Tsalolikhin (2001b)	sand, 0.5, 2m deep
	Epitobrilus sp.	?	Lake Biwa	B	Littoral	Gagarin (2000)	
	Eutobrilus grandipapillatus (Brakenhoff 1914)	?	Lake Biwa	B	Littoral	Gagarin (2000, 2003)	
	Eutobrilus japonicus Gagarin 2000	?	Lake Biwa	B	Littoral	Gagarin (2000, 2003)	
Family	Tripylidae						
	Tripyla glomerans Bastian 1865	–	Lake Biwa, Lake Hovsgol, Russia	B	Littoral?	Gagarin (2000, 2003), Tsalolikhin (2002)	muddy sand, 20m deep
Order	Monhystrerida						
Family	Monhysteridae						
	Monhystera stagnalis Bastian 1865	?	Lake Biwa	B	Littoral	Gagarin (2000, 2003)	
	Tridentulus obscurus Gagarin 2001	–	Lake Biwa and its basin, Russia	B	Littoral	Gagarin (2001b)	
	Tridentulus minor Gagarin 2001	?	Lake Biwa and its basin	B	Littoral	Gagarin (2001b)	
Family	Xyalidae						
	Daptonema obesum Gagarin 2001	?	Lake Biwa and its basin	B	Littoral	Gagarin (2000, 2001b, 2003)	
	Daptonema timoshkini Tsalolikhin 2002	?	Lake Biwa	B	Littoral	Tsalolikhin (2002)	near Kita-komatsu, sand littoral
	Mongolotheristus timoshkini Gagarin 2001	?	Lake Biwa and its basin	B	Littoral	Gagarin (2000, 2001b, 2003)	
Family	Leptolaimidae						
	Leptolaimus sp.	?	Lake Biwa	B	Littoral	Gagarin (2000)	

(continued)

Appendix 2.13
(continued)

Taxonomic level	Scientific name	Endemicity	Distribution	Benthic (B) or Parasitic (P)	Littoral	References	Remarks (habitat or host species)
	Aphanolaimus viviparus Plotnikov 1899	?	Lake Biwa	B	Littoral	Gagarin (2000, 2003)	
	Aphanolaimus sp.	?	Lake Biwa	B	Littoral	Gagarin (2000)	
Family	Plectidae						
	Plectus cirratus Bastian 1865	–	Lake Biwa, Lake Hovsgol	B	Littoral	Gagarin (2000, 2003)	
	Plectus tenuis Bastian 1865	?	Lake Biwa	B	Littoral	Gagarin (2000, 2003)	
Order	Tylenchida						
Family	Tylenchidae						
	Filendus sp.	?	Lake Biwa	B	Littoral	Gagarin (2000)	
Class	Secernentea						
Order	Ascaridida						
Family	Anisakidae						
	Raphidascaris gigi Fujita 1928	+	Lake Biwa	P		Fujita (1928), Moravec et al. (1998), Moravec and Nagasawa (2002), Nagasawa et al. (2007)	*Gnathopogon caerulescens*, *Gymnogobius isaza*, *Oncorhynchus* sp., *Opsariichthys uncirostris uncirostris*, *Pelteobagrus nudiceps*, *Plecoglossus altivelis* subsp., *Sarcocheilichthys* spp., *Squalidus chankaensis biwae*, *Tribolodon hakonensis*, *Leptodora richardii* (cladoceran intermedialy host)
	Syn. *Raphidascaris biwakoensis* Fujita 1928						
	Syn. *Raphidascaris plecoglossi* Fujita 1928						

Order	Camallanida						
Family	Camallanidae						
	Camallanus cotti Fujita 1927	–	Lake Biwa, Lake Tazawa	P		Fujita (1927a)	*Opsariichthys uncirostris uncirostris*, *Silurus* spp., *Cottus pollux*
	Procamallanus parasiluri Fujita 1927	?	Lake Biwa	P		Fujita (1927a)	*Opsariichthys uncirostris uncirostris*, *Silurus* spp., *Cottus* sp.
Family	Thelaziidae						
	Rhabdochna oncorhynchi (Fujita 1921)	?	Lake Biwa	P		Fujita (1927b)	*Plecoglossus altivelis* subsp., *Gnathopogon caerulescens*, *Squalidus chankaensis biwae*, *Opsariichthys uncirostris uncirostris*, *Tribolodon hakonensis*, *Salvelinus* sp.
	Syn. *Rhabdochna salvelini* Fujita 1927						
	Salvelinema iwana (Fujita 1928)	?	Lake Biwa	P		Fujita (1928)	*Salvelinus* sp.
	Syn. *Cystidicola iwana* Fujita 1928						
	Sterliadochona ephemeridarum (Linstow 1872)	?	Lake Biwa	P		Fujita (1928)	*Salvelinus* sp.
	Syn. *Cystidicola salvelini* (Fujita 1924)						
Order	Diplogasterida						
Family	Diplogasteridae						
	Mononchoides asiaticus Gagarin 2001	?	Lake Biwa and its basin	B		Gagarin (2001b)	
Order	Seuratoidea						
Family	Cucullanidae						
	Cuculamus gigi Fujita 1927	?	Lake Biwa	P		Fujita (1927b)	*Pelteobagrus nudiceps*

(continued)

Appendix 2.13
(continued)

Taxonomic level	Scientific name	Endemicity	Distribution	Benthic (B) or Parasitic (P)	Littoral	References	Remarks (habitat or host species)
Order	Spirurida						
Family	Cystidicolidae						
	Spinitectus gigi Fujita 1927	?	Lake Biwa	P		Fujita (1927b)	*Pelteobagrus nudiceps*
Family	Philometridae						
	Philometra parasiluri Yamaguti 1935	–	Lake Biwa, Lake Ogura	P		Yamaguti (1935), Moravec et al. (2008)	*Silurus asotus*

[a]Not found other than Lake Biwa, but further study is required to ensure the endemicity

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Appendix 2.14

A list of aquatic mollusca reported so far from Lake Biwa and its adjacent areas (by M. Nishino)

Taxonomic level	Scientific name	Japanese name	Endemicity	Distribution outside Lake Biwa		Lake	
				EJ: endemic to Japan	Origin (introduced species)	Littoral (0–10 m deep)	
Class	Gastropoda						
Superorder	Caenogastropoda						
Family	Ampullariidae						
	Pomacea canaliculata (Lamarck)	sukumi-ringogai			South America	+	
Family	Viviparidae						
	Cipangopaludina japonica (von Martens)	o-tanishi		Honshu, Kyushu, Korea, Northern China		+	
	Cipangopaludina chinensis laeta (Reeve)	maru-tanishi		Japan, Korea		–	
	Heterogen longispira (Smith)	naga-tanishi	+			+	
	Sinotaia quadrata histrica (Gould)	hime-tanishi		Honshu, Shikoku, Kyushu, Okinawa, Taiwan		+	
Family	Pleuroceridae						
	Semisulcospira (*Semisulcospira*) *kurodai* Kajiyama et Habe	kuroda-kawanina		Honshu		+	
	Semisulcospira (*Semisulcospira*) *libertina* (Gould)	kawanina		Japan		+	
	Semisulcospira (*Semisulcospira*) *reiniana* (Brot)	chirimen-kawanina		Honshu		+	
	Semisulcospira (*Biwamelania*) *arenicola* Watanabe et Nishino	hosomaki-kawanina	+			+	
	Semisulcospira (*Biwamelania*) *decipiens* (Westerlund)	tatehida-kawanina	+			+	
	Semisulcospira (*Biwamelania*) *dilatata* Watanabe et Nishino	futomaki-kawanina	+			+	

Biwa		Attached lakes or lagoons, creek	Paddy-fields, small stream, ditches	Rivers flowing into Lake Biwa	Category in the Red List (RL) by the Ministry of the Environment of Japan	Notes (Ecology)	References
Sublittoral (10–30 m deep)	Profundal (30 m deep-)				CR+EN: Critically Endangered VU: Vulnerable NT: Near Threatened DD: Data Deficient		
–	–	?	–	?			Nishino (1991), wKihira et al. (2003)
–	–	+	+	?	NT		Ohyama and Kajiyama (1959), Kuroda (1962), Kihira et al. (2003)
–	–	+	+	?	NT		Kuroda (1962), Kihira et al. (2003)
+	–	?	–	?	NT		Ohyama and Kajiyama (1959), Kuroda (1962), Hayashi (1972a, b), Nishino (1991), Kihira et al. (2003)
–	–	+	+	?			Kuroda (1962), Nishino (1991), Kihira et al. (2003)
–	–				NT		Kuroda (1962), Watanabe and Nishino (1995), Urabe and Yoshida (1995)
–	–	?	+	+			Kuroda (1962), Nishino (1991), Urabe and Yoshida (1995)
–	–	+	+	+			Nishino (1991), Watanabe and Nishino (1995), Urabe and Yoshida (1995), Kihira et al. (2003)
–	–	?	–	–	NT		Nishino (1991), Watanabe and Nishino (1995), Kihira et al. (2003)
–	–	–	–	–	NT		Kuroda (1962), Watanabe (1970), Nishino (1991), Watanabe and Nishino (1995), Kihira et al. (2003)
–	–	–	–	–	DD		Nishino (1991), Watanabe and Nishino (1995), Kihira et al. (2003)

(continued)

Appendix 2.14

(continued)

Taxonomic level	Scientific name	Japanese name	Endemicity	Distribution outside Lake Biwa	Origin (introduced species)	Lake
				EJ: endemic to Japan		Littoral (0–10 m deep)
	Semisulcospira (*Biwamelania*) *fluvialis* Watanabe et Nishino	nango-kawanina	+			+
	Semisulcospira (*Biwamelania*) *fuscata* Watanabe et Nishino	kuro-kawanina	+			+
	Semisulcospira (*Biwamelania*) *habei* Davis	habe-kawanina	+			+
	Semisulcospira (*Biwamelania*) *morii* Watanabe	mori-kawanina	+			+
	Semisulcospira (*Biwamelania*) *multigranosa* Boettger	ibo-kawanina	+			+
	Semisulcospira (*Biwamelania*) *nakasekoae* Kuroda	nakaseko-kawanina	+			+
	Semisulcospira (*Biwamelania*) *niponica* (Smith)	yamato-kawanina	+			+
	Local type: *Semisulcospira* (*Biwamelania*) *niponica* (biwae type)	chikubu-kawanina	(+)			+
	Local type: *Semisulcospira* (*Biwamelania*) *niponica* (ribbed type)	yamato-kawanina-rokugata	(+)			+
	Semisulcospira (*Biwamelania*) *ourense* Watanabe et Nishino	oura-kawanina	+			+
	Semisulcospira (*Biwamelania*) *reticulata* Kajiyama et Habe	kagome-kawanina	+			+

Biwa		Attached lakes or lagoons, creek	Paddy-fields, small stream, ditches	Rivers flowing into Lake Biwa	Category in the Red List (RL) by the Ministry of the Environment of Japan	Notes (Ecology)	References
Sublittoral (10–30 m deep)	Profundal (30 m deep-)				CR+EN: Critically Endangered VU: Vulnerable NT: Near Threatened DD: Data Deficient		
–	–	–	–	–	DD		Nishino (1991), Watanabe and Nishino (1995), Kihira et al. (2003)
–	–	–	–	–	VU		Nishino (1991), Watanabe and Nishino (1995), Kihira et al. (2003)
–	–	?	–	–			Davis (1969), Nishino (1991), Watanabe and Nishino (1995), Kihira et al. (2003)
–	–	–	–	–	NT		Nishino (1991), Watanabe and Nishino (1995), Kihira et al. (2003)
–	–	?	–	–	NT		Watanabe (1970), Nishino (1991), Watanabe and Nishino (1995), Kihira et al. (2003)
–	–	–	–	–	CR+EN		Kuroda (1962), Nishino (1991), Watanabe and Nishino (1995), Kihira et al. (2003)
–	–	+	–	–	NT		Kuroda (1962), Nishino (1991), Watanabe and Nishino (1995), Urabe and Yoshida (1995), Kihira et al. (2003)
–	–	–	–	–			Nishino (1991), Watanabe and Nishino (1995)
–	–	–	–	–			Nishino (1991), Watanabe and Nishino (1995)
–	–	–	–	–	DD		Nishino (1991), Watanabe and Nishino (1995), Kihira et al. (2003)
–	–	?	–	–	NT		Watanabe (1970), Nishino (1991), Watanabe and Nishino (1995), Kihira et al. (2003)

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Appendix 2.14
(continued)

Taxonomic level	Scientific name	Japanese name	Endemicity	Distribution outside Lake Biwa	Origin (introduced species)	Lake
				EJ: endemic to Japan		Littoral (0–10 m deep)
	Semisulcospira (*Biwamelania*) *rugosa* Watanabe et Nishino	tatejiwa-kawanina	+			+
	Semisulcospira (*Biwamelania*) *shiraishiensis* Watanabe et Nishino	shiraishi-kawanina	+			+
	Semisulcospira (*Biwamelania*) *takeshimensis* Watanabe et Nishino	takeshima-kawanina	+			+
Family	Thialidae					
	Melanoides tuberculatus (Müller)	nunome-kawanina			Amami-Oshima Islands and southward, Japan, Taiwan, Indo-Pacific	–
Superorder	Heterobranchia					
	Lower Heterobranchia					
Family	Valvatidae					
	Valvata biwaensis Preston	Biwako-mizushitadami	+			+
Family	Hydrobiidae					
	Potamopyrgus antipodarum (Gray)	komochi-kawatsubo			New Zealand	–
	Syn. *Potamopyrgus jenkinsi* (Smith)					
Family	Bithyniidae					
	Parafossarulus manchouricus japonicus	mame-tanishi		Honshu, Korea, China, Siberia		+
Order	Plumonata					
Suborder	Basommatophora					
Family	Lymnaeidae					
	Austropeplea ollula (Gould)	hime-monoaragai		Japan, China, Philippines		+

Biwa		Attached lakes or lagoons, creek	Paddy-fields, small stream, ditches	Rivers flowing into Lake Biwa	Category in the Red List (RL) by the Ministry of the Environment of Japan	Notes (Ecology)	References
Sublittoral (10–30 m deep)	Profundal (30 m deep-)				CR+EN: Critically Endangered VU: Vulnerable NT: Near Threatened DD: Data Deficient		
–	–	–	–	–	DD		Nishino (1991), Watanabe and Nishino (1995), Kihira et al. (2003)
–	–	–	–	–	NT		Nishino (1991), Watanabe and Nishino (1995), Kihira et al. (2003)
–	–	–	–	–	NT		Nishino (1991), Watanabe and Nishino (1995), Kihira et al. (2003)
–	–		+				Kihira et al. (2003)
+	+				NT		Miyadi and Mori (1933), Nishino (1991), Kihira et al. (2003)
–	–	–	+	?			Nishino (1999), Urabe (2007)
–	–				VU		Kuroda (1962), Nishino (1991), Kihira et al. (2003)
–	–						Kuroda (1962), Nishino (1991), Kihira et al. (2003)

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Appendix 2.14
(continued)

Taxonomic level	Scientific name	Japanese name	Endemicity	Distribution outside Lake Biwa	Origin (introduced species)	Lake
				EJ: endemic to Japan		Littoral (0–10 m deep)
	Fossaria truncatula (Müller)	koshitaka-monoaragai		Europe, Northern Asia, Japan		–
	Radix auricularia japonica Jay	monoaragai				+
	Pseudosuccinea columella (Say)	habutae-monoaragai			North America	–
	Radix onychia (Westerlund)	omigai	+			+
Family	Physidae					
	Physa acuta Draparnaud	sakamakigai			Europe, northern Asia	+
Family	Planorbidae					
	Camptoceras hirasei Walker	kawanejigai		Honshu, Shikoku		+
	Culmenella prashadi (Clench)	hidarimaki-monoaragai		Honshu		+
	Gyraulus biwaensis (Preston)	kado-hiramakigai	+			+
	Syn. *Choanomphalodes perstriatulus* (Preston)					
	Gyraulus amplificatus (Mori)	hirokuchi-hiramakigai	+			+
	Gyraulus chinensis hiemantium (Westerlund)	hiramaki-mizumaimai		Japan		–
	Syn. *G. chinensis spirillus* (Gould)					
	Indoplanorbis exustus (Deshayes)	indo-hiramakigai			India, South East Asia, Australia	+
	Polypylis hemisphaerula (Benson)	hiramakigai-modoki		Honshu, Kyushu, Okinawa, Taiwan, China		–
Family	Ancylidae					
	Laevapex nipponicus (Kuroda in Is. Taki)	kawakozaragai		Honshu, Okinawa		+

Biwa		Attached lakes or lagoons, creek	Paddy-fields, small stream, ditches	Rivers flowing into Lake Biwa	Category in the Red List (RL) by the Ministry of the Environment of Japan	Notes (Ecology)	References
Sublittoral (10–30 m deep)	Profundal (30 m deep-)				CR+EN: Critically Endangered VU: Vulnerable NT: Near Threatened DD: Data Deficient		
–	–	+	+				Kuroda (1962), Kihira et al. (2003)
–	–	+	+		NT		Kuroda (1962), Nishino (1991), Kihira et al. (2003)
–	–		+				Kihira et al. (2003)
–	–				NT		Kuroda (1962), Habe (1973), Nishino (1991), Kihira et al. (2003)
–	–		+				Nishino (1991), Kihira et al. (2003)
–	–				CR+EN		Kuroda (1962), Kihira et al. (2003)
–	–				CR+EN		Mori (1938a), Kuroda (1962), Kihira et al. (2003)
–	–				NT		Mori (1938a), Kuroda (1962), Nishino (1991), Kihira et al. (2003)
–	–						Mori (1938a), Kuroda (1962), Kihira et al. (2003)
–	–		?		DD		Kihira et al. (2003)
–	–						Kihira et al. (2003)
–	–		+		NT		Kuroda (1962), Kihira et al. (2003)
–	–						Kuroda (1962), Nishino (1991), Kihira et al. (2003)

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Appendix 2.14
(continued)

Taxonomic level	Scientific name	Japanese name	Endemicity	Distribution outside Lake Biwa	Origin (introduced species)	Lake
				EJ: endemic to Japan		Littoral (0–10 m deep)
	Laevapex japonica Habe et Burch	sujiiri-kawakozaragai		Honshu		+
Class	Bivalvia					
Order	Mytiloida					
Family	Mytilidae					
	Limnoperna fortunei (Dunker)	kawahibarigai			South East Asia	+
Order	Unionoida					
Family	Unionidae					
Subfamily	Unioninae					
	Anodonta japonica Clessin	tagai		EJ		
	Anodonta lauta Martens	numagai		EJ		+
	Syn. *Anodonta woodiana* (Lea)	(dobugai)				
	Anodonta calipygos Kobelt	marudobugai	+	–		+
	Cristaria plicata clessini (*Kobelt*)[a]	men-karasugai	+	–		+
	Inversidens brandti (Kobelt)	obaeboshigai		Japan		+
	Inversiunio reinianus (Kobelt)	otoko-tateboshigai	+	–		+
	Syn. *Inversidens hirasei* (Haas)	(seta-ishigai)				
	Inversiunio yanagawensis (Kondo)	nise-matsukasagai		EJ		–

Biwa		Attached lakes or lagoons, creek	Paddy-fields, small stream, ditches	Rivers flowing into Lake Biwa	Category in the Red List (RL) by the Ministry of the Environment of Japan	Notes (Ecology)	References
Sublittoral (10–30 m deep)	Profundal (30 m deep-)				CR+EN: Critically Endangered VU: Vulnerable NT: Near Threatened DD: Data Deficient		
–	–						Habe and Burch (1965), Kuroda (1962), Kihira et al. (2003)
–	–						Matsuda and Uenishi (1992), Kihira et al. (2003)
		+	+			b	Kuroda (1962), Kondo (2008)
–	–	+	+			b	Kuroda (1962), Hayashi (1972a, b), Kihira et al. (2003), Kondo (2008)
–	–				VU	c	Kuroda (1962), Hayashi (1972a, b), Nishino (1991), Kihira et al. (2003), Kondo (2008)
–	–				NT	c	Kuroda (1962), Hayashi (1972a.b), Nishino (1991), Kihira et al. (2003), Kondo (2008)
–	–				VU	d	Kuroda (1962), Hayashi (1972a, b), Nishino (1991), Kihira et al. (2003), Kondo (2008)
+	–				VU	c	Kuroda (1962), Hayashi (1972a, b), Kihira et al. (2003), Kondo (2008)
–	–		+		NT	b	Kondo (2008)

(continued)

Appendix 2.14
(continued)

Taxonomic level	Scientific name	Japanese name	Endemicity	Distribution outside Lake Biwa	Origin (introduced species)	Lake
				EJ: endemic to Japan		Littoral (0–10 m deep)
	Lanceolaria oxyrhyncha (Simpson)*	sasanohagai	+	–		+
	Oguranodonta ogurae Kuroda et Habe	ogura-numagai	+	–		+
	Obovalis omiensis (Heimburg)	katahagai		EJ		–
	Pronodularia japanensis (Lea)	matsukasagai		EJ		+
	Unio douglasiae biwae Kobelt	tateboshigai	+	–		+
Subfamily	Hyriopsinae					
	Hyriopsis schlegeli (Von Martens)	ikechogai	+	–		+
Order	Veneroidea					
Family	Corbiculidae					
	Corbicula (*Corbicula*) *sandai* Reinhardt	seta-shijimi	+	–		+
	Corbicula (*Corbiculina*) *leana* Prime	ma-shijimi		Japan		+
	Corbicula spp.				China, Taiwan, Korea	
Family	Pisidiidae					
	Sphaerium japonicum biwaense Mori	Biwako-dobushijimi		Japan		+
	Sphaerium japonicum Westerlund	dobushijimi		Honshu, Shikoku, Kyushu		–

Biwa		Attached lakes or lagoons, creek	Paddy-fields, small stream, ditches	Rivers flowing into Lake Biwa	Category in the Red List (RL) by the Ministry of the Environment of Japan	Notes (Ecology)	References
Sublittoral (10–30 m deep)	Profundal (30 m deep-)				CR+EN: Critically Endangered VU: Vulnerable NT: Near Threatened DD: Data Deficient		
–	–				NT	b	Kuroda (1962), Hayashi (1972a, b), Nishino (1991), Kihira et al. (2003), Kondo (2008)
–	–				CR+EN	c	Kuroda and Habe (1987), Kihira et al. (2003), Kondo (2008)
–	–		+		VU	e	Kihira et al. (2003), Kondo (2008)
+	–				NT	f	Kuroda (1962), Hayashi (1972a, b), Nishino (1991), Kihira et al. (2003), Kondo (2008)
+	–					g	Kuroda (1962), Hayashi (1972a, b), Nishino (1991), Kondo (1997), Kondo (2008)
–	–				CR+EN	h	Kuroda (1962), Hayashi (1972a, b), Nishino (1991), Kihira et al. (2003), Kondo (2008)
+	–				VU		Kuroda (1962), Hayashi (1972a, b), Nishino (1991), Harada and Nishino (1995), Kihira et al. (2003)
–	–	+	+		NT		Kuroda (1962), Nishino (1991), Harada and Nishino (1995), Kihira et al. (2003)
							Kihira et al. (2003)
–	–						Mori (1933), Kuroda (1962), Nishino (1991), Kihira et al. (2003)
–	–	+	+				Kihira et al. (2003)

(continued)

Appendix 2.14

(continued)

Taxonomic level	Scientific name	Japanese name	Endemicity	Distribution outside Lake Biwa	Origin (introduced species)	Lake
				EJ: endemic to Japan		Littoral (0–10 m deep)
	Pisidium japonicum Pilsbry et Hirase	mameshijimi		Hokkaido, Honshu		–
	Pisidium kawamurai Mori	kawamura-mameshijimi	+			+
	Pisidium cinereum lacustre Woodward	mizuumi-mameshijimi		Honshu, Hokkaido		+

All the mullusca in Lake Biwa is benthic

[a]Kondo (2008) synonymized *Cristaria plicata clessini* and *Lanceolaria oxyrhyncha* with *Cristaria plicata* and *Lanceolaria grayana*, respectively, and denied their endemicity

[b]Natural hosts of the glochidia are the pale chub *Zacco platypus*, pike gudgeon *Pseudogobio esocinus esocinus* and freshwater gobies *Rhinogobius* spp.

[c]Natural host of the glochidia is the freshwater gobies, *Rhinogobius* spp.

[d]Natural hosts of the glochidia are the pale chub *Zacco platypus*, the endemic gudgeon *Sarcocheilichthys* spp., field minnow *Gnathopogon elongatus* and top mouth gudgeon *Pseudorasbora parva*

[e]Natural hosts of the glochidia are the pale chub *Zacco platypus*, dark chub *Nipponocypris temmincki* and freshwater gobies *Rhinogobius* spp.

[f]Natural hosts of the glochidia are the pale chub *Zacco platypus*, dark chub *Nipponocypris temmincki*, Asian pond loach *Misgurnus anguillicaudatus* and freshwater gobies *Rhinogobius* spp.

[g]Natural hosts of the glochidia are the pale chub *Zacco platypus* and freshwater gobies *Rhinogobius* spp.

[h]Natural hosts of the glochidia are the Biwa gudgeon *Pseudogobio zezera*, fork tail bullhead *Pseudobagrus nudiceps* and freshwater gobies *Rhinogobius* spp.

Biwa		Attached lakes or lagoons, creek	Paddy-fields, small stream, ditches	Rivers flowing into Lake Biwa	Category in the Red List (RL) by the Ministry of the Environment of Japan	Notes (Ecology)	References
Sublittoral (10–30 m deep)	Profundal (30 m deep-)				CR+EN: Critically Endangered VU: Vulnerable NT: Near Threatened DD: Data Deficient		
–	–	–	+				Mori (1938b), Kihira et al (2003)
+	+						Mori (1938b), Kuroda (1962), Nishino (1991), Kihira et al. (2003)
?	?						Mori (1938b), Kuroda (1962)

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Appendix 2.15

A list of Oligochaeta (Annelida, Clitellata) in Lake Biwa and its adjacent waters (by A. Ohtaka)

Taxonomic level	Scientific name	Endemicity	Distribution outside Lake Biwa	Life form	Lake Biwa		
				B: benthic, PA: planktonic, PE: pleuston, PR: parasitic	Littoral (0–10 m deep)	Sublittoral (10–30 m deep)	Profundal (30 m deep-)
Family	Lumbriculidae						
	Lumbriculus mukoensis Yamaguchi 1953	–		B	+		
Family	Naididae						
Subfamily	Naidinae						
	Chaetogaster diastrophus (Gruithuisen 1828)	–	Cosmopolitan	B	+		
	Syn. *Chaetogaster annandalei* Stephenson 1917			B	+		
	Chaetogaster diaphanus (Gruithuisen 1828)	–	holarctic	B	+		
	Chaetogaster limnaei von Baer 1827	–	Cosmopolitan	PR	+		
	Specaria josinae (Vejdovsky 1883)	–	holarctic	B	+	+	+
	Uncinais uncinata (Ørsted 1842)	–	Holarctic	B	+	+	+
	Ophidonais serpentina (Müller 1773)	–	Cosmopolitan	B	+		
	Nais communis Piguet 1906	–	Cosmopolitan	B	+		
	Nais variabilis Piguet 1906	–	Cosmopolitan	B			
	Nais bretscheri Michaelsen 1899	–	Cosmopolitan	B	+		
	Nais pardalis Piguet 1906	–	Cosmopolitan	B	+		
	Nais barbata Müller 1773	–	Holarctic	B	+		
	Allonais pectinata (Stephenson 1910)	–	Asia, Australia, Africa	B	+		
	Haemonais waldvogeli Bretscher 1900	–	Cosmopolitan	B	+		

Lake Biwa		Attached lakes or lagoons, creek	Paddyfields, small stream, ditches	Rivers flowing into Lake Biwa	Notes (Ecology)	References
Pelagic	Unknown				Hosts (intermediate, additional) (if parasitic)	
		+				Torii and Ohtaka (2007)
		+				Ohtaka (1993), Ohtaka and Nishino (1995), Nihsino et al. (1999)
						Stephenson (1917)
		+				Ohtaka and Nishino (1995), Nisino et al. (1999)
					Radix	Ohtaka and Nishino (1995), Nisino et al. (1999)
		+				Ohtaka and Nishino (1995), Nishino et al. (1999)
						Ohtaka and Nishino (1995), Nishino et al. (1999)
		+				Ohtaka and Nishino (1995, 1999), Nisino et al. (1999)
		+				Ohtaka and Nishino (1995), Nishino et al. (1999)
		+				Ohtaka and Nishino (2006)
		+				Ohtaka (1993), Ohtaka and Nishino (1995), Nishino et al. 1999)
		+				Ohtaka (1993), Ohtaka and Nishino (1995), Nishino et al. (1999)
						Ohtaka (1993), Ohtaka and Nishino (1995), Nishino et al. (1999)
		+				Ohtaka and Nishino (2006)
		+				Ohtaka and Nishino (1999), Nishino et al. (1999)

(continued)

Appendix 2.15
(continued)

Taxonomic level	Scientific name	Endemicity	Distribution outside Lake Biwa	Life form	Lake Biwa		
				B: benthic, PA: planktonic, PE: pleuston, PR: parasitic	Littoral (0–10 m deep)	Sublittoral (10–30 m deep)	Profundal (30 m deep-)
	Slavina appendiculata (d'Udekem1855)	–	Cosmopolitan	B	+	+	+
	Vejdovskyella (*Vejdovskyella*) *simplex* Liang 1958	–	China, Russia, Japan	B	+	+	+
	Arcteonais lomondi (Martin1907)	–	Eupope, N. America, Asia	B	+	+	
	Ripistes parasita (Schmidt 1847)	–	Europe, Asia	B	+		
	Stylaria fossularis Leidy 1852	–	Asia	B	+		
	Syn. *Stylaria lacustris* Linnaeus 1767			B	+		
	Stephensoniana trivandrana (Aiyer 1926)	–	Asia, Africa	B	+		
	Branchiodrilus hortensis (Stephenson 1910)	–	Asia, Australia, Africa	B			
	Dero digitata (Müller 1773)	–	Cosmopolitan	B	+	+	
	Dero dorsalis Ferronniere 1899	–	Asia, Europe	B			
	Aulophorus furcatus (Müller 1773)	–	Cosmopolitan	B	+		
	Aulophorus flabelliger Stephenson 1931	–	Asia, Australia, Africa	B			
	Aulophorus tonkinensis (Vejdovsky 1894)	–	Asia, Africa	B			
	Pristina proboscidea Beddard 1896	–	Asia, Australia, south America	B	+		
	Pristina biserrata Chen 1940	–	Asia	B	+		
	Pristina aequiseta Bourne 1891	–	Cosmopolitan	B	+		
	Pristina longiseta Ehrenberg 1828	–	Cosmopolitan	B	+		
Subfamily	Rhyacodrilinae						

Lake Biwa		Attached lakes or lagoons, creek	Paddyfields, small stream, ditches	Rivers flowing into Lake Biwa	Notes (Ecology)	References
Pelagic	Unknown				Hosts (intermediate, additional) (if parasitic)	
		+				Ohtaka (1993) Ohtaka and Nishino (1995) Nishino et al. (1999)
		+				Ohtaka and Nishino (1995), Nishino et al. (1999)
		+				Ohtaka (1993), Ohtaka and Nishino (1995), Nishino et al. (1999)
		+				Ohtaka and Nisino (1999), Nisino et al. (1999)
		+				Ohtaka (1993), Ohtaka and Nishino (2006)
						Ohtaka and Nishino (1995), Nishino et al. (1999)
		+				Ohtaka and Nishino (1999), Nishino et al. (1999)
		+	+			Ohtaka and Nishino (1995), Nishino et al. (1999)
		+				Ohtaka and Nishino (2006)
		+				Ohtaka and Nishino (2006)
		+				Ohtaka and Nishino (2006)
		+				Ohtaka and Nishino (2006)
		+				Ohtaka and Nishino (2006)
		+				Ohtaka and Nishino (2006)
		+				Ohtaka and Nishino (2006)
		+				Ohtaka and Nishino (1995), Nishino et al. (1999)
		+				Ohtaka and Nishino (1995) Nishino et al. (1999)

(continued)

Appendix 2.15

(continued)

Taxonomic level	Scientific name	Endemicity	Distribution outside Lake Biwa	Life form	Lake Biwa		
				B: benthic, PA: planktonic, PE: pleuston, PR: parasitic	Littoral (0–10 m deep)	Sublittoral (10–30 m deep)	Profundal (30 m deep-)
	Rhyacodrilus hiemalis Ohtaka 1995	–	Japan	B	+	+	+
	Bothrioneurum vejdovskyanum Stolc 1886	–	Cosmopolitan	B	+	+	+
	Branchiura sowerbyi Beddard 1892	–	Cosmopolitan	B	+	+	+
	Syn. *Kawamuria japonica* Stephenson 1917	–		B			+
Subfamily	Tubifiicnae						
	Tubifex tubifex (Müller 1774)	–	Cosmopolitan	B		+	+
	Teneridrilus mastix (Brinkhurst 1978)	–	Circum Pacific	B	+	+	+
	Limnodrilus hoffmeisteri Claparède 1862	–	Cosmopolitan	B	+	+	+
	Limnodrilus claparedianus Ratzel 1868	–	Cosmopolitan	B	+		
	Limnodrilus profundicola (Verrill 1871)	–	Cosmopolitan	B		+	+
	Limnodrilus grandisetosus Nomura 1932	–	Asia	B	+	+	+
	Limnodrilus amblysetus Brinkhurst et al. 1990	–	China, Japan	B	+		
	Embolocephalus yamaguchii (Brinkhurst 1971)	–	Japan	B	+	+	+
	Syn. *Peloscolex yamaguchii* Brinkhurst 1971			B	+		
	Ilyodrilus templetoni (Southern 1909)	–	Cosmopolitan	B	+	+	

Lake Biwa		Attached lakes or lagoons, creek	Paddyfields, small stream, ditches	Rivers flowing into Lake Biwa	Notes (Ecology)	References
Pelagic	Unknown				Hosts (intermediate, additional) (if parasitic)	
						Ohtaka (1995), Ohtaka and Nishino (1995), Ohtaka and Kikuchi (1997), Nishino et al. (1999)
		+				Ohtaka and Nishino (1995), Nishino et al. (1999)
		+	+			Ohtaka (1993), Ohtaka and Nishino (1995, 1999, 2006), Nishino et al. (1999)
						Stephenson (1917)
						Ohtaka and Nishino (1999), Nishino et al. (1999)
						Ohtaka and Nishino (1995, 1999), Nishino et al. (1999)
		+				Ohtaka (1993), Ohtaka and Nishino (1995), Ohtaka and Kikuchi (1997), Nishino et al. (1999)
						Ohtaka (1993), Ohtaka and Nishino (1995), Nishino et al. (1999)
						Ohtaka (1992), Ohtaka and Nishino (1995), Ohtaka (1993), Nishino and Ohtaka (1999)
		+				Ohtaka (1993), Ohtaka and Nishino (1995), Nishino et al. (1999)
						Ohtaka and Nishino (1999), Nishino et al. (1999)
		+				Ohtaka (1994), Ohtaka and Nishino (1995), Nishino et al. (1999)
						Brinkhurst (1971)
		+				Ohtaka and Nishino (2006)

(continued)

Appendix 2.15
(continued)

Taxonomic level	Scientific name	Endemicity	Distribution outside Lake Biwa	Life form	Lake Biwa		
				B: benthic, PA: planktonic, PE: pleuston, PR: parasitic	Littoral (0–10 m deep)	Sublittoral (10–30 m deep)	Profundal (30 m deep-)
	Aulodrilus limnobius Bretscher 1899	–	Cosmopolitan	B	+	+	+
	Aulodrilus japonicus Yamaguchi 1953	–	Holarctic	B	+	+	+
	Aulodrilus pigueti Kowalewski 1914	–	Cosmopolitan	B	+		
Family	Phreodrilidae						
	Astacopsidrilus ryuteki Martin and Ohtaka 2008	–	Japan	B			+
Family	Moniligastridae						
	Drawida hattamimizu Hatai 1930	–	Japan	B			+
Family	Criodrilidae						
	Biwadrilus bathybates (Stephenson 1917)	–	Japan	B	+		
	Syn. *Criodrilus bathybates* Stephenson 1917			B			+
Family	Lumbricidae						
	Helodrilus hachiojii Blakemore 2007	–	Japan	B			

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Lake Biwa		Attached lakes or lagoons, creek	Paddyfields, small stream, ditches	Rivers flowing into Lake Biwa	Notes (Ecology)	References
Pelagic	Unknown				Hosts (intermediate, additional) (if parasitic)	
		+				Ohtaka and Nishino (1995), Nishino et al. (1999)
		+				Ohtaka and Nishino, (1995) Nishino et al. (1999)
		+				Ohtaka (1993), Ohtaka and Nishino (1995), Nishino et al. (1999)
					? Introduced	Martin and Ohtaka (2008)
			+			
						Ohtaka (1993), Ohtaka and Nishino (1995), Blakemore (2003, 2008)
						Stephenson (1917)
			+			Blakemore (2007)

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Appendix 2.16

A list of Hirudinea in Lake Biwa and its adjacent waters (by T. Itoh)

Taxonomic level	Scientific name	Endemicity	Distribution outside Lake Biwa	Life form	Lake Biwa		
				B: benthic, PA: planktonic, PE: pleuston, PR: parasitic	Littoral (0–10 m deep)	Sublittoral (10–30 m deep)	Profundal (30 m deep-)
Family	Hirudinidae						
	Hirudo nipponia Whitman 1886	–		PR			
Family	Haemopidae						
	Whitmania laevis (Baird 1869)	–	Japan (Honshu: Chiba near Tateyama Bay); China (Si-Dong-Ding, Tai-Hu)	B			
	Whitmania pigra (Whitman 1884)	–	China (Tong-Dong-Ding creek, Tai-Hu); Sino-Japanese region	B	+	?	?
Family	Salifidae						
	Barbronia weberi formosana (Oka 1929)	–	Japan (Honshu: Kyoto); Nepal and China (*B. weberi*)	B	+	?	?
	Odontobdella blanchardi (Oka 1910)	–	Japan (Honshu: Kyoto); China; Sino-Japanese region	B			
Family	Erpobdellidae						
	Erpobdella octoculata (Linnaeus 1758)	–	Sino-Japanese region	B			
	Erpobdella testacea (Savigny 1822)	–	Sino-Japanese region	B			
	Dina lineata (Müller 1774)	–	Europe; Palaearctic region	B			
	Dina japonica (Pawlowski 1962)	–		B			
Family	Cylicobdellidae						
	Mimobdella japonica Blanchard 1897	–	Japan (Shiga: Komatsu); Sino-Japanese region	B			

Lake Biwa		Attached lakes or lagoons, creek	Paddyfields, small stream, ditches	Rivers flowing into Lake Biwa	Notes (Ecology)	References
Pelagic	Unknown				Hosts(intermediate, additional) (if parasitic)	
	+					Oka (1917b)
	+					Oka (1917b)
?			+			Nishino (1993), Oka (1917b), Sawyer (1986)
?				+		Nesemann (1995)
	+		+	+	Gravel and under stone outside the water (include water line), eulittoral of rivers and streams	Nesemann (1995), Oka (1917b), Sawyer (1986)
	+					Oka (1917b), Sawyer (1986)
	+	+		+		Nishino (1993), Sawyer (1986)
	+	+		+		Nishino (1993)
	+	+		+		Nesemann (1995), Oka (1917b)
	+					Oka (1917b), Sawyer (1986)

(continued)

Appendix 2.16
(continued)

Taxonomic level	Scientific name	Endemicity	Distribution outside Lake Biwa	Life form	Lake Biwa		
				B: benthic, PA: planktonic, PE: pleuston, PR: parasitic	Littoral (0–10 m deep)	Sublittoral (10–30 m deep)	Profundal (30 m deep-)
Family	Glossiphoniidae						
	Glossiphonia lata (Oka 1910)	–	China; Sino-Japanese region	B			
	Glossiphonia complanata (Linnaeus 1758)	–		B	+	?	?
	Placobdella ornata (Verrill 1872)	–	China; North America; Canada; Mexico	PR			
	Hemiclepsis marginata (Müller 1774)	–	China; Sino-Japanese region; Indian region; Europe; Palaearctic region	PR			
	Batracobdella kasmiana (Oka 1910)	–	Japan (Honshu: Kasumigaura, Owari, Bizen), China	PR			
	Helobdella stagnalis (Linnaeus 1758)	–		B			
	Ancyrobdella smaragdina (Oka 1910)	–	Japan (Honshu: Kyoto; Shikoku: Kochi)	B			
	Ancyrobdella biwae Oka 1917	+		B	?	?	+

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Lake Biwa		Attached lakes or lagoons, creek	Paddyfields, small stream, ditches	Rivers flowing into Lake Biwa	Notes (Ecology)	References
Pelagic	Unknown				Hosts(intermediate, additional) (if parasitic)	
	+				Attached to stones or water grasses	Oka (1917b), Sawyer (1986)
?		+				Nishino (1993), Oka (1917b)
	+	+	+		Freshwater turtles	Autrum (1936), Oka (1917b), Soos (1969), Yang (1996)
	+				Freshwater turtle (*Damonia reevesii*), frogs (both adults and larvae) and fishes (Carp)	Nishino (1993), Oka (1917b), Sawyer (1986)
	+				Freshwater bivalves (in shell) (*Anodonta woodiana woodiana*, *Anodonta* sp., *Unio douglasiae* and *Dipsas* sp.)	Autrum (1936), Oka (1917b), Sawyer (1986)
	+					Oka (1917b)
	+		+	+	Bivalves (family Unionidae)	Nesemann (1997), Oka (1917b), Sawyer (1986)
?					Bottom of Lake Biwa (80 m)	Autrum (1936), Nagao (1967), Nesemann (1997), Nishino (1993), Oka (1917a, b), Oka (1927), Oka and Nagao (1965), Sawyer (1986), Soos (1969)

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Appendix 2.17

A list of Cladocera (Crustacea, Branchiopoda) in Lake Biwa and its adjacent waters (by S. Tanaka)

Taxonomic level	Scientific name	Japanese name	Endemicity	Lifestyle Pl: plankton, M: meiobenthos, Ph: phytalfauna	Pelagic	Littoral zone and attached lake
Family	Sididae					
	Sida crystallina (O. F. Müller)	Shida		Ph		+
	Diaphanosoma macrophthalma Korovchinsky et Mirabdullaev	Ome-onaga-mijinko		Pl	+	
Family	Holopediidae					
	Holopedium gibberum Zaddach	Horo-mijinko		Pl	+	
Family	Daphniidae					
	[a]*Daphnia longispina* (O. F. Müller)	Harinaga-mijinko		Pl		+
	[b]*Daphnia biwaensis* Uéno	Biwa-mijinko	En	Pl	+	
	Daphnia galeata Sars	Kabuto-mijinko		Pl	+	
	Daphnia ambigua Scourfield	Magire-mijinko		Pl		+
	Scapholeberis kingi Sars			Pl		+
	Simocephalus mixtus Sars	Okame-mijinko		Ph		+
	Syn. *Simocephalus vetulus* (O. F. Müller)					
	Simocephalus exspinosus (De Geer)	Toge-okame-mijinko		Ph		+
	Simocephalus serrulatus (Koch)	Togari-okame-mijinko		Ph		+
	Ceriodaphnia cornuta Sars	Togari-nekoze-mijinnko		Pl		+
	Ceriodaphnia pulchella Sars	Hime-nekoze-mijinko		Pl		+
	Ceriodaphnia dubia Richard	Nise-nekoze-mijinko		Pl		+
	Ceriodaphnia quadrangula (O. F. Müller)	Nekoze-mijinko				+
Family	Moinidae					
	Moina macrocopa (Straus)	Tama-mijinko		Pl		+
	Moina micrura Kurz	Sukashi-tama-mijinko		Pl		+

(continued)

Appendix 2.17

(continued)

Taxonomic level	Scientific name	Japanese name	Endemicity	Lifestyle	Pelagic	Littoral zone and attached lake
				Pl: plankton, M: meiobenthos, Ph: phytalfauna		
Family	Ilyocryptidae					
	Ilyocryptus spinifer Herrick	Toge-futookebuka-mijinko		M		+
	Ilyocryptus cuneatus Stifter			M		+
	[a]*Ilyocryptus agilis* Kurz			M		+
Family	Macrothricidae					
	Macrothrix rosea (Liévin)	Kebuka-mijinko		Ph		+
	Macrothrix spinosa King	Toge-kebuka-mijinko		Ph		+
Family	Bosminidae					
	Bosmina longirostris (O. F. Müller)	Zo-mijinko		Pl	+	+
	Bosmina fatalis Burckhardt	Nisezo-mijinko		Pl	+	+
	Bosminopsis deitersi Richard	Zo-mijinko-modoki		Pl		+
Family	Eurycercidae					
	[b]*Eurycercus nipponica* Tanaka et Fujita			Ph		+
Family	Chydoridae					
	Camptocercus rectirostris Schödler	Hirata-mijinko		Ph		+
	Acroperus harpae (Baird)	Funazoko-mijinko		Ph		+
	Graptoleberis testudinaria (Fischer)	Hirohashi-mijinko		Ph		+
	Kurzia latissima (Kurz)			Ph		+
	Leydigia leidigi (Leydig)	Hiroo-mijinko		Ph		+
	Leydigia acanthocercoides (Fischer)	Toge-hiroo-mijinko		Ph		+
	Leydigia ciliata (Gauthier)	Kaku-toge-hiroo-mijinko		Ph		+
	Alona affinis (Leydig)	Oshikaku-mijinko		Ph		+
	Alona quadrangularis (O. F. Müller)	Shikaku-mijinko		Ph		+
	Alona guttata Sars	Mon-shikaku-mijinko		Ph		+
	Alona costata Sars	Osuji-shikaku-mijinko		Ph		+
	Alona elegans Kurz			Ph		+
	Alona intermedia Sars			Ph		+

(continued)

Appendix 2.17

(continued)

Taxonomic level	Scientific name	Japanese name	Endemicity	Lifestyle (Pl: plankton, M: meiobenthos, Ph: phytalfauna)	Pelagic	Littoral zone and attached lake
	Coronatella rectangula (Sars)	Koshikaku-mijinko		Ph		+
	Karualona karua (King)	Nise-shikaku-mijinko		Ph		+
	Leberis diaphanus (King)	Sukashi-shikaku-mijinko		Ph		+
	Notoalona globulosa (Daday)			Ph		+
	Oxyurella tenuicaudis (Sars)			Ph		+
	Monospirus dispar Sars	Hitotsume-maru-mijinko		M		+
	Dunhevedia crassa King			Ph		+
	Disparalona rostrata (Koch)	Hashi-shikaku-mijinko-modoki		Ph		+
	Disparalona hamata (Birge)	Kagi-hashi-mijinko		Ph		+
	Picripleuroxus laevis (Sars)			Ph		+
	Pleuroxus trigonellus (O. F. Müller)	Hashi-mijinko		Ph		+
	Pleuroxus uncinatus Baird			Ph		+
	Alonella excisa (Fischer)	Shikaku-mijinko-modoki		Ph		+
	Epohemeroporus barroisi (Richard)			Ph		+
	Chydorus sphaericus Kurz	Maru-mijinko		Ph, M		+
	Pseudochydorus globosus (Baird)			M		+
Family	Leptodoridae					
	Leptodora kindti (Focke)	Noro		Pl	+	

[a]Presence in the lake needs to be confirmed
[b]Validity of the species needs further investigation
[c]This list is based on Table 3 of Tanaka et al (2004)

Reference

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Appendix 2.18

A list of Copepoda (Crustacea, Maxillopoda) in Lake Biwa and its adjacent waters (by K. Kawabata)

Taxonomic level	Scientific name	Lake Biwa			Rivers flowing into Lake Biwa	References
		Pelagic	Littoral	Profundal		
Order	Cyclopoida					
Family	Cyclopidae					
	Macrocyclops albidus (Jurine 1820)		+			Ishida (1993)
	Eucyclops speratus (Lilljeberg 1901)		+			Ishida and Hiruta (1999)
	Eucyclops biwensis Ishida 1998		+			Ishida (1998)
	Paracyclops fimbriatus (Fischer 1853)		+			Ishida (1993)
	Paracyclops poppei (Rehberg 1880)		+			Ishida (1993)
	Paracyclops affinis (Sars 1863)		+			Ishida (1993)
	Cyclops kikuchii Smirnov 1932	+				Ishida (2002)
	Cyclops strenuus Fischer 1851		+			Ishida (1993)
	Acanthocyclops vernalis (Fischer 1853)		+			Ishida (2002)
	Acanthocyclops robustus (Sars 1863)		+			Ishida (2002)
	Diacyclops bicuspidatus (Claus 1857)		+			Ishida (1993)
	Microcyclops varicans (Sars 1863)		+			Ishida (2002)
	Mesocyclops pehpeiensis Hu 1943		+			Ishida (2002)
	Mesocyclops dissimilis Defaye et Kawabata 1993	+				Defaye and Kawabata (1993)
Order	Calanoida					
Family	Diaptomidae					
	Eodiaptomus japonicus (Burckhardt 1913)	+				Kiefer (1932)
Order	Harpacticoida					
Family	Ameiridae					
	Nitocra pietschmanni (Chappuis 1934)		+			Ishida and Kikuchi (2000)
Family	Canthocamptidae					
	Canthocamptus iaponicus Brehm 1927			+		Ishida and Kikuchi (1999)
	Canthocamptus kitaurensis Kikuchi 1999		+			Ishida and Kikuchi (1999)
	Canthocamptus macrosetifer Ishida 1999		+			Ishida and Kikuchi (1999)

(continued)

Appendix 2.18
(continued)

Taxonomic level	Scientific name	Lake Biwa			Rivers flowing into Lake Biwa	References
		Pelagic	Littoral	Profundal		
	Canthocamptus semicirculus Kikuchi 1994		+			Kikuchi and Ishida (1994)
	Canthocamptus resupinatus Ishida 1994				+	Kikuchi and Ishida (1994)
	Canthocamptus tomikoae Ishida 1994				+	Kikuchi and Ishida (1994)
	Attheyella nakaii (Brehm 1927)				+	Ishida (1989)
	Attheyella coiffaiti Chappuis 1958				+	Ishida (1989)
	Attheyella paucisetosa Chan et Kim 1992				+	Ishida and Kikuchi (2000)
	Attheyella crassa (Sars 1862)				+	Ishida (1989)
	Attheyella byblis Chan et Kim 1992				+	Ishida and Kikuchi (2000)
	Elaphoidella grandidieri (Guerne et Richard 1893)		+			Ishida (1993)
	Moraria varica (Graeter 1911)				+	Ishida (1989)
	Bryocamptus zschokkei (Schmeil 1893)				+	Ishida (1989)
	Bryocamptus nivalis (Willey 1925)				+	Ishida and Kikuchi (2000)
Family	Cletodidae					
	Limnocletodes behningi Borutzky 1926		+			Ishida (1993)
	Onychocamptus mohammed (Blanchard et Richard 1891)		+			Ishida (1993)

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Appendix 2.19

A list of Ostracoda (Crustacea) in Lake Biwa (by R. J. Smith)

Taxonomic level	Scientific name	Endemicity	Distribution outside Lake Biwa	Life style	Lake Biwa				References
				B: benthic, NB: Neckto-benthic	Interstitial (0 m)	Littoral (0–10 m deep)	Sublittoral (10–30 m deep)	Profundal (30 m + deep)	
Family	Candonidae								
	Candonopsis tenuis (Brady 1886)	–	Australia, S.E. Asia, Samoa and Tonga	B		+			Smith and Janz (2008)
	Fabaeformiscandona akaina Smith et Janz 2008	?		B			+	+	Smith and Janz (2008)
	Fabaeformiscandona condylea Smith et Janz 2008	?		B	+				Smith and Janz (2008)
	Fabaeformiscandona dolabella Smith et Janz 2008	?		B		+			Smith and Janz (2008)
	Fabaeformiscandona japonica (Okubo 1990)	–	Japan, Spain	B		+	+		Smith and Janz (2008)
	Fabaeformiscandona myllaina Smith et Kamiya 2007	–	Japan	B		+	+	+	Smith and Janz (2008)
	Fabaeformiscandona nishinoae Smith et Janz 2008	?		B				+	Smith and Janz (2008)
	Fabaeformiscandona okuboi Smith et Janz 2008	?		B		+	+		Smith and Janz (2008)
	Fabaeformiscandona paterea Smith et Janz 2008	?		B		+	+	+	Smith and Janz (2008)
	Fabaeformiscandona pedana Smith et Janz 2008	?		B		+			Smith and Janz (2008)

(continued)

Appendix 2.19
(continued)

Taxonomic level	Scientific name	Endemicity	Distribution outside Lake Biwa	Life style	Lake Biwa				References
				B: benthic, NB: Neckto-benthic	Interstitial (0 m)	Littoral (0–10 m deep)	Sublittoral (10–30 m deep)	Profundal (30 m + deep)	
	Fabaeformiscandona pedana Smith et Janz 2007	–	Japan	B		+	+		Smith and Janz (2008)
	Fabaeformiscandona velifera Smith et Janz 2008	?		B		+			Smith and Janz (2008)
	Fabaeformiscandona yajimae Smith et Janz 2008	?		B		+			Okubo (2004), Smith and Janz (2008)
	Pseudocandona abei Smith et Janz 2008	–	Japan	B		+			Smith and Janz (2008)
	Pseudocandona sarsi (Hartwig 1899)	–	Europe, Japan	B		+			Smith and Janz (2008)
	Cypria matzkeae Smith et Janz 2008	?		NB		+	+	+	Smith and Janz (2008)
	Physocypria biwaensis (Okubo 1990)	?		NB		+	+	+	Okubo (1990, 2004), Smith and Janz (2008)
	Physocypria nipponica Okubo 1990	–	Japan	NB		+			Okubo (2004), Smith and Janz (2008)
Family	Cyprididae								
	Cypretta seurati (Gauthier 1929)	–	Circumtropical regions and circum-Mediterranean areas	NB		+			Smith et al. (2011)
	Bradleytriebella lineata (Victor & Fernando 1981)	–	Philippines, Sudan, Thailand	NB		+			Okubo (2004), Smith et al. (2011)
	Bradleycypris vittata (Sars 1903)	–	Asia	NB		+			Smith et al. (2011)
	Cypris sp.[a]	–	India, Asia, Africa	NB		+			Smith et al. (2011)
	Cypridopsis vidua (Mueller 1776)	–	Cosmopolitan	NB		+	+		Okubo (2004), Smith et al. (2011)

	Heterocypris incongruens (Ramdohr 1808)	–	Cosmopolitan	NB		+			Smith et al. (2011)
	Chrissia formosa (Klie 1938)	–	East Asia	NB		+			Smith et al. (2011)
	Ilyodromus intermedius Okubo 2011	–	Japan	NB		+			Smith et al. (2011)
	Stenocypris hislopi Ferguson 1969	–	Asia	NB		+	+		Okubo (2004), Smith et al. (2011)
	Stenocypris malayica Victor et Fernando 1981	–	Malayisa, Oceania, Japan	NB		+			Smith et al. (2011)
Family	Ilyocyprididae								
	Ilyocypris salebrosa Stepanaitys 1960	–	Canada, Italy, Serbia, Turkey, Far-East Russia, China, South Korea, Japan	NB		+	+		Smith et al. (2011)
Family	Cytherideidae								
	Cytherissa lacustris (Sars 1863)	–	Europe, Asia and North America	B			+	+	Okubo (2004), Smith and Janz (2009)
Family	Limnocytheridae								
	Limnocythere stationis Várva 1891	–	Europe, Russia (including Siberia) and Africa	B		+	+		Smith and Janz (2009)
	Limnocythere kamiyai Smith et Janz 2009	?		B		+			Smith and Janz (2009)
	Limnocythere fude Smith et Janz 2009	?		B		+			Smith and Janz (2009)
	Limnocythere levigatus Smith et Janz 2009	?		B		+			Smith and Janz (2009)
	Limnocythere cyphoma Smith et Janz 2009	?		B		+	+		Smith and Janz (2009)
	Metacypris digitiformis Smith et Hiruta 2004	–	Japan	B		+			Smith and Janz (2009)
Family	Darwinulidae								

(continued)

Appendix 2.19

(continued)

Taxonomic level	Scientific name	Endemicity	Distribution outside Lake Biwa	Life style	Lake Biwa				References
				B: benthic, NB: Neckto-benthic	Interstitial (0 m)	Littoral (0–10 m deep)	Sublittoral (10–30 m deep)	Profundal (30 m + deep)	
	Darwinula stevensoni (Brady et Robertson 1870)	–	Cosmopolitan	B		+	+		Okubo (2001), Smith and Janz (2009)
	Vestalenula cylindrica (Straub 1952)	?		B		+			Smith and Janz (2009)
	Vestalenula lundi (Neale et Victor 1978)	–	Sri Lanka, Japan	B	+				Smith and Janz (2009)
	Vestalenula molopoensis (Martens et Rossetti 1997)	–	South Africa, Thailand, Japan	B	+				Smith and Janz (2009)

[a]Typically called "Cypris subglobosa Sowerby, 1840", although this name is already taken by a different fossil species. This living species is therefore currently unnamed

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Appendix 2.20

A list of Branchiura and Malacostraca (Crustacea) in Lake Biwa and its adjacent waters (by M. Nishino)

Taxonomic level	Scientific name	Japanese name	Endemicity	Distribution	Origin (introduced)	
					Host species	References
Class	Branchiura					
Order	Arguilla					
Family	Argulidae					
	Argulus sp.		–			
Class	Malacostraca					
Order	Amphipoda					
Family	Gammaridae					
	Crangonyx floridanus	furorida-mamizuyokoebi		USA		Nishino (2007)
	Jesogammarus (*Annanogammmarus*) *annandalei*	annandale-yokoebi	+			Narita (1976), Morino (1985), Morino and Martens (1994)
	Jesogammarus (*Annanogammmarus*) *naritai*	narita-yokoebi	+			Morino (1985), Nishino (1993)
Family	Corophiidae					
	Kamaka biwae	Biwa-kamaka	+			Ueno (1943), Nishino (1993)
Order	Isopoda					
Family	Cymothoidae					
	Ichthyoxenus japonensis Richardson, 1913			Japan	Acheilognathus spp.	Ishii (1916a)
	Ichthyoxenus opisthopterygium Ishii, 1916		?	Lake Biwa	Acheilognathus tabira	Ishii (1916a, b)
Family	Corallanidae					
	Tachea chinensis	ebinokoban	–	Japan		Nishino (1993)
Family	Asellidae					
	Asellus higendorfii	mizumushi	–	Japan		Nishino (1993)

(continued)

Appendix 2.20
(continued)

Taxonomic level	Scientific name	Japanese name	Endemicity	Distribution	Origin (introduced)	
					Host species	References
Order	Decapoda					
Family	Atyidae					
	Paratya compressa compressa	numaebi	–	Japan		Nishino (1981), Ikeda et al. (1994), Nishino (1993)
	Neocaridina denticulata denticulata	minami-numaebi	–	Westen Japan		Annandale (1922)
	Neocaridina spp.	kawarinumaebi-zoku			China ?	Nishino and Niwa (2004)
Family	Palaemonidae					
	Palaemon paucidens	sujiebi	–	Japan, Sakhalin		Nishino (1980, 1984)
	Macrobrachium nipponense	tenagaebi	–	Honshu, Shikoku, Kyushu	Lake Kasumiga-ura ?	Kobayashi and Ohno (1957), Nishino (1993), Harada & Nishino (2004)
Family	Astacidae					
	Procambarus clarkii	amerika-zarigani			USA	Nishino (1993, 2002)
Family	Grapsidae					
	Eriocheir japonicus	mokuzugani	–	Japan		Nishino (1993)
Family	Potamonidae					
	Geothelphusa dehaani	sawagani	–	Western Japan		Nishino (1993)

*Kobayashi and Ohno (1957) insisted that *M. nipponense* in Lake Biwa was transplanted from Lake Kasumigaura during 1918–1923, but Harada and Nishino (2004) reported that this species was recorded in the lake from the mid-1800s, based on the old documents in Edo and Meiji Era.

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Appendix 2.21

A list of Odonata (Hexapoda) in Lake Biwa and its adjacent waters (by K. Masunaga)

Taxonomic level	Scientific name	Japanese name	Eendemicity		Habitat			
				Origin of introduced species	Lake Biwa	Attached lake	River, water-way, ditches	Category in the Red List (RL) by the Ministry of the Environment of Japan (2007): CR + EN: Critically Endangered, VU: Vulnerable, NT: Near Threatened, DD: Data Deficient
Family	Calopterygidae							
	Calopteryx atrata Selys 1853	haguro-tonbo					+	
Family	Lestidae							
	Lestes japonicus Selys 1883	kobane-ao-itotonbo				+		CR+EN
	Lestes sponsa (Hansemann 1823)	ao-itotonbo				+		
	Lestes temporalis Selys 1883	o-ao-itotonbo				+		
	Indolestes peregrinus (Ris 1916)	hosomi-otsunen-tonbo				+		
Family	Coenagrionidae							
	Mortonagrion selenion (Ris 1916)	morton-itotonbo				+		NT
	Cercion calamorum calamorum (Ris 1916)	kuro-itotonbo			+	+		
	Cercion hieroglyphicum Brauer 1865	sesuji-itotonbo			+	+		
	Cercion sexlineatum (Selys 1883)	musuji-itotonbo			+	+		
	Cercion sieboldii Selys 1876	o-itotonbo				+		
	Aciagrion migratum (Selys 1876)	hosomi-itotonbo				+		
	Ischnura asiatica Brauer 1865	ajia-itotonbo				+		
	Ischnura senegalensis (Rambur 1842)	aomon-itotonbo				+		

	Ceriagrion melanurum Selys 1876	ki-itotonbo				+		
Family	Platycnemididae							
	Copera annulata (Selys 1863)	monosashi-itotonbo				+		
Family	Aeshnidae					+		
	Anaciaeschna martini (Selys 1897)	marutan-yanma						
	Anax nigrofasciatus nigrofasciatus Oguma 1915	kurosuji-gin-yanma				+		
	Anax parthenope julius Brauer 1865	gin-yanma				+		
	Gynacantha japonica Bartenef 1909	katori-yanma				+		
	Aeschnophlebia anisoptera Selys 1883	neakayoshi-yanma				+		NT
	Aeschnophlebia longistigma Selys 1883	ao-yanma				+		
	Boyeria maclachlani (Selys 1883)	koshiboso-yanma					+	
Family	Cordulegastridae							
	Anotogaster sieboldii (Selys 1854)	oni-yanma					+	
Family	Gomphidae							
	Asisogomphus maacki (Selys 1872)	miyama-sanae					+	
	Asiagomphus melaenops (Selys 1854)	yama-sanae					+	
	Asiagomphus pryeri (Selys 1883)	kiiro-sanae					+	

(continued)

Appendix 2.21
(continued)

Taxonomic level	Scientific name	Japanese name	Eendemicity	Origin of introduced species	Habitat			Category in the Red List (RL) by the Ministry of the Environment of Japan (2007): CR + EN: Critically Endangered, VU: Vulnerable, NT: Near Threatened, DD: Data Deficient
					Lake Biwa	Attached lake	River, water-way, ditches	
	Gomphus postocularis Selys 1869	hon-sanae			+		+	
	Stylurus annulatus (Dijakonov 1926)	osaka-sanae			+			NT
	Stylurus oculatus Asahina 1949	megane-sanae			+			NT
	Sieboldius albardae Selys 1886	ko-oni-yanma			+		+	
	Ictinogomphus pertinax (Selys 1854)	taiwan-uchiwa-yanma				+		
	Sinictinogomphus clavatus (Fabricius 1775)	uchiwa-yanma			+			
	Davidius nanus (Selys 1869)	davido-sanae					+	
	Stylogomphus suzukii (Matsumura 1926)	ojiro-sanae					+	
	Trigomphus interruptus (Selys 1854)	futasuji-sanae				+		
	Trigomphus ogumai Asahina 1949	oguma-sanae				+		VU
	Nihonogomphus viridis Oguma 1926	ao-sanae			+		+	
	Onychogomphus viridicostus (Oguma 1926)	onaga-sanae			+		+	
	Epitheca marginata (Selys 1883)	torafu-tonbo				+		

Family	Corduliidae							
	Epophthalmia elegans elegans (Brauer 1865)	oyama-tonbo			+	+		
	Macromia amphigena amphigena Selys 1871	koyama-tonbo					+	
Family	Libellulidae							
	Libellula quadrimaculata asahinai Schmidt 1957	yotsuboshi-tonbo				+		
	Lyriothemis pachygastra Selys 1878	harabiro-tonbo				+		
	Orthetrum albistylum speciosum (Uhler 1858)	shiokara-tonbo				+		
	Orthetrum japonicum japonicum (Uhler 1858)	shioya-tonbo				+		
	Orthetrum triangulare melania Selys 1883	o-shiokara-tonbo				+		
	Crocothemis servilia mariannae Kiauta 1983	shojo-tonbo				+		
	Deielia phaon (Selys 1883)	kofuki-tonbo				+		
	Sympetrum croceolum Selys 1883	ki-tonbo				+		
	Sympetrum eroticum eroticum (Selys 1883)	mayutate-akane				+		
	Sympetrum kunckeli (Selys 1884)	maiko-akane				+		
	Rhyothemis fuliginosa (Selys 1883)	cho-tonbo				+		
	Pantala flavescens (Fabricius 1798)	usubaki-tonbo				+		
	Pseudothemis zonata (Burmeister 1839)	koshiaki-tonbo				+		

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All references are depended on the Odonatological Society of Osaka (1998)

The Odonatological Society of Osaka, 1998. Dragonflies and Damaselflies (Insecta: Odonata) of Shiga Prefecture, Honshu, Japan. Research Report of the Lake Biwa Museum 10. Lake Biwa Museum, Kusatsu, Shiga. (in Japanese with English summary)

Appendix 2.22

A list of Ephemeroptera (Hexapoda) in Lake Biwa and its adjacent waters (by S. Ishiwata)

Taxonomic level	Scientific name	Lake inhabitant	Endemicity	Distribution outside Lake Biwa	Life form	Lake Biwa	
					B: benthic, PA: planktonic, PE: pleuston, PR: parasitic	Littoral (0-10m deep)	Sublittoral (10-30m deep)
Family	Leptophlebiidae						
	Choroterpes (*Euthraulus*) *altioculus* (Kluge 1984)	–	–	Japan (Honshu, Shikoku, Kyushu), Korea, China, Russia	B	+	–
	Paraleptophlebia japonica (Matsumura 1931)	–	–	Japan (Honshu, Shikoku, Kyushu), Korea, Russia	B	+	–
Family	Potamanthidae						
	Potamanthus (*Potamanthodes*) *formosus* (Eaton 1892)	–	–	Japan (Honshu, Shikoku, Kyushu), Korea, China, Vietnam, Thailand, Myanmar, Malaysia	B	+	–
	Potamanthus (*Potamanthus*) *huoshanensis* (Wu 1987)	?	–	Japan (Honshu), China	B	+	–
Family	Ephemeridae						
	Ephemera japonica (McLachlan 1875)	–	–	Japan (Hokkaido, Honshu, Shikoku, Kyushu), Russia	B	+	–
	Ephemera orientalis (McLachlan 1875)	+	–	Japan (Hokkaido, Honshu, Shikoku, Kyushu), Korea, China, Mongolia, Russia	B	+	–
Family	Polymitarcyidae						
	Ephoron limnobium (Ishiwata 1996)	+	+	Japan (Honshu)	B	+	–

Lake Biwa		Attached lakes or lagoons	Ditches	Rivers flowing into Lake Biwa	Notes (Habitat)	Notes (Ecology)	References
Profundal (30mdeep-)	Pelagic					Hosts(intermediate, additional) (if parasitic)	
–	–	–	–	+	Underside of rocks along margins larger streams and lakes near stream inlets		Ishiwata and Takemon (2005a)
–	–	–	–	+	Underside of rocks or among dead leaves in streams and lakes near stream inlets		Ishiwata and Takemon (2005a)
–	–	–	–	+	Under the stones in sandy bottom moderately to swift rivers, streams and lakes near stream inlets		Uéno (1928)
–	–	Paddy field	?	+			Ishiwata (2005)
–	–	–	–	+	In fines and gravel of cool streams		Takemon (1989)
–	–	+	–	+	In small fines and organic detritus in pools in streams or lakes		Takemon (1989)
–	–	–	–	–	In deposits of fines and gravels under rubble or rocks		Ishiwata and Nishino unpublished

(continued)

Appendix 2.22
(continued)

Taxonomic level	Scientific name	Lake inhabitant	Endemicity	Distribution outside Lake Biwa	Life form	Lake Biwa	
					B: benthic, PA: planktonic, PE: pleuston, PR: parasitic	Littoral (0-10m deep)	Sublittoral (10-30m deep)
Family	Caenidae						
	Caenis nishinoae (Malzacher 1996	+	?	Japan (Honshu)	B	+	–
Family	Ephemerellidae						
	Ephacerella longicaudata (Uéno 1928)	+	–	Japan (Honshu, Shikoku, Kyushu), Korea, Russia	B	+	–
	Ephemerella notata (Eaton 1887)	–	–	Japan (Honshu, Kyushu), Europe, Russia	B	+	–
	Ephemerella sp.	+	–		B	+	–
Family	Ameletidae						
	Ameletus sp.	–	–		B	+	–
	Ameletus montanus (Imanishi 1930)	–	–	Japan (Honshu, Kyushu), Korea	B	+	
Family	Baetidae						
	Baetis sahoensis (Gose 1980)	+	–	Japan (Hokkaido, Honshu, Shikoku, Kyushu)	B	+	–
	Baetis thermicus (Uéno 1931)	–	–	Japan (Hokkaido, Honshu, Shikoku, Kyushu, Okinawa Is.), Taiwan	B	+	–
	Cloeon dipterum (Linnaeus 1761)	+	–	Japan (Hokkaido, Honshu, Shikoku, Kyushu)	B	+	–

Lake Biwa		Attached lakes or lagoons	Ditches	Rivers flowing into Lake Biwa	Notes (Habitat)	Notes (Ecology)	References
Profundal (30mdeep-)	Pelagic					Hosts(intermediate, additional) (if parasitic)	
–	–	?	–	?	On well-sorted fine sediment substrates covered with CPOM and FPOM	Nymphs often covered with organic debris	Ishiwata and Nishino unpublished
–	–	–	–	+	On small fine sediments and gravel covered with CPOM and FPOM in quiet areas along stream margins and pools	Nymphs often covered with organic debris	Uéno (1928), Ishiwata and Nishino unpublished
–	–	–	–	+	Among living vegetation in slow-flowing streams		Ishiwata and Nishino unpublished
–	–	?	–	+	On or under rocks along margins		Ishiwata and Nishino unpublished
–	–	–	–	+	Stones and detritus along the margins of streams		Ishiwata and Nishino unpublished
	–	–	–	+	Stones and detritus along the margins of streams		Ishiwata and Takemon (2005a)
–	–	–	+	+	Along pond among decaying organic matter and stems of living aquatic macrophytes, but wide range of lotic habitats	Radix	Kobayashi (1989)
–	–	–	+	+	On coarse rocks of swift streams and lakes near stream inlets, but wide range of lotic habitats		Kobayashi (1989), Ishiwata and Nishino unpublished
–	–	+	+	+	Along pond among decaying organic matter, steams of living aquatic macrophytes, paddy field, temporally pool		Uéno (1928), Ishiwata and Takemon (2005a)

(continued)

Appendix 2.22
(continued)

Taxonomic level	Scientific name	Lake inhabitant	Endemicity	Distribution outside Lake Biwa	Life form	Lake Biwa	
					B: benthic, PA: planktonic, PE: pleuston, PR: parasitic	Littoral (0-10m deep)	Sublittoral (10-30m deep)
	Cloeon ryogokuense (Gose 1980)	+	–	Japan (Honshu, Kyushu),	B	+	–
	Labiobaetis atrebatinus orientalis (Kluge 1983)	+	–	Korea, Russia	B	+	–
	Procloeon sp.	+	?		B	+	–
Family	Siphlonuridae						
	Siphlonurus binotatus (Eaton 1892)	–	–	Japan (Honshu, Shikoku), Korea	B	+	–
	Siphlonurus sanukensis (Takahashi 1929)	–	–	Japan (Hokkaido, Honshu, Shikoku), China	B	+	–
Family	Isonychiidae						
	Isonychia (*Isonychia*) *japonica* (Ulmer 1919)	–	–	Japan (Hokkaido, Honshu, Shikoku, Kyushu), Korea, China, Russia	B	+	–
Family	Heptageniidae						
	Cinygmula hirasana (Imanishi 1935)	–	–	Japan (Honshu), Korea	B	+	–
	Ecdyonurus kibunensis (Imanishi 1936)	–	–	Japan (Honshu, Shikoku, Kyushu), Korea, Rrussia	B	+	–
	Ecdyonurus naraensis (Gose 1968)	+	–	Japan (Honshu)	B	+	–
	Ecdyonurus tobiironis (Takahashi 1929)	–	–	Japan (Honshu, Shikoku, Kyushu)	B	+	–
	Ecdyonurus yoshidae (Takahashi 1924)	+	–	Japan (Honshu, Shikoku, Kyushu)	B	+	–

Lake Biwa		Attached lakes or lagoons	Ditches	Rivers flowing into Lake Biwa	Notes (Habitat)	Notes (Ecology)	References
Profundal (30mdeep-)	Pelagic					Hosts(intermediate, additional) (if parasitic)	
–	–	–	–	+	?		
–	–	+	+	+	Among submerged aquatic plants in streams		Ishiwata and Nishino unpublished
–	–	?	–	+	Among submerged aquatic plants in streams, but wide range of lotic habitats		Ishiwata and Nishino unpublished
–	–	+	–	+	In quiet areas along stream margins and pools, temporally pool, and lakes near stream inlets		Ishiwata and Takemon (2005a)
–	–	+	–	+	Among organic detritus of quiet pool, flooded stream margins and lakes near stream inlets		Ishiwata and Nishino unpublished
–	–	–	–	+	On pebbles in rapidly flowing streams and lakes near stream inlets		Uéno (1928)
–	–	–	–	+	Under pebbles in slowly-flowing streamsand		Uéno (1959)
–	–	–	–	+	On gravel in flowing streams		Ishiwata and Nishino unpublished
–	–	–	–	+	On gravel in the swiftly flowing streams or in sandy bottom of lakes		Ishiwata and Nishino unpublished
–	–	–	–	+	On stones in shallow slowly-flowing streams		Uéno (1931)
–	–	–	–	+	On rocks along streams		Ishiwata and Nishino unpublished

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Appendix 2.23

A list of Plecoptera, Hemiptera, Megaloptera, Neuroptera and Coleoptera (Hexapoda) in Lake Biwa (by M. Nishino)

Taxonomic level	Scientific name	Japanese name	Endemicity	Distribution	Origin (introduced)	
						References
Order	Plecoptera					
Family	Perlidae					
	Neoperla geniculata (Pictet)	futatsume-kawagera	–	Littoral		Nishino (1992)
Order	Hemiptera					
Family	Aphelocheiridae					
	Aphelocheirus kawamurae Matsumura	kawamura-nabebutamushi	– (*)	Littoral		Esaki (1934)
Order	Megaloptera					
Family	Sialidae					
	Sialis mitsuhashii Okamoto	neguro-senburi	–	Littoral		Nishino (1992)
Family	Corydalidae					
	Parachauliodes continentalis v.d.Veele	tairikukurosuji-hebitonbo	–	Littoral		Nishino (1992)
Order	Neuroptera					
Family	Sisyridae					
	Sisyra sp.	mizukagero-zoku	–	Littoral		Nishino (1992)
Order	Coleoptera					
Family	Dytiscidae					
	Hydroglyphus japonicus (Sharp)	chibi-gengoro	–	Littoral		Nishino (1992)
	Rhantus pulverosus (Stephens)	hime-gengoro	–	Littoral		Nishino (1992)
	Hydaticus grammicus Germar	koshima-gengoro	–	Littoral		Nishino (1992)
Family	Hydrophilidae					
	Berosus signaticollis punctipennis Harold	gomafu-gamushi	–	Littoral		Nishino (1992)
Family	Psephenidae					
	Psephenoides japonicus Masuda	masuda-chibi-hiratadoromushi	–	Littoral		Nishino (1992)
	Mataeopsephus japonicus (Matsumura)	hiratadoromushi	–	Littoral		Nishino (1992)

(continued)

Appendix 2.23

(continued)

Taxonomic level	Scientific name	Japanese name	Endemicity	Distribution	Origin (introduced)	
						References
	Eubrianax ramicornis Kiesenwetter	maru-hiratadoromushi	–	Littoral		Nishino (1992)
Family	Curculionidae					
	Lissorhoptrus oryzophilus Kuschel	inemizu-zomushi	–	Littoral	North America	Nishino (1992)

*Recorded from Southern Lake Biwa, Lake Biwa Canal (Shiga and Kyoto) and Korea

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Appendix 2.24

A list of Chironomidae (Hexapoda) in Lake Biwa and its adjacent waters (by E. Inoue and T. Kobayashi)

Taxonomic level	Scientific name	Endemicity	Distribution outside Lake Biwa	Life form	Lake Biwa	
				B: benthic, PA: planktonic, PE: pleuston, PR: parasitic	Littoral (0–10 m deep)	Sublittoral (10–30 m deep)
Family	Chironomidae					
Subfamily	Chironominae					
Tribe	Chironomini					
	Chironomus (*Camptochironomus*) *biwaprimus* Sasa et Kawai 1987	–	Japan	B	+	–
	Chironomus (*Chironomus*) *circumdatus* (Kieffer 1916)	–	Europe, Japan, Oriental	B	+	–
	Chironomus (*Chironomus*) *flaviplumus* Tokunaga 1940	–	Japan	B	+	–
	Chironomus (*Chironomus*) *kiiensis* Tokunaga 1936	–	Japan, Oriental	B	+	–
	Chironomus (*Chironomus*) *nippodorsalis* Sasa 1979	–	Japan	B	+	–
	Chironomus (*Chironomus*) *nipponensis* Tokunaga 1939	–	Russia, Japan	B	+	–
	Chironomus (*Chironomus*) *plumosus* (Linnaeus 1758)	–	Holarctic	B	+	+
	Chironomus (*Chironomus*) *samoensis* Edwards 1928	–	Europe, Japan	B	+	–
	Chironomus (*Chironomus*) *yoshimatsui* Martin et Sublette 1972	–	Russia, Japan	B	+	–
	Cryptochironomus albofasciatus (Staeger 1840)	–	Europe, Japan	B	+	–
	Cryptotendipes fujiquartus Sasa 1985	–	Japan	B	+	–
	Demicryptochironomus vulneratus (Zetterstedt 1838)	–	Palaearctic	B	+	–
	Dicrotendipes nigrocephalicus Niitsuma 1995	–	Japan	B	+	–
	[Synonym]: *Dicrotendipes nervosus* (Staeger 1839) sensu Sasa and Kawai 1987 and Kawai et al. (2002)					
	Dicrotendipes niveicaudus (Kieffer 1921)	–	Europe, Japan	B	+	–
	Dicrotendipes pelochloris (Kieffer 1912)	–	China, Korea, Japan, Oriental, Australasian	B	+	–
	Einfeldia dissidens (Walker 1851)	–	Palaearctic, Oriental	B	+	–
	Endochironomus pekanus (Kieffer 1916)	–	Korea, Japan, Oriental	B	+	–

Lake Biwa		Attached lakes or lagoons, creek	Small stream, ditches	Rivers flowing into Lake Biwa	Notes (Ecology)	References
Profundal (30 m deep-)	Pelagic				Hosts (intermediate, additional) (if parasitic)	
–	–	?	?	?	?	Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987)
–	–	?	?	?	?	Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Sasa and Kawai (1987)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Kawai et al. (2002), Niitsuma (1995)
–	–	?	?	?	?	Sasa and Kawai (1987)
–	–	?	?	?	?	Kaneko et al. (2010), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Kawai et al. (2002)

(continued)

Appendix 2.24
(continued)

Taxonomic level	Scientific name	Endemicity	Distribution outside Lake Biwa	Life form	Lake Biwa	
				B: benthic, PA: planktonic, PE: pleuston, PR: parasitic	Littoral (0–10 m deep)	Sublittoral (10–30 m deep)
	Fissimentum sp.	?	?	B	+	–
	Glyptotendipes biwasecundus Sasa et Kawai 1987	–	Japan	B	+	–
	Glyptotendipes tokunagai Sasa 1979	–	Korea, Japan	B	+	–
	Harnischia angularis Albu et Bontnariuc 1966	–	Europe, China, Japan	B	+	–
	[Synonym]: *Harnischia biwacurtis* Kawai, Okamoto et Imabayashi 2002					
	[Synonym]: *Harnischia* sp. sensu Kawai et al. (2002)					
	Harnischia curtilamellata (Malloch 1915)	–	Holarctic, Oriental	B	+	–
	Harnischia ohmuraensis Kobayashi et Suzuki 1999	–	Japan	B	+	–
	Lipiniella moderata Kalugina 1970	–	Russia, Japan	B	+	–
	[Synonym]: *Chironomus fujiprimus* Sasa 1985					
	Microchironomus tener (Kieffer 1918)	–	Holarctic, Oriental, Australasian	B	+	–
	Microtendipes britteni (Edwards 1929)	–	Europe, Japan	B	+	–
	Microtendipes chloris (Meigen 1818)	–	Europe, Japan	B	+	–
	Nilothauma sasai Adam et Sæther 1999	–	Japan	B	+	–
	Parachironomus arcuatus Goetghebuer 1921	–	Palaearctic	B	+	–
	Paracladopelma camptolabis (Kieffer 1913)	–	Palaearctic	B	+	–
	Paratendipes albimanus (Meigen 1818)	–	Holarctic	B	+	–
	[Synonym]: *Paratendipes tamayubai* Sasa 1983					
	Polypedilum (*Pentapedilum*) *pseudotritum* Ree et Kim 1988	–	Korea, Japan	B	+	–
	Polypedilum (*Pentapedilum*) *tigrinum* Hashimoto 1983	–	Japan	B	+	–

Lake Biwa		Attached lakes or lagoons, creek	Small stream, ditches	Rivers flowing into Lake Biwa	Notes (Ecology)	References
Profundal (30 m deep-)	Pelagic				Hosts (intermediate, additional) (if parasitic)	
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Sasa and Kawai (1987)
–	–	?	?	?	?	Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010), Kawai et al. (2002)
–	–	?	?	?	?	Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kawai et al. (2002)

(continued)

Appendix 2.24

(continued)

Taxonomic level	Scientific name	Endemicity	Distribution outside Lake Biwa	Life form	Lake Biwa	
				B: benthic, PA: planktonic, PE: pleuston, PR: parasitic	Littoral (0–10 m deep)	Sublittoral (10–30 m deep)
	Polypedilum (*Pentapedilum*) *tritum* (Walker 1856)	–	Holarctic	B	+	–
	Polypedilum (*Polypedilum*) *albicorne* (Meigen 1838)	–	Holarctic	B	+	–
	Polypedilum (*Polypedilum*) *asakawaense* Sasa 1980	–	Japan	B	+	–
	Polypedilum (*Polypedilum*) *kyotoense* (Tokunaga 1938)	–	Japan	B	+	–
	Polypedilum (*Polypedilum*) *nubeculosum* (Meigen 1804)	–	Europe, Japan	B	+	–
	Polypedilum (*Polypedilum*) *nubifer* (Skuse 1889)	–	Holarctic	B	+	–
	Polypedilum (*Polypedilum*) *tamanigrum* Sasa 1983	–	Japan	B	+	–
	Polypedilum (*Polypedilum*) *tsukubaense* Sasa 1983	–	Japan	B	+	–
	Polypedilum (*Tripodura*) *japonicum* (Tokunaga 1938)	–	Japan	B	+	–
	Polypedilum (*Tripodura*) *masudai* (Tokunaga 1938)	–	Japan	B	+	–
	Polypedilum (*Tripodura*) *parapicatum* Niitsuma 1991	–	Japan	B	+	–
	Polypedilum (*Tripodura*) *sagittiferum* (Tokunaga 1938)	–	Japan	B	+	–
	Polypedilum (*Tripodura*) *tamahinoense* Sasa et Ichimori 1983	–	Japan	B	+	–
	Polypedilum (*Tripodura*) *unifascium* (Tokunaga 1938)	–	Japan	B	+	–
	Polypedilum (*Uresipedilum*) *cultellatum* Goetghebuer 1931	–	Holarctic	B	+	–
	Polypedilum (*Uresipedilum*) *surugense* Niitsuma 1992	–	Japan	B	+	–
	Saetheria tylus (Townes 1945)	–	Holarctic	B	+	–
	Sergentia kizakiensis (Tokunaga 1940)	–	Japan	B	+	–
	Stenochironomus takahashii (Tokunaga 1938)	–	Japan	B	+	–
	Stictochironomus akizukii (Tokunaga 1940)	–	Russia, Japan	B	+	–

Lake Biwa		Attached lakes or lagoons, creek	Small stream, ditches	Rivers flowing into Lake Biwa	Notes (Ecology)	References
Profundal (30 m deep-)	Pelagic				Hosts (intermediate, additional) (if parasitic)	
–	–	?	?	?	?	Sasa and Kawai (1987)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Sasa and Kawai (1987)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Kawai et al. (2002)

(continued)

Appendix 2.24
(continued)

Taxonomic level	Scientific name	Endemicity	Distribution outside Lake Biwa	Life form	Lake Biwa	
				B: benthic, PA: planktonic, PE: pleuston, PR: parasitic	Littoral (0–10 m deep)	Sublittoral (10–30 m deep)
	Stictochironomus histrio (Fabricius 1794)	–	Europe, Japan	B	+	–
	Stictochironomus kisopallidus Sasa et Kondo 1994	–	Japan	B	+	–
	Stictochironomus multannulatus (Tokunaga 1938)	–	Russia, Japan	B	+	–
	Stictochironomus pictulus (Meigen 1818)	–	Palaearctic	B	?	+
	Xenochironomus xenolabis (Kieffer 1916)	–	Holarctic, Oriental	B	+	–
Tribe	Tanytarsini					
	Biwatendipes biwamosaicus Sasa et Nishino 1996	?	Japan	B	+	–
	Biwatendipes motoharui Tokunaga 1965	–	Japan	B	+	–
	Cladotanytarsus vanderwulpi (Edwards 1929)	–	Palaearctic	B	+	–
	Micropsectra chuzelonga Sasa 1984	–	Japan	B	+	–
	Neozavrelia bicoliocula (Tokunaga 1938)	–	Japan	B	+	–
	Paratanytarsus biwatertius Sasa et Kawai 1987	+?		B	+	–
	Paratanytarsus kuramacircus Sasa 1989	–	Japan	B	+	–
	Paratanytarsus miikesecundus (Sasa 1985)	–	Japan	B	+	–
	Paratanytarsus stagnarius (Tokunaga 1938)	–	Japan	B	+	–
	Paratanytarsus tamanegi Sasa 1983	–	Japan	B	+	–
	Rheotanytarsus aestuarius (Tokunaga 1938)	–	Japan	B	+	–
	Rheotanytarsus kyotoensis (Tokunaga 1938)	–	Japan	B	+	–
	Rheotanytarsus tamaquartus Sasa 1980	–	Japan	B	+	–
	Stempellina sp. cf. *bausei*	?	?	B	+	–
	[Synonym]: *Stempellina subglabripennis* (Brundin 1947) sensu Kawai et al. (2002)					

Lake Biwa		Attached lakes or lagoons, creek	Small stream, ditches	Rivers flowing into Lake Biwa	Notes (Ecology)	References
Profundal (30 m deep-)	Pelagic				Hosts (intermediate, additional) (if parasitic)	
–	–	?	?	?	?	Sasa and Kawai (1987)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010)
+	–	?	?	?	?	Kiyashko et al. (2004)
–	–	?	?	?	?	Kaneko et al. (2010), Kawai et al. (2002)
–	–	?	?	?	?	Sasa and Nishino (1996)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Sasa and Nishino (1995)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010), Kawai et al. (2002)
–	–	?	?	?	?	Sasa and Kawai (1987)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010), Kawai et al. (2002)

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Appendix 2.24
(continued)

Taxonomic level	Scientific name	Endemicity	Distribution outside Lake Biwa	Life form	Lake Biwa	
				B: benthic, PA: planktonic, PE: pleuston, PR: parasitic	Littoral (0–10 m deep)	Sublittoral (10–30 m deep)
	Stempellinella tamaseptima (Sasa 1980)	–	Russia, Japan	B	+	–
	Tanytarsus bathophilus Kieffer 1911	–	Europe, Japan	B	+	–
	[Synonym]: *Tanytarsus nippogregarius* Sasa et Kamimura 1987					
	Tanytarsus biwatrifurcatus Sasa et Kawai 1987	–	Japan	B	+	–
	Tanytarsus chinyensis Goetghebuer 1934	–	Europe, Japan	B	+	–
	[Synonym]: *Tanytarsus tamadecimus* Sasa 1980					
	Tanytarsus curticornis Kieffer 1911	–	Europe, Japan	B	+	–
	Tanytarsus gregarius Kieffer 1909	–	Europe, Japan	B	+	–
	Tanytarsus kirai Sasa et Kawai 1987	+?		B	+	–
	Tanytarsus konishii Sasa et Kawai 1985	–	Japan	B	+	–
	Tanytarsus mendax Kieffer 1925	–	Holarctic	B	+	–
	Tanytarsus okuboi Sasa et Kikuchi 1986	–	Japan	B	+	–
	Tanytarsus oyamai Sasa 1979	–	Japan	B	+	–
	Tanytarsus shoudigitatus Sasa 1989	–	Japan	B	+	–
	Tanytarsus takahashii Kawai et Sasa 1985	–	Japan	B	+	–
	Tanytarsus tamagotoi Sasa 1983	–	Japan	B	+	–
	Tanytarsus tamakutibasi Sasa 1983	–	Japan	B	+	–
	Tanytarsus unagiseptimus Sasa 1985	–	Japan	B	+	–
Subfamily	Diamesinae					
	Potthastia gaedii (Meigen 1838)	–	Holarctic	B	+	–
	Potthastia longimana Kieffer 1922	–	Holarctic	B	+	–
	Sympotthastia takatensis (Tokunaga 1936)	–	China, Russia, Japan	B	+	–
Subfamily	Orthocladiinae					
	Brillia japonica Tokunaga 1939	–	Korea, Japan	B	+	–
	Brillia bifida (Kieffer 1909)	–	Russia, Japan	B	+	–

Lake Biwa		Attached lakes or lagoons, creek	Small stream, ditches	Rivers flowing into Lake Biwa	Notes (Ecology)	References
Profundal (30 m deep-)	Pelagic				Hosts (intermediate, additional) (if parasitic)	
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Sasa and Kawai (1987)
–	–	?	?	?	?	Sasa and Kawai (1987)
–	–	?	?	?	?	Sasa and Kawai (1987)
–	–	?	?	?	?	Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010)

(continued)

Appendix 2.24
(continued)

Taxonomic level	Scientific name	Endemicity	Distribution outside Lake Biwa	Life form	Lake Biwa	
				B: benthic, PA: planktonic, PE: pleuston, PR: parasitic	Littoral (0–10 m deep)	Sublittoral (10–30 m deep)
	[Synonym]: *Brillia modesta* (Meigen 1830)					
	Corynoneura lacustris Edwards 1924	–	Europe	B	+	–
	Corynoneura lobata Edwards 1924	–	Holarctic	B	+	–
	Corynoneura longipennis Tokunaga 1936	–	Japan	B	+	–
	Corynoneura scutellata (Winnertz 1846)	–	Palaearctic	B	+	–
	Cricotopus (*Cricotopus*) *bicinctus* (Meigen 1818)	–	Holarctic	B	+	–
	Cricotopus (*Cricotopus*) *bimaculatus* Tokunaga 1936	–	Russia, Japan	B	+	–
	Cricotopus (*Cricotopus*) *biwannulatus* Sasa et Kawai 1987	+?		B	+	–
	Cricotopus (*Cricotopus*) *metatibialis* Tokunaga 1936	–	Japan	B	+	–
	Cricotopus (*Cricotopus*) *triannulatus* (Macquart 1826)	–	Holarctic	B	+	–
	Cricotopus (*Cricotopus*) *yoshimurai* Tokunaga 1936	–	Japan	B	+	–
	Cricotopus (*Isocladius*) *sylvestris* (Fabricius 1809)	–	Holarctic	B	+	–
	Cricotopus (*Isocladius*) *tricinctus* (Meigen in Panzer 1813)	–	Europe, Japan	B	+	–
	Cricotopus (*Isocladius*) *trifasciatus* (Meigen in Panzer 1813)	–	Holarctic	B	+	–
	Eukiefferiella coerulescens (Kieffer 1926)	–	Holarctic	B	+	–
	Eukiefferiella yasunoi Sasa 1979	–	Japan	B	+	–
	Hydrobaenus biwagrandis Sasa et Nishino 1996	+?		B	+	–
	Hydrobaenus biwaquartus (Sasa et Kawai 1987)	–	Japan	B	+	–
	[Synonym]: *Eukiefferiella biwaquarta* Sasa et Kawai 1987					
	Hydrobaenus kisosecundus Sasa et Kondo 1991	–	Japan	B	+	–
	Hydrobaenus kondoi Sæther 1989	–	Japan	B	+	–
	Limnophyes fujinonus Sasa 1985	–	Japan	B	+	–

Lake Biwa		Attached lakes or lagoons, creek	Small stream, ditches	Rivers flowing into Lake Biwa	Notes (Ecology)	References
Profundal (30 m deep-)	Pelagic				Hosts (intermediate, additional) (if parasitic)	
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Sasa and Nishino (1996)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Sasa and Nishino (1995)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Sasa and Kawai (1987)

(continued)

Appendix 2.24
(continued)

Taxonomic level	Scientific name	Endemicity	Distribution outside Lake Biwa	Life form	Lake Biwa	
				B: benthic, PA: planktonic, PE: pleuston, PR: parasitic	Littoral (0–10 m deep)	Sublittoral (10–30 m deep)
	Limnophyes minimus (Meigen 1818)	–	Holarctic	B	+	–
	Limnophyes tamakitanaides Sasa 1981	–	Japan	B	+	–
	Limnophyes tamakireides Sasa 1983	–	Japan	B	+	–
	Nanocladius asiaticus Hayashi 2003	–	Japan	B	+	–
	Nanocladius seoulensis (Ree et Kim 1981)	–	Korea, Japan	B	+	–
	Nanocladius tamabicolor Sasa 1981	–	Russia, Japan	B	+	–
	Orthocladius (*Eudactylocladius*) *biwaniger* (Sasa et Nishino 1995)	+?		B	+	–
	Orthocladius (*Euorthocladius*) *kanii* Tokunaga 1939	–	Russia, Japan	B	+	–
	Orthocladius (*Orthocladius*) *biwainfirmus* Sasa et Nishino 1996	+?		B	+	–
	Orthocladius (*Orthocladius*) *glabripennis* Goetghebuer 1921	–	Europe, Japan	B	+	–
	Orthocladius (*Orthocladius*) *tamarutilus* Sasa 1981	–	Japan	B	+	–
	Parakiefferiella bathophila (Kieffer 1912)	–	Holarctic	B	+	–
	Paraphaenocladius impensus (Walker 1856)	–	Holarctic, Oriental	B	+	–
	Paratrichocladius rufiventris (Meigen 1830)	–	Holarctic	B	+	–
	Paratrichocladius tamaater Sasa 1981	–	Japan	B	+	–
	Propsilocerus akamusi (Tokunaga 1938)	–	China, Korea, Japan	B	+	–
	[Synonym]: *Tokunagayusurika akamusi* (Tokunaga 1938)					
	Psectrocladius aquatronus Sasa 1979	–	Japan	B	+	–
	Psectrocladius yunoquartus Sasa 1984	–	Japan	B	+	–
	Pseudorthocladius fujiquintus (Sasa 1985)	–	Japan	B	+	–
	Pseudosmittia nishiharaensis Sasa et Hasegawa 1988	–	Palaearctic?	B	+	–
	Pseudosmittia togadistalis Sasa, Watanabe et Arakawa 1992	–	Japan	B	+	–

Lake Biwa		Attached lakes or lagoons, creek	Small stream, ditches	Rivers flowing into Lake Biwa	Notes (Ecology)	References
Profundal (30 m deep-)	Pelagic				Hosts (intermediate, additional) (if parasitic)	
–	–	?	?	?	?	Kaneko et al. (2010), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987)
–	–	?	?	?	?	Sasa and Nishino (1995)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Sasa and Nishino (1995)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010), Kawai et al. (2002)
–	–	?	?	?	?	Sasa and Kawai (1987)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010)

(continued)

Appendix 2.24
(continued)

Taxonomic level	Scientific name	Endemicity	Distribution outside Lake Biwa	Life form	Lake Biwa	
				B: benthic, PA: planktonic, PE: pleuston, PR: parasitic	Littoral (0–10 m deep)	Sublittoral (10–30 m deep)
	Rheocricotopus chalybeatus (Edwards 1929)	–	Palaearctic	B	+	–
	Smittia aterrima (Meigen 1818)	–	Holarctic	B	+	–
	Smittia itachipennis Sasa et Kawai 1987	–	Japan	B	+	–
	Smittia nudipennis (Goetghebuer 1913)	–	Europe, Japan	B	+	–
	Smittia pratorum (Goetghebuer 1926)	–	Holarctic	B	+	–
	Synorthocladius tamaparvulus Sasa 1981	–		B	+	–
	Thienemanniella vittata (Edwards 1924)	–	Europe, Japan	B	+	–
	Tvetenia tamaflava (Sasa 1981)	–	Japan	B	+	–
Subfamily	Prodiamesinae					
	Monodiamesa bathyphila (Kieffer 1918)	–	Holarctic	B	+	+
	Prodiamesa levanidovae Makarchenko 1982	–	Russia, Japan	B	+	–
	[Synonym]: *Prodiamesa nagaii* Sasa et Kawai 1985					
Subfamily	Tanypodinae					
	Ablabesmyia monilis (Linnaeus 1958)	–	Holarctic, Taiwan	B	+	–
	Ablabesmyia longistyla Fittkau 1962	–	Palaearctic	B	+	–
	Ablabesmyia prorasha Kobayashi et Kubota 2002	–	Japan	B	+	–
	Clinotanypus sugiyamai Tokunaga 1937	–	China, Japan	B	+	+
	Conchapelopia japonica (Tokunaga 1937)	–	Japan	B	+	–
	Conchapelopia quatuormaculata Fittkau 1957	–	Europe, Japan	B	+	–
	Hayesomyia tripunctata (Goetghebuer 1922)	–	Europe, Japan	B	+	–
	Macropelopia paranebulosa Fittkau 1962	–	Russia, Japan	B	+	–
	Psectrotanypus orientalis Fittkau 1962	–	Japan	B	+	–

Lake Biwa		Attached lakes or lagoons, creek	Small stream, ditches	Rivers flowing into Lake Biwa	Notes (Ecology)	References
Profundal (30 m deep-)	Pelagic				Hosts (intermediate, additional) (if parasitic)	
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kawai et al. (2002)
–	–	?	?	?	?	Sasa and Kawai (1987)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010)
+?	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987)
–	–	?	?	?	?	Kaneko et al. (2010), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010)
+?	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Kawai et al. (2002)
–	–	?	?	?	?	Kawai et al. (2002)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010)

(continued)

Appendix 2.24
(continued)

Taxonomic level	Scientific name	Endemicity	Distribution outside Lake Biwa	Life form	Lake Biwa	
				B: benthic, PA: planktonic, PE: pleuston, PR: parasitic	Littoral (0–10 m deep)	Sublittoral (10–30 m deep)
	Procladius choreus (Meigen 1804)	–	Palaearctic	B	+	+
	[Synonym]: *Procladius sagittalis* (Kieffer 1909)					
	Procladius iris (Kieffer 1916)	–	Japan, Taiwan	B	+	–
	Rheopelopia toyamazea (Sasa 1996)	–	Japan	B	+	–
	Saetheromyia tedoriprima (Sasa 1994)	–	Japan	B	+	–
	Tanypus punctipennis Meigen 1818	–	Holarctic, Oriental	B	+	–

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Lake Biwa		Attached lakes or lagoons, creek	Small stream, ditches	Rivers flowing into Lake Biwa	Notes (Ecology)	References
Profundal (30 m deep-)	Pelagic				Hosts (intermediate, additional) (if parasitic)	
–	–	?	?	?	?	Kaneko et al. (2010), Kawai et al. (2002), Sasa and Kawai (1987)
–	–	?	?	?	?	Sasa and Kawai (1987)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010)
–	–	?	?	?	?	Kaneko et al. (2010), Sasa and Kawai (1987), Kawai et al. (2002)

Appendix 2.25

A list of Trichoptera (Hexapoda) in Lake Biwa and its adjacent waters (by M. Uenishi and K. Tanida)

Taxonomic level	Scientific name	Endemicity	Distribution outside Lake Biwa	Main habitat on larval stage	Lake Biwa				
			EP: east palearctic, WP: west palearctic, OR: oriental, NA: nearctic	Le: lentic, Lo: lotic	Littoral (0–10 m deep)	Sub-littoral (10–30 m deep)	Pro-fundal (30 m deep-)	Emergent plant zone (reed zone)	In the sub-marged plant area
Family	Hydroptilidae								
	Hydroptila phenianica Botosaneanu 1970	–	EP	Le, Lo	+				
	Syn. *Hydroptila matsuii* Kobayashi 1974								
Family	Rhyacophilidae								
	Rhyacophila articulata Morton 1900	–	EP	Lo					
Family	Glossosomatidae								
	Glossosoma ussuricum Martynov 1934	–	EP	Lo					
	Syn. *Mystrophora inops* Tsuda 1940								
Family	Stenopsychidae								
	Stenopsyche marmorata Navas 1920	–	EP	Lo					
	Syn. *Stenopsyche griseipennis* McLachlan 1866								
	Stenopsyche sauteri Ulmer 1907	–	EP, OR	Lo					
Family	Psychomyiidae								
	Paduniella sp.	–	EP	Le	+				

Lake Biwa						Attached lakes or lagoons, creek	Paddyfields, small stream, ditches	Rivers flowing into Lake Biwa	Seta rivers flowing from Lake Biwa and Sosui channals	References
Rocky shores	Pebble shores	Sandy shores	Muddy shores	Artificial embank-ments (unnatu-ral shores)	Unknown					
										Tanida et al. (1999)
								+		Komatsu (1964b)
								+		Komatsu (1964a, b)
								+		Komatsu (1964a, b)
								+		Komatsu (1964a, b)
	+			+						Tanida and Nishino (1992), Tanida et al. (1999) (as *Paduniella amurensis* Martynov)

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Appendix 2.25
(continued)

Taxonomic level	Scientific name	Endemicity	Distribution outside Lake Biwa	Main habitat on larval stage	Lake Biwa				
			EP: east palearctic, WP: west palearctic, OR: oriental, NA: nearctic	Le: lentic, Lo: lotic	Littoral (0–10 m deep)	Sub-littoral (10–30 m deep)	Pro-fundal (30 m deep-)	Emergent plant zone (reed zone)	In the sub-marged plant area
Family	Dipseudopsidae								
	Dipseudopsis collaris McLachlan 1863	–	EP	Le	+				
	Syn. *Bathytinodes alba* Iwata 1930								
	Syn. *Dipseudopsis stellata* McLachlan 1875								
Family	Ecnomidae								
	Ecnomus tenellus Rambur 1842	–	WP, EP, OR	Le, Lo	+				
	Syn. *Ecnomus omiensis* Tsuda 1942								
	Ecnomus yam ashironis Tsuda 1942	–	EP	unknown					
Family	Polycentropodidae								
	Neucentropus mandjuricus Martynov 1907	–	EP	Lo	+				
	Syn. *Kyopsyche japonica* Tsuda 1942								

Lake Biwa						Attached lakes or lagoons, creek	Paddyfields, small stream, ditches	Rivers flowing into Lake Biwa	Seta rivers flowing from Lake Biwa and Sosui channals	References
Rocky shores	Pebble shores	Sandy shores	Muddy shores	Artificial embank-ments (unnatu-ral shores)	Unknown					
		+	+			+				Iwata (1927), Tsuda (1937, 1942a, b), Akagi (1953b), Mori and Matutani (1953), Tanida and Nishino(1992), Tanida et al. (1999)
+	+									Tsuda (1942a, b), Mori and Matutani (1953), Tanida and Nishino (1992), Tanida et al. (1999)
+	+									
										Tsuda (1942a), Tanida and Nishino (1992), Tanida et al. (1999)
+	+								+	Tsuda (1942a, b), Mori and Matutani (1953), Tanida et al. (1999)

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Appendix 2.25
(continued)

Taxonomic level	Scientific name	Endemicity	Distribution outside Lake Biwa	Main habitat on larval stage	Lake Biwa				
			EP: east palearctic, WP: west palearctic, OR: oriental, NA: nearctic	Le: lentic, Lo: lotic	Littoral (0–10 m deep)	Sub-littoral (10–30 m deep)	Pro-fundal (30 m deep-)	Emergent plant zone (reed zone)	In the sub-marged plant area
Family	Hyalopsychidae								
	Hyalopsyche sachalinica Martynov 1910	–	EP	Lo?					
	Phylocentropus shigae Tsuda 1942	–	EP	Lo?					
Family	Hydropsychidae								
	Cheumatopsyche brevilineata (Iwata 1927)	–	EP	Lo	+				
	Cheumatopsyche infascia Martynov 1934	–	EP	Lo					
	Hydropsyche orientalis Martynov 1934	–	EP	Lo					
	Syn. *Hydropsyche ulmeri* Tsuda 1940								
	Hydropsyche setensis Iwata 1927	–	EP	Lo					
	Syn. *Hydropsyche japonica* Iwata 1927								
	Syn. *Hydropsyche nakaharai* Tsuda 1949								

Lake Biwa						Attached lakes or lagoons, creek	Paddyfields, small stream, ditches	Rivers flowing into Lake Biwa	Seta rivers flowing from Lake Biwa and Sosui channals	References
Rocky shores	Pebble shores	Sandy shores	Muddy shores	Artificial embank-ments (unnatu-ral shores)	Unknown					
					+					Tanida and Nishino (1992), Tanida et al. (1999)
					+					Tsuda (1942a), Tanida et al. (1999)
+	+						+	+	+	Tsuda (1942a, b), Tsuda and Kawai (1956), Komatsu (1964b) (as *Hydropsychodes brevilineata*), Tanida and Nishino (1992), Tanida et al. (1999)
								+		Tanida et al. (1999)
								+		Komatsu (1964b)
								+	+	Tsuda and Kawai (1956)

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Appendix 2.25
(continued)

Taxonomic level	Scientific name	Endemicity	Distribution outside Lake Biwa	Main habitat on larval stage	Lake Biwa				
			EP: east palearctic, WP: west palearctic, OR: oriental, NA: nearctic	Le: lentic, Lo: lotic	Littoral (0–10 m deep)	Sub-littoral (10–30 m deep)	Pro-fundal (30 m deep-)	Emergent plant zone (reed zone)	In the sub-marged plant area
	Macrostemum radiatum (McLachlan 1862)	–	EP, OR	Lo					
	Syn. *Macronema lacustris* Iwata 1927								
	Potamyia chinensis (Ulmer 1915)	–	EP, OR	Lo					
	Syn. *Hydropsyche echigoensis* Tsuda 1949								
Family	Phryganopsychidae								
	Phryganopsyche latipennis (Banks 1906)	–	EP	Le, Lo					
Family	Phryganeidae								
	Phryganea japonica McLachlan 1866	–	EP	Le	+				
Family	Brachycentridae								
	Brachycentrus kuwayamai Wiggins et al. 1985	–	EP	Le					
	Syn. *Brachycentrus* sp. BA								
Family	Lepidostomatidae								
	Lepidostoma japonicum (Tsuda 1936)	–	EP	Lo	+				
	Lepidostoma bipertitum (Kobayashi 1955)	–	EP	Lo	+				

Lake Biwa						Attached lakes or lagoons, creek	Paddyfields, small stream, ditches	Rivers flowing into Lake Biwa	Seta rivers flowing from Lake Biwa and Sosui channals	References
Rocky shores	Pebble shores	Sandy shores	Muddy shores	Artificial embank-ments (unnatu-ral shores)	Unknown					
								?	+	Iwata (1927) (as *Macronema lacustris*), Tsuda (1942a, b), Tsuda and Kawai (1956), Tanida et al. (1999)
								+	+	Tanida and Nishino (1992), Tanida et al. (1999)
+								+		Tanida et al. (1999)
										Tsuda (1942a, b), Tanida et al. (1999)
								+		Komatsu (1964)
+	+							+		Tanida et al. (1999)
+	+							+		Tanida et al. (1999)

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Appendix 2.25
(continued)

Taxonomic level	Scientific name	Endemicity	Distribution outside Lake Biwa	Main habitat on larval stage	Lake Biwa				
			EP: east palearctic, WP: west palearctic, OR: oriental, NA: nearctic	Le: lentic, Lo: lotic	Littoral (0–10 m deep)	Sub-littoral (10–30 m deep)	Pro-fundal (30 m deep-)	Emergent plant zone (reed zone)	In the sub-marged plant area
	Lepidostoma tsudai (Tani 1971)	–	EP	Lo	+				
	Lepidostoma orientale (Tsuda 1942)	–	EP	Le, Lo	+				
Family	Limnephilidae								
	Limnephilus fuscovittatus Matsumura 1904	–	EP, OR	Le	+			+	
	Limnephilus nipponicus Schmid 1964	–	EP	Le					
	Limnephilus orientalis Martynov 1935	–	EP	Le	+			+	
	Nemotaulius admorsus (McLachlan 1866)	–	EP	Le	+			+	
	Nothopsyche pallipes Banks 1906	–	EP	Le	+				
	Nothopsyche ruficollis (Ulmer 1905)	–	EP	Lo	+				
Family	Apatanidae								
	Apatania biwaensis Nishimoto 1994	+	EP	Le	+				

Lake Biwa						Attached lakes or lagoons, creek	Paddyfields, small stream, ditches	Rivers flowing into Lake Biwa	Seta rivers flowing from Lake Biwa and Sosui channals	References
Rocky shores	Pebble shores	Sandy shores	Muddy shores	Artificial embank-ments (unnatu-ral shores)	Unknown					
+	+							+		Tanida et al. (1999)
+	+							+	+	Tsuda (1942a), Tanida et al. (1999)
										Tsuda (1942a, b), Tanida and Nishino (1992), Tanida et al. (1999)
				+						Nozaki and Tanida (1996)
										Tanida and Nishino (1992), Tanida et al. (1999)
										Tsuda (1939), Tsuda (1942a), Tanida et al. (1999)
+	+							+		Tsuda (1942a), Tsuda and Yuki (1943), Tanida et al. (1999)
+	+							+		Tsuda (1942a), Tsuda and Yuki (1943), Tanida and Nishino (1992), Tanida et al. (1999)
+										Nishimoto (1994), Tanida and Nishino (1992), Tanida et al. (1999)

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Appendix 2.25
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Taxonomic level	Scientific name	Endemicity	Distribution outside Lake Biwa	Main habitat on larval stage	Lake Biwa				
			EP: east palearctic, WP: west palearctic, OR: oriental, NA: nearctic	Le: lentic, Lo: lotic	Littoral (0–10 m deep)	Sub-littoral (10–30 m deep)	Pro-fundal (30 m deep-)	Emergent plant zone (reed zone)	In the sub-marged plant area
	Apatania tsudai Schmid 1954	–	EP	Lo	+				
Family	Goeridae								
	Goera japonica Banks 1906	–	EP	Le, Lo	+				
Family	Leptoceridae								
	Athripsodes tsudai (Akagi 1993)	–	EP	Lo					
	Ceraclea (*Ceraclea*) *albimacula* (Rambur 1842)	–	EP, WP	Le	+				
	Syn. *Leptocerus spinosa* Tsuda 1942								
	Syn. *Leptocerus biwaensis* Tsuda 1955								
	Syn. *Ceraclea* (*Ceraclea*) *albogut-tata* (Hagen 1860)								
	Ceraclea (*Ceraclea*) *nigronervosa* (Retzius 1783)	–	EP, WP, NA	Le, Lo	+				
	Ceraclea (*Ceraclea*) *superba* (Tsuda 1942)	–	EP	Le, Lo					

Lake Biwa						Attached lakes or lagoons, creek	Paddyfields, small stream, ditches	Rivers flowing into Lake Biwa	Seta rivers flowing from Lake Biwa and Sosui channals	References
Rocky shores	Pebble shores	Sandy shores	Muddy shores	Artificial embank-ments (unnatu-ral shores)	Unknown					
+	+						+			Tanida et al. (1999)
+	+	+						+	+	Komatsu (1964), Tanida and Nishino (1992), Tanida et al. (1999)
								+		Komatsu (1964)
+				+						Tsuda(1942a), Akagi (1956), Uenishi (1993), Tanida and Nishino (1993), Tanida et al. (1999)
+										Tsuda (1942a,b), Mori (1946), Mori and Matutani (1953), Tanida and Nishino (1993), Tanida et al. (1999)
					+				+	Tsuda (1942a), Tsuda and Kawai (1956), Tanida and Nishino (1993), Tanida et al. (1999)

(continued)

Appendix 2.25
(continued)

Taxonomic level	Scientific name	Endemicity	Distribution outside Lake Biwa	Main habitat on larval stage	Lake Biwa				
			EP: east palearctic, WP: west palearctic, OR: oriental, NA: nearctic	Le: lentic, Lo: lotic	Littoral (0–10 m deep)	Sub-littoral (10–30 m deep)	Pro-fundal (30 m deep-)	Emergent plant zone (reed zone)	In the sub-marged plant area
	Ceraclea (*Athripsodina*) *complicata* (Kobayashi 1984)			Lo					
	Ceraclea (*Athripsodina*) *lobulata* (Martynov 1935)	–	EP	Lo					
	Syn. *Leptocerus miyakonis* Tsuda 1942								
	Ceraclea sp. LC	–	EP	Lo					
	Leptocerus biwae (Tsuda 1942)	–	EP	Le					
	Mystacides azureus (Linnaeus 1761)	–	EP, WP	Le, Lo	+			+	
	Mystacides sp.	–	EP	Le	+			+	
	Oecetis morii Tsuda 1942	–	EP	Le					

Lake Biwa						Attached lakes or lagoons, creek	Paddyfields, small stream, ditches	Rivers flowing into Lake Biwa	Seta rivers flowing from Lake Biwa and Sosui channals	References
Rocky shores	Pebble shores	Sandy shores	Muddy shores	Artificial embank-ments (unnatu-ral shores)	Unknown					
								+		
								+		Tsuda (1942a), Uenishi (1993), Tanida et al. (1999)
								+		Komatsu (1964a) (as *Leptocerus* sp. LC)
										Tsuda (1942a, b), Mori and Matutani (1953), Uenishi (1993), Tanida et al. (1999)
								+		Tsuda (1942a), Mori and Matutani (1953), Uenishi (1993), Tanida et al. (1999)
										Tsuda (1942a, b), Mori and Matutani (1953) (as *Mystacides longicornis*), Uenishi (1993), Tanida and Nishino (1993), Tanida et al. (1999)
					+					Tsuda (1942a, b), Tanida et al. (1999)

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Appendix 2.25

(continued)

Taxonomic level	Scientific name	Endemicity	Distribution outside Lake Biwa	Main habitat on larval stage	Lake Biwa				
			EP: east palearctic, WP: west palearctic, OR: oriental, NA: nearctic	Le: lentic, Lo: lotic	Littoral (0–10 m deep)	Sub-littoral (10–30 m deep)	Pro-fundal (30 m deep-)	Emergent plant zone (reed zone)	In the sub-marged plant area
	Oecetis nigropunctata Ulmer 1908	–	EP	Le, Lo	+				
	Oecetis tripunctata (Fabricius 1793)	–	EP, WP	Le	+				
	Oecetis tsudai Fischer 1970	–	EP	Le, Lo	+				
	Oecetis yukii Tsuda 1942	–	EP	Lo					
	Setodes ujiensis (Akagi 1960)	–	EP	Lo					
	Triaenodes unanimis McLachlan 1877	–	EP, WP	Le	+				
	Syn. *Triaenodes yamamotoi* Tsuda 1942								
	Triplectides misakianus (Matsumura 1931)	–	EP	Le, Lo					

Lake Biwa						Attached lakes or lagoons, creek	Paddyfields, small stream, ditches	Rivers flowing into Lake Biwa	Seta rivers flowing from Lake Biwa and Sosui channals	References
Rocky shores	Pebble shores	Sandy shores	Muddy shores	Artificial embank-ments (unnatu-ral shores)	Unknown					
+									+	Tsuda (1942a), Mori and Matutani (1953), Tsuda and Kawai (1956), Tanida and Nishino (1993), Tanida et al. (1999)
+					+					Uenishi (1993), Tanida et al. (1999)
+										Tsuda (1942a, b), Tanida and Nishino (1993), Tanida et al. (1999)
										Tsuda (1942a, b), Tanida et al. (1999)
									+	Akagi (1953), Tsuda and Kawai (1956)
						+				Tsuda (1942a, b), Mori and Matutani (1953), Uenishi (1993), Tanida and Nishino (1993), Tanida et al. (1999)
										Tsuda (1942a, b), Uenishi (1993), Tanida et al. (1999)

(continued)

Appendix 2.25
(continued)

Taxonomic level	Scientific name	Endemicity	Distribution outside Lake Biwa	Main habitat on larval stage	Lake Biwa				
			EP: east palearctic, WP: west palearctic, OR: oriental, NA: nearctic	Le: lentic, Lo: lotic	Littoral (0–10 m deep)	Sub-littoral (10–30 m deep)	Pro-fundal (30 m deep-)	Emergent plant zone (reed zone)	In the sub-marged plant area
Family	Molannidae								
	Molanna moesta (Banks 1906)	–	EP	Le, Lo	+	+			
	Syn. *Molanna falcata* Ulmer 1908								
Family	Calamoceratidae								
	Georgium japonicum (Ulmer 1905)	–	EP, OR	Le, Lo	+				
	Syn. *Anabolia kawamurai* Iwata 1927								
Family	Odontoceridae								
	Psilotreta japonica (Banks 1906)	–	EP	Lo					
Family	Sericostomatidae								
	Gumaga orientalis (Martynov 1935)	–	EP	Le, Lo	+				

Lake Biwa						Attached lakes or lagoons, creek	Paddyfields, small stream, ditches	Rivers flowing into Lake Biwa	Seta rivers flowing from Lake Biwa and Sosui channals	References
Rocky shores	Pebble shores	Sandy shores	Muddy shores	Artificial embank-ments (unnatu-ral shores)	Unknown					
+	+								+	Tsuda (1942a, b), Mori and Matutani (1953), Tsuda and Kawai (1956), Tanida and Nishino (1993), Tanida et al. (1999)
										Iwata (1927), Tsuda (1942a, b), Mori and Matutani (1953), Tanida et al. (1999)
										Iwata (1927)
					+					Tsuda (1942a)
+	+							+		Tsuda (1942a, b), Mori and Matutani (1953), Komatsu (1964a) (as *Gumaga okinawaensis*), Tanida and Nishino (1993), Tanida et al. (1999)

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Appendix 2.26

A list of Bryozoa (Phylactolaemata and Gymnolaemata) in Lake Biwa and its adjacent waters (by M. Nishino)

Taxonomic level	Scientific name	Japanese name	Endemicity	Distribution	Origin (introduced)	
Class	Phylactolaemata					
Order	Plumatellida					
Family	*Fredericellidae*					
	Fredericella indica Annandale 1909	kobu-karakusa-kokemushi	–	Littoral		Hirose and Mawatari (2011)
	Syn. *Fredericella sultana* sensu Toriumi (1951) (in part)					
	Fredericella sultana (Blumenbach 1779)	karakusa-kokemushi	–	Unkown		Mizuno and Tetsukawa (1965)
	Fredericella toriumii Hirose et Mawatari 2011	ryukotsu-karakusa-kokemushi	+(*)	Littoral		Hirose and Mawatari (2011)
Family	Lophopodidae					
	Asajirella gelatinosa (Oka 1891)	kanten-kokemushi	–	Littoral		Mizuno and Tetsukawa (1965), Nishino (1993)
	Syn. *Pectinatella gelatinosa* Oka 1891					
	Lophopodella carteri Hyatt 1868	himeten-kokemushi	–	Littoral		Mizuno and Tetsukawa (1965), Nishino (1993)
Family	Pectinatellidae					
	Pectinatella magnifica (Leidy 1851)	omari-kokemushi		Littoral	North America	Nishino (1993), Hirose and Mawatari (2011)
Family	Plumatellidae					
	Plumatella casmiana Oka 1907	kasumi-hane-kokemushi	–	Littoral		Hirose and Mawatari (2011)
	Plumatella emarginata Allman 1844	yahazu-hane-kokemushi	–	Littoral		Mizuno and Tetsukawa (1965), Hirose and Mawatari (2011)
	Plumatella fungosa (Pallas 1768)	kobu-hane-kokemushi	–	Littoral		Hirose and Mawatari (2011)
	Plumatella mukaii Wood 2001	toge-yahazu-hane-kokemushi	–	Littoral		Hirose and Mawatari (2011)
	Plumatella repens (Linnaeus 1758)	hane-kokemushi	–	Littoral		Hirose and Mawatari (2011)
	Rumarcanella vorstmani (Toriumi 1952)	sukashi-hane-kokemushi	–	Littoral		Hirose and Mawatari (2011)

(continued)

Appendix 2.26

(continued)

Taxonomic level	Scientific name	Japanese name	Endemicity	Distribution	Origin (introduced)	
Family	Stephanellidae					
	Stephanella hina Oka 1908	hina-kokemushi	–	Littoral		Hirose and Mawatari (2011)
Class	Gymnolaemata					
Order	Ctenostomata					
Family	Hislopiidae					
	Hislopia prolixa Hirose et Mawatari 2011	akari-kokemushi	–	Littoral		Hirose and Mawatari (2011)
Family	Paludicellidae					
	Paludicella articulata (Ehrenberg 1831)	chamidoro-kokemushi	–	Littoral		Hirose and Mawatari (2011)

*Not found other than Lake Biwa, but further study is required to ensure the endemicity

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Appendix 2.27

A list of fishes (Agnatha and Gnathostomata) in Lake Biwa and its adjacent waters (by M. Maehata)

Taxonomic level	Scientific name	English name	Japanese name	Endemicity	Origin (introduced species)
Family	Petromyzontidae				
	Lethenteron reissneri (Dybowski 1869)	Sand lamprey, Pacific brook lamprey	suna-yatsume		
Family	Salmonidae				
	Oncorhynchus masou subsp.	Biwa salmon	Biwa-masu	+	
	Oncorhynchus masou ishikawae Jordan et McGregor 1925	Red-spot masu salmon	amago (land locked type), satsuki-masu (sea-run form)		
Family	Osmeridae				
	Plecoglossus altivelis subsp. [a]	Biwa-ayu (ayu fish)	Biwako-ayu	+	
	Hypomesus nipponensis McAllister 1963	Japanese smelt	wakasagi		Japan
Family	Cyprinidae				
	Gnathopogon elongatus elongatus (Temminck et Schlegel 1846)	Field minnow	ta-moroko		
	Gnathopogon caerulescens (Sauvage 1883)	Willow minnow	hon-moroko	+	
	Squalidus chankaensis biwae (Jordan et Snyder 1900)	Sugo gudgeon	sugo-moroko	+	
	Squalidus japonicus japonicus (Sauvage 1883)	Deme gudgeon	deme-moroko		
	Sarcocheilichthys biwaensis Hosoya 1982	Oily minnow	abura-higai	+	
	Sarcocheilichthys variegatus microoculus Mori 1927	Biwa minnow	Biwa-higai	+	

Habitat			Distribution outside Lake Biwa		Category in the Red List (RL) by the Ministry of Environment of Japan	References
Lake Biwa		Around the lake				
Pelagic	Littral zone and attached lakes	Inlet rivers, waterways, ditches	Japan	Out of Japan	CR: Critically Endangered EN: Endangered VU: Vulnerable NT: Near Threatened DD: Data Deficient	
+	+	+	All over Japan	Northern China, Korea, Maritime Province	VU	Kawanabe et al. (2001)
+		+			NT	Kawanabe et al. (2001)
+		+	Honshu (south of Sizuoka Pref.), Shikoku, Kyushu (Oita, Miyazaki Pref.)			Kawanabe et al. (2001)
+	+	+	Seta River (outlet of Lake Biwa)			Kawanabe (1996), Kawanabe et al. (2001)
+	+	+	Hokkaido, areas north of Tokyo, Shimane Pref. in Honshu.	California (USA)		Nakabo (2000), Kawanabe et al. (2001)
	+	+	Tohkai, Kinki, Sanyo area, and Shikoku island			Kawanabe et al. (2001)
+	+		Seta River (outlet of Lake Biwa)		CR	Kawanabe et al. (2001)
+	+				NT	Kawanabe et al. (2001)
+	+		Nobi Plain		VU	Kawanabe et al. (2001)
	+	+			CR	Hosoya (1982), Kawanabe et al. (2001)
	+	+	Seta River (outlet river of Lake Biwa)			Hosoya (1982), Kawanabe et al. (2001)

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Taxonomic level	Scientific name	English name	Japanese name	Endemicity	Origin (introduced species)
	Hemibarbus barbus (Temminck et Schlegel 1846)	Steed barbel	nigoi		
	Hemibarbus labeo (Pallas 1776)	Korai steed barbel	korai-nigoi		
	Abbottina rivularis (Basilewsky 1855)	Chinese false gudgeon	tsuchifuki		Japan
	Pseudogobio esocinus esocinus (Temminck et Schlegel 1846)	Pike gudgeon	kamatsuka		
	Biwia zezera (Ishikawa 1895)	Biwa gudgeon	zezera		
	Biwia yodoensis Kawase et Hosoya 2010	Yodo gudgeon	Yodo-zezera	+	
	Pseudorasbora parva (Temminck et Schlegel 1846)	Top mouth gudgeon, stone moroko	motsugo		
	Tribolodon hakonensis (Günther 1877)	Japanese dace	ugui		
	Hemigrammocypris rasborella Fowler 1910	Golden venus fish	kawabata-moroko		
	Mylopharyngodon piceus (Richardson 1846)	Black carp	ao-uo		China

Habitat			Distribution outside Lake Biwa		Category in the Red List (RL) by the Ministry of Environment of Japan	References
Lake Biwa		Around the lake				
Pelagic	Littral zone and attached lakes	Inlet rivers, waterways, ditches	Japan	Out of Japan	CR: Critically Endangered EN: Endangered VU: Vulnerable NT: Near Threatened DD: Data Deficient	
	+	+	areas north of Chubu region in Honshu, Yamaguchi Pref, Kyushu			Nakabo (2000), Kawanabe et al. (2001)
	+	+	Chubu to Sanyo region, Shikoku	Korea, China, Taiwan		Nakabo (2000)
	+	+	Nobi Plain, Kinki and Sanyo regions, northeast Kyusyu	eastern China, Korean Peninsula		Nakabo (2000), Kawanabe et al. (2001)
	+	+	Areas south of Iwate and Yamagata Prefectures in Honshu, Kyushu, Iki islamd (Nagasaki Pref.)	Northern China, Korean Peninsula		Nakabo (2000), Kawanabe et al. (2001)
	+		Nobi Plain, Lake Biwa- Yodo River system, Sanyo region, northern Kyushu			Nakabo (2000), Kawanabe et al. (2001)
	+	+	Yodo River (outlet of Lake Biwa)			Kawase and Hosoya (2010)
+	+	+	Areas west of Kanto District in Honshu, Shikoku, Kyushu	Korean Penunsula, Taiwan, China, Russia		Nakabo (2000), Kawanabe et al. (2001)
	+	+	All over Japan	Sakhalin, Korea, China, Rossia,		Nakabo (2000), Kawanabe et al. (2001)
	(+)	(+)	Pacific coast of western central Honshu, Shikoku and northern Kyushu		EN	Nakabo (2000), Kawanabe et al. (2001)
	+	+	Tone-Edo River system	Eastern Asia		Nakabo (2000), Kawanabe et al. (2001)

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Taxonomic level	Scientific name	English name	Japanese name	Endemicity	Origin (introduced species)
	Ctenopharyngodon idellus (Valenciennes 1844)	Grass carp, white Amur	so-gyo		China
	Nipponocypris sieboldii Temminck et Schlegel 1846	Pond cub	numa-mutsu		
	Zacco platypus Temminck et Schlegel 1846	Pale chub	oikawa		
	Opsariichthys uncirostris uncirostris (Temminck et Schlegel 1846)	Piscivorous chub	hasu		
	Ischikauia steenacheri (Sauvage 1883)	Biwa culter	wataka	+	
	Hypophthalmichthys molitrix (Valenciennes 1844)	Silver bighead, silver carp	hakuren		China
	Carassius sp.	Silver crucian carp, silver Johny carp, silver prussian carp	gin-buna		
	Carassius auratus grandoculis Temminck et Schlegel 1846	Round crucian carp	nigoro-buna	+	
	Carassius cuvieri Temminck et Schlegel 1846	Deepbodied crucian carp, Japanese (white) crucian carp	gengoro-buna	+	
	Cyprinus carpio Linnaeus 1758	Carp, common carp	koi		

Habitat			Distribution outside Lake Biwa		Category in the Red List (RL) by the Ministry of Environment of Japan	
Lake Biwa		Around the lake				
Pelagic	Littral zone and attached lakes	Inlet rivers, waterways, ditches	Japan	Out of Japan	CR: Critically Endangered EN: Endangered VU: Vulnerable NT: Near Threatened DD: Data Deficient	References
	+	+	Edo River system	Eastern Asia (Amur River to northern Viet Nam)		Nakabo (2000), Kawanabe et al. (2001)
	+	+	Areas south of Chubu District in Honshu, Shikoku, northern Kyushu			Hosoya et al. (2003)
	+	+	Areas west of Kanto District in Honshu, Sikoku, northern Kyushu	West Korean Penunsula, northern China to northern Viet Nam		Nakabo (2000), Kawanabe et al. (2001)
+	+	+	Yodo River (outlet of Lake Biwa), Lake Mikata (Fukui Pref.)		VU	Nakabo (2000), Kawanabe et al. (2001)
	+	+	Yodo River (outlet of Lake Biwa), Lake Mikata (Fukui Pref.; extinction)		EN	Nakabo (2000), Kawanabe et al. (2001)
+	+		Tohoku District in Honshu, Shikoku, Kyushu	Eastern Asia		Nakabo (2000), Kawanabe et al. (2001)
	+	+	All over Japan	Korean Penunsula, China		Nakabo (2000), Kawanabe et al. (2001)
+	+		Yodo River (outlet of Lake Biwa)		EN	Nakabo (2000), Kawanabe et al. (2001)
+	+	+	Yodo River (outlet of Lake Biwa)		EN	Nakabo (2000), Kawanabe et al. (2001)
+	+	+	All over Japan	Eurasia Continent		Nakabo (2000), Kawanabe et al. (2001)

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Appendix 2.27
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Taxonomic level	Scientific name	English name	Japanese name	Endemicity	Origin (introduced species)
	Tanakia lanceolata (Temminck et Schlegel 1846)	Slender bitterling	yari-tanago		
	Acheilognathus cyanostigma Jordan et Fowler 1903	Striped bitterling	ichimonji-tanago		
	Acheilognathus tabira tabira Jordan et Thompson 1914	White-fin bitterling	shirohire-tabira		
	Acheilognathus rhombeus (Temminck and Schlegel 1846)	Flat bitterling	kanehira		
	Rhodeus ocellatus kurumeus Jordan et Thompson 1914	Japanese rose bitterling	nippon-bara-tanago		
	Rhodeus ocellatus ocellatus (Kner 1866)	Rose bitterling	tairiku-bara-tanago		China
Family	Cobitidae				
	Cobitis sp. S	Biwa striated spined loach	sujishima-dojo-kogatashu-Biwako-gata	+	
	Cobitis sp. L	Large striated striped loach	sujishima-dojo-ogatashu	+	
	Parabotia curta (Temminck et Schlegel 1846)	Kissing loach	ayu-modoki		
Family	Siluridae				
	Silurus asotus Linnaeus 1758	Far Eastern catfish	namazu		
	Silurus lithophilus (Tomoda 1961)	Rock catfish	iwatoko-namazu	+	
	Silurus biwaensis (Tomoda 1961)	Biwa catfish	Biwako-o-namazu	+	

Habitat			Distribution outside Lake Biwa		Category in the Red List (RL) by the Ministry of Environment of Japan	
Lake Biwa		Around the lake				
Pelagic	Littral zone and attached lakes	Inlet rivers, waterways, ditches	Japan	Out of Japan	CR: Critically Endangered EN: Endangered VU: Vulnerable NT: Near Threatened DD: Data Deficient	References
	+	+	Honshu, Sikoku, Kyushu	West Korean Peninsula		Nakabo (2000), Kawanabe et al. (2001)
	+	+	Nobi Plain, Kinki District		CR	Nakabo (2000), Kawanabe et al. (2001)
	+	+	Western Honshu		EN	Arai et al. (2007)
	+	+	Areas west of Nobi Plain in Honshu, northwest Kyushu	West Korean Peninsula		Kawanabe et al. (2001)
	(+)	(+)	Kinki, Cyugoku, Kyushu		CR	Kimura and Nagata (1992)
	+	+	All over Japan	Eastern Asia and Taiwan		Kawanabe et al. (2001)
	+	+			EN	Saitoh and Aizawa (1987)
	+	+			EN	Saitoh and Aizawa (1987)
	(+)	(+)	Lake Biwa, Yodo River, and several rivers of the Okayama Prefecture		CR	Kawanabe et al. (2001)
	+	+	Hnshu, Shikoku, Kyushu	Korean Penunsula, Taiwan, China, Russia		Tomoda (1961), Kobayakawa (1989)
	+		Seta River, Lake Yogo (Lake Biwa basin)		NT	Tomoda (1961), Kobayakawa (1989)
+	+		Yodo River (Lake Biwa basin)			Tomoda (1961), Kobayakawa (1989)

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Appendix 2.27
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Taxonomic level	Scientific name	English name	Japanese name	Endemicity	Origin (introduced species)
Family	Bagridae				
	Pelteobagrus nudiceps (Sauvage 1883)	Forktail bullhead	gigi		
Family	Anguillidae				
	Anguilla japonica Temminck et Schlegel 1846	Japanese ell	unagi		
Family	Adrianichthyidae				
	Oryzias latipes Temminck et Schlegel 1846	Medaka (fish), Japanese rice-fish	medaka		
	Gambusiaaffinis (Baird et Girard 1853)	Common gambusia, mosquitofish	kadayashi		USA
Family	Channidae				
	Channa argus (Cantor 1842)	Northern snakehead	kamuruchi		China
Family	Centrarchidae				
	Lepomis macrochirus Rafinesque 1819	Bluegill, bluegill sunfish	buru-giru		USA
	Micropterus salmoides (Lacepède 1802)	Largemouth bass	okuchi basu, burakku-basu		USA
Family	Gobiidae				
	Odontobutis obscura obscura (Temminck and Schlegel 1845)	Dark sleeper	donko		
	Rhinogobius sp. OR	Freshwater orange goby	to-yoshinobori		
	Rhinogobius sp. BW	Biwa yellow-gill	Biwa-yoshinobori	+	

Habitat			Distribution outside Lake Biwa		Category in the Red List (RL) by the Ministry of Environment of Japan	References
Lake Biwa		Around the lake				
Pelagic	Littral zone and attached lakes	Inlet rivers, waterways, ditches	Japan	Out of Japan	CR: Critically Endangered EN: Endangered VU: Vulnerable NT: Near Threatened DD: Data Deficient	
	+	+	Western Honshu, Kyushu, Shikoku			Kawanabe et al. (2001)
	+	+	All over Japan	Japan to the East China Sea, Taiwan, Korea, China and northern Philippines.		Kawanabe et al. (2001)
	+	+	All over Japan except Hokkaido	Japan, Korea, China and Viet Nam	VU	Kawanabe et al. (2001)
	+	+	All over Japan	North and central America		Kawanabe et al. (2001)
	+	+	All over Japan	China and western and southern Korea.		Kawanabe et al. (2001)
	+	+	All over Japan	North America		Kawanabe et al. (2001)
	+	+	All over Japan	North America		Kawanabe et al. (2001)
	+	+	Honshu, Sikoku, Kyushu	South China, Korea		Kawanabe et al. (2001)
	+	+	all over Japan except Ryukyu Islands			Kawanabe et al. (2001)
	+	+				Takahashi and Okazaki (2002), Tsujimoto et al. (2003)

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Taxonomic level	Scientific name	English name	Japanese name	Endemicity	Origin (introduced species)
	Gymnogobius urotaenia (Hilgendorf 1879)	Floating goby, folktongue goby	uki-gori		
	Gymnogobius isaza (Tanaka 1916)	Biwa goby	isaza	+	
	Tridentiger brevispinis Katsuyama, Arai et Nakamura 1972	Short-spined Japanese trident goby	numa-chichibu		Japan
Family	Cottidae				
	Cottus reinii Hilgendorf 1879	Biwa sculpin	utsusemi-kajika	+	

[a]Based on Kawanabe (1996) showed below

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Habitat			Distribution outside Lake Biwa		Category in the Red List (RL) by the Ministry of Environment of Japan	References
Lake Biwa		Around the lake				
Pelagic	Littral zone and attached lakes	Inlet rivers, waterways, ditches	Japan	Out of Japan	CR: Critically Endangered EN: Endangered VU: Vulnerable NT: Near Threatened DD: Data Deficient	
	+		Hokkaido, Honshu, Kyushu	Korea, Sakhalin, Kuril Islands		Kawanabe et al. (2001)
+					CR	Kawanabe et al. (2001)
	+	+	Hokkaido to Kyushu	Korea, China, Kuril Islands, Sakhalin		Kawanabe et al. (2001)
	+	+			EN	Kawanabe et al. (2001)

Appendix 2.28

A list of Amphibia in Lake Biwa and its adjacent waters (by M. Matsui)

Taxonomic level	Scientific name	English name	Japanese name	Habitat	Category in the Red List (RL) by the Ministry of Environment of Japan	References
Class	Amphibia					
Order	Caudata					
Family	Hynobiidae					
	Hynobius nebulosus (Temminck et Schlegel 1838)	Clouded salamander	Kasumi sansho-uo	Hill add lowland areas (paddy fields, marsh lands)	VU	Matsui (1979)
	Hynobius kimurae (Dunn 1923)	Hida salamander	Hida sansho-uo	Low mountain area (forest streams)	NT	Matsui (1979)
	Onychodactylus japonicus (Houttuyn 1782)	Japanese clawed salamander	Hakone sansho-uo	Low mountain area (forest streams)		Matsui (1979)
Family	Cryptobranchidae					
	Andrias japonicus (Temminck 1836)	Japanese giant salamander	O sansho-uo	Low mountains to lowland areas (rivers)	VU	
Family	Salamandridae					
	Cynops pyrrhogaster (Boie 1826)	Japanese fire-bellied newt	Nihon imori	Low mountains to lowland areas (ponds, paddy fields, marshes, dams, streams , etc.)	NT	Matsui (1979)
Order	Anura					
Family	Bufonidae					
	Bufo torrenticola (Matsui 1976)	Japanese stream toad	Nagare hiki-gaeru	Low mountain area (forest streams)		Matsui (1979)
	Bufo japonicus formosus (Boulenger 1883)	Eastern-Japanese common toad	Azuma hiki-gaeru	Low mountain to lowland areas (ponds and marshlands)		Matsui (1979)
Family	Hylidae					
	Hyla japonica (Günther 1859)	Japanese tree frog	Nihon ama-gaeru	Low mountain to lowland areas (ponds, marshlands, paddies)		Matsui (1979)
Family	Ranidae					
	Rana catesbeiana (Shaw 1802)	American bull frog	Ushi-gaeru (Shokuyo-gaeru)	Lowland areas (littral zone, ponds, paddy fields, rivers)		Matsui (1979)

	Rana porosa brevipoda (Ito 1941)	Daruma pond frog	Daruma-gaeru	Lowlands (paddy fields, ponds)	EN	Matsui (1979)
	Rana rugosa (Temminck et Schlegel 1838)	Wrinkled frog	Tuchi-gaeru	Low mountains to lowlandns (paddy fields, ponds, marshes, mountain streams)		Matsui (1979)
	Rana nigromaculata (Hallowell 1861)	Black-spotted pond frog	Tonosama-gaeru	Lowland area (paddy fields, ponds, marshlands)		Matsui (1979)
	Rana japonica (Boulenger 1879)	Japanese brown frog	Nihon aka-gaeru	Lowland area (paddy fields, mashlands)		Matsui (1979)
	Rana tagoi tagoi (Okada 1931)	Tago's brown frog	Tago-gaeru	Low mountain area (forest headstreams)		Matsui (1979)
	Rana ornativentris (Werner 1903)	Montane brown frog	Yama aka-gaeru	Low mountain to lowland area (paddy fields, mashlands, ponds)		Matsui (1979)
	Fejervarya limnocharis (Gravenhorst 1829)	Indian rice frog	Numa-gaeru	Lowland area (paddy fields)		Matsui (1979)
Family	Rhacophoridae					
	Rhacophorus schlegelii (Günther 1859)	Schlegel's green frog	Schlegel ao-gaeru	Low mountain to lowland areas (paddy fields, mashlands)		Matsui (1979)
	Rhacophorus arboreus (Okada et Kawano 1924)	Forest green tree frog	Mori ao-gaeru	Low mountain to lowland areas (ponds, paddy fields, mashlands)		Matsui (1979)
	Buergeria buergeri (Temminck et Schlegel 1838)	Kajika frog	Kajika-gaeru	Low mountain to lowland areas (forest streams and rivers)		Matsui (1979)

Reference

Matsui M (1979) Amphibians of Shiga Prefecture. In: Foundation of Nature Conservation in Shiga Prefecture (ed.) Land and life in Shiga prefecture. Otsu, Shiga, pp 591–614

Appendix 2.29

A list of Reptilia in and around Lake Biwa (M. Matsui)

Taxonomic level	Scientific name	English name	Japanese name	Habitat	Category in the Red List (RL) by the Ministry of Environment of Japan	References
Class	Reptilia					
Order	Testudines					
Family	Geoemydidae					
	Mauremys japonica (Temminck et Schlegel 1835)	Japanese pond turtle	Nihon ishi-game	Low mountain to lowland areas (littral zone, paddy fields, ponds, rivers)	DD	
	Mauremys mutica mutica (Cantor 1842)	Asian brown pond turtle	Minami ishi-game	lowland area (paddy fields, warerways)		
	Chinemys reevesii (Gray 1831)	Reeves' pond turtle	Kusa-game	Lowland area (rivers, ponds, paddy fields)		
Family	Emydidae					
	Trachemys scripta elegans (Wied 1839)	Red-eared slider	Mishishippi akamimi-game	Lowland area (littral zone, paddy fields, ponds, rivers)		
Family	Trionychidae					
	Pelodiscus sinensis (Wiegmann 1835)	Chinese softshell turtle	Suppon	Lowland area (littral zone, rivers)	DD	Fukada (1979)
Order	Squamata					
Suborder	Lacertilia					
Family	Gekkonidae					
	Gekko japonicus (Duméril et Bibron 1836)	Japanese gecko	Nihon yamori	Lowland area (human habitations)		
Family	Scincidae					
	Plestiodon japonicus (Peters 1864)	Japanese five-lined skink	Nihon tokage	Low mountain to lowland areas		
Family	Lacertidae					
	Takydromus tachydromoides (Schlegel 1838)	Japanese grass lizard	Nihon kanahebi	Low mountain to lowland areas (grasslands)		

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Taxonomic level	Scientific name	English name	Japanese name	Habitat	Category in the Red List (RL) by the Ministry of Environment of Japan	References
Suborder	Serpentes					
Family	Colubridae					
	Euprepiophis conspicillatus (Boie 1826)	Burrowing ratsnake	Jimuguri	Low mountain to lowland areas (forests)		Fukada (1979)
	Achalinus spinalis (Peters 1869)	Japanese odd-scaled snake	Takachiho hebi	Low mountain area (forests)		Fukada (1979)
	Elaphe climacophora (Boie 1826)	Japanese ratsnake	Aodaisho	Low mountain to lowland areas		Fukada (1979)
	Elaphe quadrivirgata (Boie 1826)	Japanese four-lined snake	Shima hebi	Low mountain to lowland areas		Fukada (1979)
	Amphiesma vibakari vibakari (Boie 1826)	Japanese keelback	Hibakari	Low mountain to lowland areas (paddy fields, marshlands)		Fukada (1979)
	Dinodon orientale (Hilgendorf 1880)	Oriental odd-tooth snake	Shiro-madara	Low mountain area (forests)		Fukada (1979)
	Rhabdophis tigrinus tigrinus (Boie 1826)	Tiger keelback	Yama-kagashi	Low mountain to lowland areas (paddy fields, marshlands)		Fukada (1979)
Family	Viperidae					
	Gloydius blomhoffii (Boie 1826)	Japanese mamushi	Nihon mamushi	Low mountain to lowland areas		Fukada (1979)

Reference

Fukada H (1979) Reptiles of Shiga Prefecture. In: Foundation of Nature Conservation in Shiga Prefecture (ed.) Land and life in Shiga. Otsu, Shiga, pp 567–589

Appendix 2.30

A list of Aves in and around Lake Biwa (by K. Kameda, J. Ueda, H. Hashimoto and H. Sugawa)

Taxonomic level	Scientific name	Japanese name	Origin of introduced species	Seasonal status[a]	Habitat		
					Lake Biwa and Attached Lakes		
					Pelagic[b] (>800 m from the shore)	Littoral (0–800 m from the shore)	Sand shores/ mud Flats
Order	Gaviiformes						
Family	Gaviidae						
	Gavia stellata	Abi		IA		+	
	Gavia arctica	O-hamu		W	+	+	
	Gavia pacifica	Shiroeri-ohamu		IA		+	
Order	Podicipediformes						
Family	Podicipedidae						
	Tachybaptus ruficollis	Kaitsuburi		R	+	+	
	Podiceps nigricollis	Hajiro-kaitsuburi		W	+	+	
	Podiceps auritus	Mimi-kaitsuburi		W		+	
	Podiceps grisegena	Akaeri-kaitsuburi		W		+	
	Podiceps cristatus	Kanmuri-kaitsuburi		R	+	+	
Order	Procellariiformes						
Family	Procellariidae						
	Calonectris leucomelas	O-mizunagidori		P		+	
Order	Pelecaniformes						
Family	Sulidae						
	Sula sula	Akaashi-katsuodori		IA	+	+	
Family	Phalacrocoracidae						
	Phalacrocorax carbo	Kawa-u		R	+	+	
	Phalacrocorax capillatus	Umi-u		IA		+	
	Phalacrocorax pelagicus	Hime-u		IA	+	+	
Order	Ciconiiformes						
Family	Ardeidae						
	Botaurus stellaris	Sankano-goi		R			

Habitat			Category in the Red List (RL) by the Ministry of the Environment of Japan (2007): CR:Criticall Endangered, EN:Endangered, VU: Vulnerable, NT: Near Threatened, DD: Data Deficient	References
Lake Biwa and Attached Lakes		Around the lake		
Reedbed	Riparian woods	Rivers, ponds, waterways, paddy Fields		
				Mori and Miura (1990)
				Sugawa (1991), Hashimoto and Sugawa (2008)
				Sugawa (1991)
+		+		Mori and Miura (1990), Sugawa (1991), Hashimoto and Sugawa (2008)
		+		Mori and Miura (1990), Sugawa (1991), Hashimoto and Sugawa (2008)
				Mori and Miura (1990), Hashimoto and Sugawa (2008)
				Mori and Miura (1990), Hashimoto and Sugawa (2008)
+		+		Mori and Miura (1990), Sugawa (1991), Hashimoto and Sugawa (2008)
				Mori and Miura (1990)
			EN	
		+		Mori and Miura (1990), Sugawa (1991), Hashimoto and Sugawa (2008)
				Mori and Miura (1990)
			EN	Sugawa (1991)
+			EN	

(continued)

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(continued)

Taxonomic level	Scientific name	Japanese name	Origin of introduced species	Seasonal status[a]	Habitat		
					Lake Biwa and Attached Lakes		
					Pelagic[b] (>800 m from the shore)	Littoral (0–800 m from the shore)	Sand shores/ mud Flats
	Ixobrychus sinensis	Yoshi-goi		S			
	Nycticorax nycticorax	Goi-sagi		R	+	+	
	Butorides striatus	Sasa-goi		S			
	Bubulcus ibis	Ama-sagi		S		+	
	Egretta alba	Dai-sagi		R	+	+	+
	Egretta intermedia	Chu-sagi		S		+	
	Egretta garzetta	Ko-sagi		R	+	+	+
	Egretta sacra	Kuro-sagi		IA		+	
	Ardea cinerea	Ao-sagi		R	+	+	+
	Ardea purpurea	Murasaki-sagi		IA		+	
Family	Threskiornithidae						
	Platalea minor	Kurotsura-herasagi		IA		+	+
Order	Anseriformes						
Family	Anatidae						
	Branta bernicla	Koku-gan		IA		+	
	Anser albifrons	Ma-gan		W		+	
	Anser fabalis	Hishikui		W		+	
	Cygnus cygnus	O-hakucho		W		+	
	Cygnus columbianus	Ko-hakucho		W		+	
	Tadorna ferruginea	Aka-tsukushigamo		IA		+	
	Tadorna tadorna	Tsukushi-gamo		IA		+	
	Aix galericulata	Oshidori		R	+	+	

Habitat			Category in the Red List (RL) by the Ministry of the Environment of Japan (2007): CR:Criticall Endangered, EN:Endangered, VU: Vulnerable, NT: Near Threatened, DD: Data Deficient	References
Lake Biwa and Attached Lakes		Around the lake		
Reedbed	Riparian woods	Rivers, ponds, waterways, paddy Fields		
+			NT	Mori and Miura (1990)
		+		Mori and Miura (1990), Sugawa (1991)
+	+	+		Mori and Miura (1990)
		+		Mori and Miura (1990)
		+		Mori and Miura (1990), Sugawa (1991), Hashimoto and Sugawa (2008)
		+	NT	Mori and Miura (1990)
		+		Mori and Miura (1990), Sugawa (1991), Hashimoto and Sugawa (2008)
		+		Mori and Miura (1990), Sugawa (1991), Hashimoto and Sugawa (2008)
+				
			CR	
			VU	
		+	NT	Mori and Miura (1990)
		+	NT[c]	Mori and Miura (1990), Sugawa (1991), Hashimoto and Sugawa (2008)
		+		Mori and Miura (1990), Hashimoto and Sugawa (2008)
		+		Sugawa (1991), Hashimoto and Sugawa (2008)
			DD	
			EN	
		+	DD	Mori and Miura (1990), Sugawa (1991), Hashimoto and Sugawa (2008)

(continued)

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(continued)

Taxonomic level	Scientific name	Japanese name	Origin of introduced species	Seasonal status[a]	Habitat		
					Lake Biwa and Attached Lakes		
					Pelagic[b] (>800 m from the shore)	Littoral (0–800 m from the shore)	Sand shores/ mud Flats
	Anas platyrhynchos	Ma-gamo		R	+	+	
	Anas poecilorhyncha	Karu-gamo		R	+	+	+
	Anas crecca	Ko-gamo		W	+	+	
	Anas formosa	Tomoe-gamo		W		+	
	Anas falcata	Yoshi-gamo		W	+	+	
	Anas strepera	Oka-yoshigamo		W	+	+	
	Anas penelope	Hidori-gamo		W	+	+	
	Anas americana	Amerika-hidori		W		+	
	Anas acuta	Onaga-gamo		W	+	+	
	Anas querquedula	Shimaaji		P		+	
	Anas clypeata	Hashibiro-gamo		W	+	+	
	Netta rufina	Akahashi-hajiro		W		+	
	Aytha ferina	Hoshi-hajiro		W	+	+	
	Aytha valisineria	O-hoshihajiro		IA		+	
	Aytha nyroca	Mejiro-gamo		IA		+	
	Aytha baeri	Aka-hajiro		IA		+	
	Aytha fuligula	Kinkuro-hajiro		W	+	+	

Habitat			Category in the Red List (RL) by the Ministry of the Environment of Japan (2007): CR:Criticall Endangered, EN:Endangered, VU: Vulnerable, NT: Near Threatened, DD: Data Deficient	References
Lake Biwa and Attached Lakes		Around the lake		
Reedbed	Riparian woods	Rivers, ponds, waterways, paddy Fields		
+		+		Mori and Miura (1990), Sugawa (1991), Hashimoto and Sugawa (2008)
+		+		Mori and Miura (1990), Sugawa (1991), Hashimoto and Sugawa (2008)
+		+		Mori and Miura (1990), Sugawa (1991), Hashimoto and Sugawa (2008)
		+	VU	Mori and Miura (1990), Hashimoto and Sugawa (2008)
		+		Mori and Miura (1990), Sugawa (1991), Hashimoto and Sugawa (2008)
		+		Mori and Miura (1990), Sugawa (1991), Hashimoto and Sugawa (2008)
		+		Mori and Miura (1990), Sugawa (1991), Hashimoto and Sugawa (2008)
		+		Hashimoto and Sugawa (2008)
		+		Mori and Miura (1990), Sugawa (1991), Hashimoto and Sugawa (2008)
+		+		Mori and Miura (1990)
		+		Mori and Miura (1990), Sugawa (1991), Hashimoto and Sugawa (2008)
				Hashimoto and Sugawa (2008)
		+		Mori and Miura (1990), Sugawa (1991), Hashimoto and Sugawa (2008)
				Hashimoto and Sugawa (2008)
			DD	Hashimoto and Sugawa (2008)
		+		Mori and Miura (1990), Sugawa (1991), Hashimoto and Sugawa (2008)

(continued)

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(continued)

Taxonomic level	Scientific name	Japanese name	Origin of introduced species	Seasonal status[a]	Habitat		
					Lake Biwa and Attached Lakes		
					Pelagic[b] (>800 m from the shore)	Littoral (0–800 m from the shore)	Sand shores/ mud Flats
	Aytha marila	Suzu-gamo		W	+	+	
	Melanitta fusca	Birodo-kinkuro		IA		+	
	Histrionicus histrionicus	Shinori-gamo		IA		+	
	Clangula hyemalis	Kori-gamo		IA		+	
	Bucephala clangula	Hojiro-gamo		W	+	+	
	Mergus albellus	Miko-aisa		W	+	+	
	Mergus serrator	Umi-aisa		W	+	+	
	Mergus squamatus	Korai-aisa		IA		+	
	Mergus merganser	Kawa-aisa		W	+	+	
Order	Falconoformes						
Family	Accipitridae						
	Pandion haliaetus	Misago		R	+	+	
	Milvus migrans	Tobi		R	+	+	
	Haliaeetus albicilla	Ojiro-washi		W		+	
	Haliaeetus pelagicus	O-washi		W		+	
	Accipiter gentilis	O-taka		R	+	+	
	Accipiter nisus	Hai-taka		W		+	
	Buteo buteo	Nosuri		W	+	+	
	Spizaetus nipalensis	Kuma-taka		R		+	
	Circus cyaneus	Haiiro-chuhi		W		+	
	Circus spilonotus	Chuhi		R		+	
Family	Falconidae						

Habitat			Category in the Red List (RL) by the Ministry of the Environment of Japan (2007): CR:Criticall Endangered, EN:Endangered, VU: Vulnerable, NT: Near Threatened, DD: Data Deficient	References
Lake Biwa and Attached Lakes		Around the lake		
Reedbed	Riparian woods	Rivers, ponds, waterways, paddy Fields		
		+		Mori and Miura (1990), Sugawa (1991), Hashimoto and Sugawa (2008)
				Mori and Miura (1990)
		+		Mori and Miura (1990), Sugawa (1991), Hashimoto and Sugawa (2008)
		+		Mori and Miura (1990), Sugawa (1991), Hashimoto and Sugawa (2008)
		+		Mori and Miura (1990), Sugawa (1991), Hashimoto and Sugawa (2008)
			DD	
		+		Mori and Miura (1990), Sugawa (1991), Hashimoto and Sugawa (2008)
	+		NT	Mori and Miura (1990), Hashimoto and Sugawa (2008)
	+	+		Mori and Miura (1990), Sugawa (1991), Hashimoto and Sugawa (2008)
	+		EN	Hashimoto and Sugawa (2008)
	+		VU	
	+	+	NT	Sugawa (1991), Hashimoto and Sugawa (2008)
	+	+	NT	Hashimoto and Sugawa (2008)
	+	+		Hashimoto and Sugawa (2008)
			EN	
+				Hashimoto and Sugawa (2008)
+		+	EN	Sugawa (1991), Hashimoto and Sugawa (2008)

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(continued)

Taxonomic level	Scientific name	Japanese name	Origin of introduced species	Seasonal status[a]	Habitat		
					Lake Biwa and Attached Lakes		
					Pelagic[b] (>800 m from the shore)	Littoral (0–800 m from the shore)	Sand shores/ mud Flats
	Falco peregrinus	Hayabusa		R	+	+	
	Falco columbarius	Ko-chogenbo		W		+	
Order	Guruiformes						
Family	Rallidae						
	Rallus aquaticus	Kuina		W		+	
	Porzana fusca	Hi-kuina		S		+	
	Gallinula chloropus	Ban		R		+	
	Fulica atra	O-ban		R		+	
Order	Charadriiformes						
Family	Rostratulidae						
	Rostratula benghalensis	Tama-shigi		S		+	
Family	Charadriidae						
	Charadrius dubius	Ko-chidori		S		+	+
	Charadrius placidus	Ikaru-chidori		R		+	+
	Charadrius alexandrinus	Shiro-chidori		IA		+	+
	Charadrius mongolus	Medai-chidori		P		+	+
	Pluvialis fulva	Munaguro		P		+	+
	Pluvialis squatarola	Daizen		P		+	+
	Vanellus cinereus	Keri		R		+	+
	Vanellus vanellus	Ta-geri		W		+	+
Family	Scolopacidae						
	Arenaria interpres	Kyojo-shigi		P		+	+
	Calidris ruficollis	Tonen		P		+	+
	Calidris subminuta	Hibari-shigi		P		+	+
	Calidris acuminata	Uzura-shigi		P		+	+
	Calidris alpina	Hama-shigi		W		+	+
	Calidris tenuirostris	Oba-shigi		P		+	+

Habitat			Category in the Red List (RL) by the Ministry of the Environment of Japan (2007): CR:Criticall Endangered, EN:Endangered, VU: Vulnerable, NT: Near Threatened, DD: Data Deficient	References
Lake Biwa and Attached Lakes		Around the lake		
Reedbed	Riparian woods	Rivers, ponds, waterways, paddy Fields		
		+	VU	Sugawa (1991), Hashimoto and Sugawa (2008)
		+		Hashimoto and Sugawa (2008)
+		+		
+		+	VU	
+		+		Mori and Miura (1990), Sugawa (1991), Hashimoto and Sugawa (2008)
+		+		Mori and Miura (1990), Sugawa (1991), Hashimoto and Sugawa (2008)
		+		
		+		
		+		Sugawa (1991), Hashimoto and Sugawa (2008)
		+		Sugawa (1991)
		+		
		+		
		+		
		+		Sugawa (1991)
		+		Sugawa (1991), Hashimoto and Sugawa (2008)
		+		Hashimoto and Sugawa (2008)
		+		
		+		
		+		
		+		Sugawa (1991), Hashimoto and Sugawa (2008)
		+		

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(continued)

Taxonomic level	Scientific name	Japanese name	Origin of introduced species	Seasonal status[a]	Habitat		
					Lake Biwa and Attached Lakes		
					Pelagic[b] (>800 m from the shore)	Littoral (0–800 m from the shore)	Sand shores/ mud Flats
	Eurynorhynchus pygmeus	Hera-shigi		IA		+	+
	Tringa erythropus	Tsuru-shigi		P		+	+
	Tringa stagnatilis	Ko-aoashishigi		P		+	+
	Tringa nebularia	Aoashi-shigi		P		+	+
	Tringa ochropus	Kusa-shigi		P		+	+
	Tringa glareola	Takabu-shigi		P		+	+
	Heteroscelus brevipes	Kiashi-shigi		P		+	+
	Actitis hypoleucos	Iso-shigi		R		+	+
	Xenus cinereus	Sorihashi-shigi		P		+	+
	Limosa limosa	Oguro-shigi		P		+	+
	Limosa lapponica	O-sorihashigi		P		+	+
	Numenius arquata	Dai-shakushigi		P		+	+
	Numenius madagascariensis	Horoku-shigi		P		+	+
	Numenius phaeopus	Chushaku-shigi		P		+	+
	Gallinago gallinago	Ta-shigi		W		+	+
	Gallinago hardwickii	Oji-shigi		P		+	+
Family	Phalaropodidae						
	Phalaropus lobatus	Akaeri-hireashishigi		P		+	
Family	Stercorariidae						
	Stercorarius pomarinus	Tozoku-kamome		IA		+	
	Stercorarius longicaudus	Shirohara-tozokukamome		IA		+	
Family	Laridae						
	Larus ridibundus	Yuri-kamome		W	+	+	
	Larus argentatus	Seguro-kamome		W	+	+	
	Larus schistisagus	O-segurokamome		W		+	
	Larus canus	Kamome		W	+	+	

Habitat			Category in the Red List (RL) by the Ministry of the Environment of Japan (2007): CR:Criticall Endangered, EN:Endangered, VU: Vulnerable, NT: Near Threatened, DD: Data Deficient	References
Lake Biwa and Attached Lakes		Around the lake		
Reedbed	Riparian woods	Rivers, ponds, waterways, paddy Fields		
		+	CR	
		+		
		+		
		+		
		+		
		+		
		+		
		+		Sugawa (1991), Hashimoto and Sugawa (2008)
		+		
		+		
		+		
		+		
		+	VU	
		+		
		+		Hashimoto and Sugawa (2008)
		+	NT	
		+		Mori and Miura (1990), Sugawa (1991), Hashimoto and Sugawa (2008)
				Mori and Miura (1990), Hashimoto and Sugawa (2008)
				Mori and Miura (1990), Sugawa (1991), Hashimoto and Sugawa (2008)

(continued)

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(continued)

Taxonomic level	Scientific name	Japanese name	Origin of introduced species	Seasonal status[a]	Habitat		
					Lake Biwa and Attached Lakes		
					Pelagic[b] (>800 m from the shore)	Littoral (0–800 m from the shore)	Sand shores/ mud Flats
	Larus crassirostris	Umineko		W	+	+	
	Larus saundersi	Zuguro-kamome		W		+	+
	Rissa tridactyla	Mitsuyubi-kamome		IA		+	
	Chlidonias hybridus	Kurohara-ajisashi		IA		+	
	Gelochelidon nilotica	Hashibuto-ajisashi		IA		+	
	Sterna hirundo	Ajisashi		P		+	
	Sterna fuscata	Seguro-ajisashi		IA		+	
	Sterna albifrons	Ko-ajisashi		S		+	+
Family	Alcidae						
	Brachyramphus marmoratus	Madara-umisuzume		IA		+	
	Synthliboramphus antiquus	Umisuzume		IA		+	
Order	Columbiformes						
Family	Columbidae						
	Streptolelia orientalis	Kiji-bato		R	+	+	
	Sphenurus sieboldii	Ao-bato		R		+	
	Columba livia	Do-bato	+	R		+	
Order	Cuculiformes						
Family	Cuculidae						
	Cuculus canorus	Kakko		S		+	
	Cuculus saturatus	Tsutsudori		S		+	
Order	Coradiiformes						
Family	Alcedinidae						
	Alcedo atthis	Kawa-semi		R	+	+	
Order	Piciformes						
Family	Picidae						
	Picus awokera	Ao-gera		R		+	
	Dendrocopos major	Aka-gera		R		+	
	Dendrocopos kizuki	Ko-gera		R	+	+	

Habitat			Category in the Red List (RL) by the Ministry of the Environment of Japan (2007): CR:Criticall Endangered, EN:Endangered, VU: Vulnerable, NT: Near Threatened, DD: Data Deficient	References
Lake Biwa and Attached Lakes		Around the lake		
Reedbed	Riparian woods	Rivers, ponds, waterways, paddy Fields		
				Mori and Miura (1990), Sugawa (1991)
			VU	Hashimoto and Sugawa (2008)
				Mori and Miura (1990)
				Hashimoto and Sugawa (2008)
				Mori and Miura (1990)
		+	VU	Mori and Miura (1990)
			DD	
			CR	
	+	+		Sugawa (1991), Hashimoto and Sugawa (2008)
	+			
	+	+		Hashimoto and Sugawa (2008)
	+			
	+			
+	+	+		Mori and Miura (1990), Sugawa (1991), Hashimoto and Sugawa (2008)
+	+			
	+			
	+			Hashimoto and Sugawa (2008)

(continued)

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(continued)

Taxonomic level	Scientific name	Japanese name	Origin of introduced species	Seasonal status[a]	Habitat		
					Lake Biwa and Attached Lakes		
					Pelagic[b] (>800 m from the shore)	Littoral (0–800 m from the shore)	Sand shores/ mud Flats
Order	Passeriformes						
Family	Alaudidae						
	Alauda arvensis	Hibari		R		+	
Family	Hirundinidae						
	Riparia riparia	Shodo-tsubame		P		+	
	Hirundo rustica	Tsubame		S	+	+	
	Hirundo daurica	Koshiaka-tsubame		S			
Family	Motacillidae						
	Motacilla cinerea	Ki-sekirei		R		+	+
	Motacilla alba	Haku-sekirei		R	+	+	+
	Motacilla grandis	Seguro-sekirei		R	+	+	+
	Anthus hodgsoni	Binzui		W		+	
	Anthus spinoletta	Tahibari		W		+	
Family	Pycnonotidae						
	Hypsipetes amaurotis	Hiyodori		R	+	+	
Family	Laniidae						
	Lanius bucephalus	Mozu		R		+	
Family	Turdidae						
	Luscinia calliope	No-goma		P			
	Tarsiger cyanurus	Ruri-bitaki		W		+	
	Phoenicurus auroreus	Jo-bitaki		W	+	+	
	Saxicola torquata	No-bitaki		P			
	Monticola solitarius	Iso-hiyodori		W	+	+	
	Turdus naumanni	Tsugumi		W		+	
Family	Sylviidae						
	Cettia diphone	Uguisu		R		+	
	Locustella ochotensis	Shima-sennyu		P			

Habitat			Category in the Red List (RL) by the Ministry of the Environment of Japan (2007): CR:Criticall Endangered, EN:Endangered, VU: Vulnerable, NT: Near Threatened, DD: Data Deficient	References
Lake Biwa and Attached Lakes		Around the lake		
Reedbed	Riparian woods	Rivers, ponds, waterways, paddy Fields		
		+		Hashimoto and Sugawa (2008)
+				
+				Sugawa (1991)
+				
		+		Sugawa (1991), Hashimoto and Sugawa (2008)
		+		Sugawa (1991), Hashimoto and Sugawa (2008)
+		+		Sugawa (1991), Hashimoto and Sugawa (2008)
+	+			Hashimoto and Sugawa (2008)
+		+		Sugawa (1991), Hashimoto and Sugawa (2008)
+	+	+		Sugawa (1991), Hashimoto and Sugawa (2008)
+	+	+		Sugawa (1991), Hashimoto and Sugawa (2008)
+	+			
+	+			Hashimoto and Sugawa (2008)
+	+	+		Hashimoto and Sugawa (2008)
+		+		
				Sugawa (1991), Hashimoto and Sugawa (2008)
+	+	+		Sugawa (1991), Hashimoto and Sugawa (2008)
+	+			Hashimoto and Sugawa (2008)
+	+			

(continued)

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(continued)

Taxonomic level	Scientific name	Japanese name	Origin of introduced species	Seasonal status[a]	Habitat		
					Lake Biwa and Attached Lakes		
					Pelagic[b] (>800 m from the shore)	Littoral (0–800 m from the shore)	Sand shores/ mud Flats
	Acrocephalus bistrigiceps	Ko-yoshikiri		P, S			
	Acrocephalus arundinaceus	O-yoshikiri		S			
	Cisticola juncidis	Sekka		R			
Family	Aegithalidae						
	Aegithalis caudatus	Enaga		R		+	
Family	Remizidae						
	Remiz pendulinus	Tsurisu-gara		W			
Family	Paridae						
	Parus varius	Yama-gara		R		+	
	Parus major	Shiju-kara		R		+	
Family	Zosteropidae						
	Zosterops japonicus	Mejiro		R		+	
Family	Emberizidae						
	Emberiza cioides	Hojiro		R		+	
	Emberiza fucata	Hoaka		W			
	Emberiza rustica	Kashiradaka		W		+	
	Emberiza elegans	Miyama-hojiro		W			
	Emberiza spodocephala	Aoji		W		+	
	Emberiza pallasi	Shiberia-Jurin		IA			
	Emberiza schoeniclus	O-jurin		W		+	
Family	Fringillidae						
	Fringilla montifringilla	Atori		W		+	
	Carduelis sinica	Kawara-hiwa		R		+	
	Leucosticte arctoa	Hagi-mashiko		W		+	+
	Uragus sibiricus	Beni-mashiko		W			
	Eophona personata	Ikaru		R		+	
	Coccothraustes coccothraustes	Shime		W		+	
Family	Ploceidae						
	Passer montanus	Suzume		R		+	

Habitat			Category in the Red List (RL) by the Ministry of the Environment of Japan (2007): CR:Criticall Endangered, EN:Endangered, VU: Vulnerable, NT: Near Threatened, DD: Data Deficient	References
Lake Biwa and Attached Lakes		Around the lake		
Reedbed	Riparian woods	Rivers, ponds, waterways, paddy Fields		
+	+			
+	+	+		
+		+		
+	+			Hashimoto and Sugawa (2008)
+	+			
	+			Hashimoto and Sugawa (2008)
+	+			Hashimoto and Sugawa (2008)
+	+			Hashimoto and Sugawa (2008)
+	+	+		Hashimoto and Sugawa (2008)
+		+		
+		+		Hashimoto and Sugawa (2008)
+	+			
+	+			Hashimoto and Sugawa (2008)
+				
+				Hashimoto and Sugawa (2008)
+	+	+		–
+	+			Hashimoto and Sugawa (2008)
+				
+	+			
	+			Hashimoto and Sugawa (2008)
	+			Hashimoto and Sugawa (2008)
				–
+	+	+		Sugawa (1991), Hashimoto and Sugawa (2008)

(continued)

Appendix 2.30

(continued)

Taxonomic level	Scientific name	Japanese name	Origin of introduced species	Seasonal status[a]	Habitat		
					Lake Biwa and Attached Lakes		
					Pelagic[b] (>800 m from the shore)	Littoral (0–800 m from the shore)	Sand shores/ mud Flats
Family	Sturnidae						
	Sturnus cineraceus	Mukudori		R		+	
Family	Corvidae						
	Corvus frugilegus	Miyama-garasu		W		+	
	Corvus corone	Hashiboso-garasu		R	+	+	
	Corvus macrorhynchos	Hashibuto-garasu		R	+	+	

There is no endemic bird species in Lake Biwa

[a]Seasonal Status, *R* resident, *S* summer visitor, *W* winter visitor, *P* passage visitor, *IA* irregular/accidental visitor

[b]Including islands in Lake Biwa

[c]NT is the category of Subspecies *Anser fabalis middendorffii* (O-hishikui) which inhabits in Lake Biwa

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Habitat			Category in the Red List (RL) by the Ministry of the Environment of Japan (2007): CR:Criticall Endangered, EN:Endangered, VU: Vulnerable, NT: Near Threatened, DD: Data Deficient	References
Lake Biwa and Attached Lakes		Around the lake		
Reedbed	Riparian woods	Rivers, ponds, waterways, paddy Fields		
+	+	+		Hashimoto and Sugawa (2008)
	+	+		Hashimoto and Sugawa (2008)
	+	+		Sugawa (1991), Hashimoto and Sugawa (2008)
	+	+		Sugawa (1991), Hashimoto and Sugawa (2008)

Appendix 3 Chronology: Major Lake Biwa-related events (M. Yoda)

Era	Year	Major Lake Biwa-related events	Major events in Japan and the world
Pliocene	Ca. 4.5 ma	Lake Oyamada, the initial stage of Lake Biwa, formed near the Iga Basin in Mie Prefecture.	Glacial, interglacial periods repeatedly influenced the Japanese archipelago.
	Ca. 1 ma	Lake Katata formed in Katata.	
Pleistocene	Ca. 0.4 ma	Northern lake basin formed.	
Paleolithic	Ca. 0.1 ma		Emergence of Paleolithic stone artifacts in the Japanese archipelago
	Ca. 40 ka		Beginning of the Late Paleolithic Period
	Ca. 20 ka	Emergence of knife-shaped stone tools around Lake Biwa, indicating the beginning of human settlement.	
Incipient Jomon	Ca. 13,000 B.C.		Beginning of pottery making and the Jomon Period
		The houses and clay figures of the Aidanikumahara Site were made around this time.	
Initial Jomon	Ca. 9,000 B.C.	The chestnut mound of the Awazu Lake Site formed.	Fishing became common. Emergence of shell mounds.
		The Tsuzurao Lake Site started to form.	
		The Ishiyama Shell Mound formed.	
Early Jomon	Ca. 5,000 B.C.	The first dugout canoe of Lake Biwa was made around Irie-Naiko (an attached lake of Lake Biwa).	
Middle Jomon	Ca. 3,500 B.C.	The Awazu Shell Mound formed.	
Late Jomon	Ca. 2,500 B.C.	The Matsubara-Naiko Site and the Shorakuji Site formed.	
		Emergence of many dugout canoes.	
Final Jomon	Ca. 1,200 B.C.	The Shigasato Site formed.	
Early Yayoi	Ca. 600 B.C.	Rice cultivation began in swamps (Ozuhama Site, Kawasaki Site, etc.).	Irrigated rice cultivation, and iron and bronze implements were brought to Japan from the Chinese continent.
	334 B.C		Alexander the Great began his conquest of the East.
Middle Yayoi	Ca. 350 B.C.	The Hattori Site and the Dainakanoko-minami Site formed.	
		Large farm villages emerged with rice paddies.	
Late Yayoi	Ca. 221 B.C.		The Qin unified China.
	Around the beginning of A.D.	Bronze bell-shaped vessels were buried in Mt. Oiwa.	
Kofun	Ca. 250	Large kofun tombs, Azuchi-Hyotanyama Kofun, Zeze-Chausuyama Kofun, and Kojinyama Kofun, were constructed facing towards Lake Biwa.	The Yamato throne was established. Emergence of keyhole-shaped tombs in the Nara (Yamato) basin.

(continued)

Appendix 3 (continued)

Era	Year	Major Lake Biwa-related events	Major events in Japan and the world
	589		The Sui Dynasty was established in China.
	593		Prince Shotoku was appointed regent for Empress Suiko.
	Ca. 600	End of keyhole-shaped tomb construction.	
Asuka	614		Inugami no Mitasuki was dispatched as a member of the first embassy to Sui China.
	622		Beginning of the Islamic Era
	624		The Tang Dynasty was established in China.
	646		The Taika Reforms was initiated.
	660		Fall of Paekche
	667	The capital was transferred to Otsu in Omi Province.	
	668		Silla unified Korea.
	671	Omi Code was enacted.	
	672	Otsu Palace was abolished.	The Jinshin Disturbance occurred.
Nara	710		The capital was transferred to Heijo-kyo.
	742	Construction of Shigarakinomiya Palace began (*Shoku Nihongi*).	
	759	Horanomiya Palace was constructed in Omi (*Shoku Nihongi*).	
	784		The capital was transferred to Nagaoka-kyo.
	788	Saicho built Enryakuji Temple.	
Heian	794	Furutsu in Omi Province was renamed as Otsu (*Shoku Nihongi*).	The capital was transferred to Heian-kyo.
	805		Saicho returned from the Tang, and established the Tendai sect.
	960		Rise of the Northern Song Dynasty in China.
	986	"Prohibition on hunting and fishing" was enforced within the area "north of Otsu, south of Kinugawa."	
	1000		*The Tale of Genji* was written by Murasaki Shikibu by this time.
	1065	The Shiotsu-Tsuruga Canal was planned by Taira no Kiyomori.	
	1066		Norman conquest of England.
	1096		First Christian Crusade.
	1127		Rise of the Southern Song Dynasty in China.

(continued)

Appendix 3 (continued)

Era	Year	Major Lake Biwa-related events	Major events in Japan and the world
	1183	Kiso Yoshinaka defeated the army of Taira no Tomomori and others in Seta.	Minamoto no Yoritomo took control of the Togoku (eastern Japan).
Kamakura	1190	Sasaki Sadatsuna was appointed *shugo* of Omi Province.	
	1192		The Kamakura Shogunate was founded.
	1215		The Magna Carta was issued.
	1262	Conflict regarding *eri*-trap fishing occurred between Chomeiji Temple and Oshima Shrine.	
	1271		Marco Polo began his journey to the East.
	1279		The Yuan unified China.
	1334		The Kemmu Restoration occurred.
	1337		The Hundred Years' War began.
Muromachi	1338	Kyogoku Doyo was appointed *shugo* of Omi Province.	Ashikaga Takauji received the title of *seii taishogun*, and founded Muromachi Shogunate.
	1354	Outbreak of a peasant uprising in Omi.	Rise of the Ming Dynasty in China.
	1368		
	1392		The Yi Dynasty was founded in Korea.
	1426	Uprising in Kyoto by *bashaku* (teamsters using horses) of Sakamoto.	
	1455		Johannes Gutenberg published the 42-line Bible, printed from movable type.
	1467		The Onin War (1467–1477)
	1492		Christopher Columbus landed in the Bahamas.
	1517		Protestant Reformation: *The 95 Theses* was published by Martin Luther.
	1571	Mt. Hiei was set on fire by Oda Nobunaga.	
Azuchi/ Momoyama	1573		Fall of Muromachi Shogunate
	1574	Nagahama-jo Castle was constructed.	
	1576	Construction of Azuchi-jo Castle began (1576–1579).	
	1582		The Honnoji Incident took place.
	1583	Toyotomi Hideyoshi enforced *kenchi* (land surveys) in Omi.	
	1587	*Otsu Hyakusosen* (a fleet of a hundred boats of Otsu) was established.	
	1598	Fall of Otsu-jo Castle.	Death of Toyotomi Hideyoshi.
	1600		The Battle of Sekigahara broke out. British East India Company was established.

(continued)

Appendix 3 (continued)

Era	Year	Major Lake Biwa-related events	Major events in Japan and the world
Edo	1603	Construction of Hikone-jo Castle began.	Tokugawa Ieyasu received the title of *seii taishogun*, and founded the Edo Shogunate.
	1644		Rise of the Qing Dynasty in China.
	1672	Transportation on Lake Biwa suffered a downturn.	Kawamura Zuiken established the Westbound Sea Route, a year after the Eastbound Sea Route.
	1734	Completion of *Omi Yochi Shiyaku* by Samukawa Tatsukiyo.	
	1776		US Declaration of Independence was issued.
	1789		The French Revolution began.
	1804		Napoleon was crowned French Emperor.
	1839		The Opium War broke out in China.
	1858	Ii Naosuke, the lord of the Hikone domain, was appointed *tairo* (Great Elder).	Treaty of Amity and Commerce between the United States and Japan was signed.
	1860		Sakuradamongai Incident occurred (Ii Naosuke was assassinated).
	1861		Civil War began in the United States.
Meiji	1868	Otsu Prefecture was established.	Meiji Restoration.
	1869	Ichiban-maru, the steamboat of the Kaga Daishoji domain, was launched between Kaizu and Otsu.	The national capital was transferred to Tokyo.
	1870	The steamship Niban-maru went into service.	
	1871		Establishment of the prefectural system. Unification of Germany.
	1876		Invention of the telephone by Alexander Graham Bell.
	1882	The Hokuriku railway line opened between Nagahama and Tsuruga. Taiko Steamboat Company was established.	
	1883	The first iron ship on Lake Biwa, First Taiko-maru was launched, followed by Second Taiko-maru.	The Sino-French War began.
	1885	Construction of the Lake Biwa Canal began.	
	1889	The Tokaido railway line in Shiga Prefecture was fully opened.	Constitution of the Empire of Japan was issued. The Tokaido Railway Line fully opened.
	1890	The first route of the Lake Biwa Canal, the in-line was completed.	First session of the Imperial Diet
	1891	The Otsu Incident occurred.	
	1895		The treaty of Shimonoseki was signed, ending the Sino-Japanese War.

(continued)

Appendix 3 (continued)

Era	Year	Major Lake Biwa-related events	Major events in Japan and the world
	1896	A massive flood occurred (the water level in the Torii River rose by 3.76 m).	The first modern Olympic Games were held in Athens.
	1900	Shiga Prefectural Fisheries Experiment Station was established in Fukumitsu Village, Inugami-gun (now Hikone City).	
	1905	The Nango Weir was completed.	End of the Russo-Japanese War.
	1907	The Hakkei-maru, an excursion boat of Taiko Steamboat Company, was launched. Nakagawa Gengo succeeded in collecting 1 million eggs of Biwa trout.	
Taisho	1912	The second route of the Lake Biwa Canal was completed.	Republic of China was established.
	1913	Construction of Uji River Power Plant was completed.	
	1914	The Otsu Hydrobiological Station of Kyoto University was established.	World War I began.
	1917		Russian Revolution.
	1919	The Mt. Ibuki Observatory started weather observation.	The Treaty of Versailles was signed, ending World War I.
	1922	The Prince of Wales went on a cruise on Lake Biwa during a visit to Japan.	
	1923	The Great Osaka-Tsuruga Canal Plan was announced.	Outbreak of the Great Kanto Earthquake.
Showa	1926	Toyo Rayon (now Toray Industries, Inc.) established its Shiga factory using Lake Biwa as the source of water.	
	1927		Financial crisis Nationalist China was established. Charles Lindbergh accomplished a nonstop solo flight across the Atlantic Ocean.
	1929		The Great Depression began.
	1933		Adolf Hitler became chancellor of Germany.
	1935	The Freshwater Pearl Farming Company was established in Shina Village, Kurita-gun (now Kusatsu City).	
	1939		World War II began in Europe.
	1941	Eleven rowing team members of the 4th Old Education System High School drowned in Lake Biwa.	The Pacific War began.
	1944	Matsubara-Naiko, Irie-Naiko (attached lakes) of Lake Biwa were designated to be reclaimed by Shiga Prefecture.	
	1945		Atomic bombs were dropped on Hiroshima and Nagasaki. Japan accepted the terms of the Potsdam Declaration. The United Nations was established.

Appendix 4 The Environmental history of Shiga Prefecture, with reference to those of Japan/world (M. Nishino & M. Maehata)

Year	Environment-related events in Shiga	Environment-related events in Japan and the world #
1950	Lake Biwa was designated as the first semi-national park in Japan (July)	
1951		
1956		"Industrial Water Law" was enacted (June)
1957	Reclamation of Dainakanoko Lake started (May)	"Natural Parks Law" was enacted (June)
1958		"Public Water Quality Preservation Law" and "Industrial Effluent Water Law" were enacted (December)
1959	*Closterium* (algae) proliferation caused water filtration failure in Kyoto	
1960	Pesticide PCP caused damage to fish and common fresh water clams (July)	
1961		
1962		
1963	*Elodea nuttallii* (waterweed) spread over the north basin of Lake Biwa	
1964		
1965	"Natural Parks Ordinance" was enacted (December)	
1966	Lakeshore landfill in Konohama town was completed (February)	
1967	Reclamation of Dainakanoko Lake was completed (October)	"Basic Act for Environmental Pollution Control" was enacted (August)
1968		
1969	• "Pollution Control Ordinance" was enacted (March)	The first "White Paper on Environmental Pollution" was published (May)
	• Moldy odor was generated in Lake Biwa, and complaints were made about musty water for the first time in Kyoto (May)	
	• Public sewers became available in Otsu	
1970	• Prefectural Pollution Control Office was established	14 environmental pollution related bills, such as the "Waste Management Law" and the "Water Pollution Prevention Law", were enacted (February)
	• About 400 complaints were made about stale water in Kyoto, Otsu and Osaka (June)	
1971	Lake Biwa was designated as a wildlife sanctuary (December)	• "Offensive Odor Control Law" was enacted
		• The Environmental Agency was established (July)

(continued)

Appendix 4 (continued)

Year	Environment-related events in Shiga	Environment-related events in Japan and the world #
1972	• Red tide was observed off the shore of Shiga Town (April)	• "Nature Conservation Law" was enacted (June)
	• Environmental standards for Lake Biwa were introduced (April)	• "Act on Special Measures for Developing the Lake Biwa Region" was enacted (June)
	• "Lake Biwa Environmental Preservation Measures" was formulated (May)	• Cabinet approval of the "Lake Biwa Comprehensive Development Plan" (December)
	• "Pollution Control Ordinance" was fully revised (December)	
	• Along with the enforcement of the "Water Pollution Control Law", the "Ordinance for More Stringent Effluent Standard" was enacted (December)	
1973	• *Egeria densa* (waterweed) overgrowth occurred in Lake Biwa	
	• "Shiga Prefecture Natural Environment Preservation Ordinance" was enacted (October)	
1974	Shiga Prefecture published the first "White Paper on Environmental Pollution"	
1975		
1976		
1977	*Uroglena* (alga) formed large red tide (May)	"Long-term Plan for Environmental Conservation" was formulated (May)
1978	Prefectural Association was formed for the Lake Biwa Soap Movement	
1979	"Lake Biwa Eutrophication Prevention Ordinance" (Lake Biwa Ordinance) was enacted (October)	
1980	• "Lake Biwa ABC Strategy" (New Lake Biwa Environmental Preservation Measures) was formulated (March)	
	• "Lake Biwa Ordinance" was enforced (July)	
1981	"Environmental Impact Assessment Guidelines" were adopted (March)	
1982		"Act on Special Measures for Developing the Lake Biwa Region" was revised, and a 10-year extension was made (March)
1983	First outbreak of blue-green algae in the south basin of Lake Biwa (September)	
1984	• Prefectural Institute of Public Health and Environmental Sciences detected the herbicides CNP and NIP from Lake Biwa fishery products (June)	• "Act on Special Measures concerning the Conservation of Lake Water Quality" was enacted (July)
	• "Ordinance for Preserving and Nurturing the Landscape of Shiga" (Landscape Preservation Ordinance) was enacted (July)	• The first World Lake Conference was held (August)
		• Cabinet approval of the "Basic Policy for the Conservation of Lake Water Quality" (December)

(continued)

Appendix 4 (continued)

Year	Environment-related events in Shiga	Environment-related events in Japan and the world #
1985	• Lake Biwa's water level dropped 95 cm due to severe drought, which was the second lowest ever recorded (January)	Lake Biwa was designated as a target of the "Act on Special Measures concerning the Conservation of Lake Water Quality" (December)
	• Along with the addition of nitrogen and phosphorus to the list of regulated items as substances affecting the lake environment in the revision of the "Order for Enforcement of the Water Pollution Control Law", the effluent standard was partially reviewed, and the "Ordinance for More Stringent Effluent Standard" was enacted (May)	
	• Shiga Prefecture chose locations for "A Hundred Views of Mother Lake" (June)	
	• The first rural public sewer was completed in Koto town (August)	
1986	• International Lake Environment Committee (ILEC) was established (February)	
	• Designation of "Lake Biwa Landscape Formation Areas" based on the "Landscape Preservation Ordinance" was announced, with a total designated area of 74,000 ha including the entire lake and surrounding lands (August)	
1987	"Water Quality Conservation Plan for Lake Biwa" based on the "Act on Special Measures concerning the Conservation of Lake Water Quality" was formulated (March)	
1988		
1989	• Unnatural death of 4 million Ayu fishes occurred in the north basin of Lake Biwa due to vibrionic infections (July)	
	• *Elodea nuttallii* spread over the south basin of Lake Biwa, and drifted to the shores in large volumes generating unusual smell (July)	
1990	• "Outline for Promoting Domestic Wastewater Measures" was enacted.	"Action Plan for the Prevention of Global Warming" was finalized (October)
	• A monitoring system was launched for red tide occurrence in Lake Biwa (April)	
1991	Abnormal growth of picoplankton in the north basin of Lake Biwa (June)	"Law for the Promotion of Utilization of Recycled Resources" was enacted (April)
1992	• "The Second Water Quality Conservation Plan for Lake Biwa" was formulated (March)	• "Seta River Weir Operating Rules" were enacted (March)
	• "Reed Colony Conservation Ordinance" was enforced (July)	• "Automobile NOx Control Law" was enacted (June)
	• "Anti-littering Ordinance" was enforced (July)	

(continued)

Appendix 4 (continued)

Year	Environment-related events in Shiga	Environment-related events in Japan and the world #
		#The "Rio Declaration on Environment and Development", and "Agenda 21" were adopted at the UN Conference on Environment and Development (The Earth Summit) (June)
1993	• Shiga Prefectural Science Museum of Water-Environment was completed (June)	"Basic Environmental Law" was enacted (November)
	• Lake Biwa became a designated wetland of the Ramsar Convention (June)	
1994	• "Agenda 21 Shiga" was formulated (April)	"Basic Environmental Plan" based on "Basic Environmental Law" was adopted at a Cabinet meeting (December)
	• "Bioenvironmental Advisory System" was adopted (June)	
	• First breakout of blue-green algae in the north basin of Lake Biwa (August)	
	• Lake Biwa's water level dropped 123 cm (record lowest) (September)	
1995	First School of Environmental Science in Japan was established at Shiga Prefectural University	• "Containers and Packaging Recycling Law" was enacted (June)
		• "National Biodiversity Strategy" was formulated (October)
		#International Environmental Technology Centre (IETC) was established in Shiga Prefecture by UNEP (April)
1996	• "Basic Environmental Ordinance", "Ordinance to Promote Domestic Wastewater Measures (Mizusumashi Ordinance)", "Ordinance for More Stringent Effluent Standard (effluent regulations of small scale businesses)" were enforced (July)	
	• Shiga Prefectural Lake Biwa Museum opened (October)	
1997	• "Third Water Quality Conservation Plan for Lake Biwa" was formulated (March)	• "Environmental Impact Assessment Law" was enacted (June)
	• Lake Biwa Comprehensive Development Project was completed (March)	• "River Law" was revised (addition of environmental conservation to its goals) (June)
	• Shiga Prefecture established the Department of Lake Biwa and the Environment (April)	
	• "Shiga Prefecture Comprehensive Environmental Plan" was formulated (October)	
		#Kyoto Protocol was adopted by COP3 in Kyoto (December)
1998	"Environmental Impact Assessment Ordinance" was enacted (December)	• "Home Appliance Recycling Law" was enacted (June)
		• Act on Promotion of Global Warming Countermeasures was enacted (October)
1999	"First Plan for Regional Promotion of Global Warming Countermeasures" was enacted (November)	"Pollutant Release and Transfer Register (PRTR) Law" was enacted (July)

(continued)

Appendix 4 (continued)

Year	Environment-related events in Shiga	Environment-related events in Japan and the world #
2000	• Landscape Guidelines "Omi Scenery Plan" were formulated (March)	• "Green Purchasing Law", "Construction Material Recycling Law", "Law for the Promotion of Effective Utilization of Resources (a fundamental revision to the 'Law for the Promotion of Utilization of Recycled Resources' enacted in 1991)" were enacted (May)
	• "Lake Biwa Comprehensive Conservation (Mother Lake 21) Plan" was formulated (March)	• "Basic Act for establishing a Recycling-based Society", and the "Food Recycling Law" were enacted (June)
		• "The Revised Basic Environmental Plan" was finalized (December)
2001	• Environmentally Friendly Agricultural Products Certification System was founded (April)	• The Environmental Agency was upgraded to the Ministry of the Environment (January)
	• Shiga Prefecture Basic Greening Initiative "Omi Green Environment 2010 Initiative" was formulated (June)	• "Automobile NOx/PM Control Law" was enacted (June)
2002	• "Fourth Water Quality Conservation Plan for Lake Biwa" was formulated (March)	• "The Revised Outline for the Promotion of Global Warming Countermeasures" was finalized (March)
	• "Waste Management Plan" was formulated (March)	• "The Revised National Biodiversity Strategy" was formulated (March)
	• "Anti-littering Ordinance" was revised (addition of penalties, guidance for participation in cleaning activities, etc.) and enforced (April)	• "Act on Soil Contamination Countermeasures" was enacted (May)
	• "Ordinance relating to the Appropriate Leisure Usage of Lake Biwa" was enacted (October)	• "Automobile Recycling Law" was enacted (July)
	• "Reed Colony Conservation Ordinance" was revised (addition of items relating to the effective usage of reeds, expansion of the scope of regulated activities) (December)	• "Law for the Promotion of Nature Restoration" was enacted (December)
		#Kyoto Protocol was concluded (June)
2003	• "Ordinance for Environmentally Friendly Agriculture Promotion" was enacted (March)	"Act on Environmental Conservation Activities/ Environmental Education Promotion" was enacted (July)
	• "Industrial Waste Tax Ordinance" was enacted (March)	
	• "Natural Parks Ordinance" was revised (addition of activity regulations in specific areas, etc.) (March)	
	• "Global Warming Countermeasures Promotion Plan" was formulated (March)	
	• "Basic Plan for the Appropriate Leisure Usage of Lake Biwa" was formulated (September)	
	• "Basic Plan for Environmentally Friendly Agriculture Promotion" was formulated (December)	

(continued)

Appendix 4 (continued)

Year	Environment-related events in Shiga	Environment-related events in Japan and the world #
2004	• "Lake Biwa Afforestation Ordinance" was enacted (March)	• "Direct Subsidy System for Environmentally Friendly Agriculture" was founded (April)
	• "Ordinance relating to the Promotion of Environmental Education" was enacted (March)	• "Invasive Alien Species Law" was enacted (June)
	• "Basic Plan for Reed Colony Conservation" was revised (June)	• "Landscape Law" was enacted (June)
	• "Environmental Education Promotion Plan" was formulated (October)	
	• "Prefectural Strategic Plan for Adoption of New Energy" was formulated (October)	
	• "Basic Plan for Lake Biwa Afforestation" was formulated (December)	
2005	• Shiga Prefectural Lake Biwa Environmental Research Institute opened (June)	• "Lake Biwa-Yodo River Basin Restoration Plan" was formulated (March)
	• "Ordinance for Prefectural Tax for Lake Biwa Afforestation" was enacted (July)	• "Act on Special Measures concerning the Conservation of Lake Water Quality" was revised (June)
		#Kyoto Protocol was enforced (February)
2006	• "Ordinance concerning the Symbiosis with Wild Fauna and Flora in Shiga Prefecture" was enacted (March)	
	• "Ordinance for Shiga Prefecture Lake Biwa Afforestation Fund" was enacted (March)	
	• "The Second Prefectural Waste Management Plan" was formulated (June)	
	• "Global Warming Countermeasures Promotion Plan" was revised (December)	
2007	• "Basic Plan concerning the Symbiosis with Wild Fauna and Flora" was formulated (March)	#"The Fourth Assessment Report of the IPCC" was released (November)
	• "The Fifth Water Quality Conservation Plan for Lake Biwa" was formulated (March)	
	• "Shiga Prefectural Government Action Plan for Global Warming Countermeasures" was revised (September)	
2008	• "Vision for a Sustainable Society in Shiga" was formulated (March)	
	• "Environmental Education Promotion Plan" was revised (March)	
	• "The Second Basic Greening Plan" was formulated (March)	
2009	• "Long-term Initiative for Biotope Network in Shiga Prefecture" was formulated (February)	
	• "Third Shiga Prefecture Comprehensive Environmental Plan" was formulated (December)	

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