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Perspectives on Integrated Coastal Zone Management

With 66 Figures, 53 Tables and Animation CD-ROM

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Preface

Coastal zone management is practised in some way or another in all coastal regions of the world. Historically, these practices have been dominated by the construction and deployment of engineering structures to defend economically valuable coastal assets against flooding and erosion. More recently the continued expansion of a range of, often competing, socio-economic activities at or close to the coastline such as fisheries, tourism, oil and gas extraction, nature conservation, industrial and urban development, has served to complicate the management task. Given the acceptance by governments of the general goal of sustainable development, a more sustainable coastal resources utilisation strategy will require a more interdisciplinary and integrated management process. Two recent conferences focused on the need for and the characteristics of integrated coastal management. The EERO-GKSS CONFERENCE "Changing Estuarine and Coastal Environments: sustainability and biodiversity in relation to economic aspects" addressed European issues; while the CDG-GKSS conference "Socio-economic Benefits of Integrated Coastal Zone Management" concentrated more on developing countries.

These two conferences and current activities taking place under the auspices of the IGBP-LOICZ scientific programme formed the knowledge pool for this book. The volume is not therefore a straightforward proceedings publication, rather it is a collection of writings selected on the basis of novelty and insightfulness. Other contributions have also been included in order to survey the strengths and limitations of a range of existing coastal zone management practises operating in different 'local' environmental and socio-economic contexts. The core message that is illuminated is that the management challenges posed are complex and multifaceted, encompassing physical forcing, natural hazard and variability and vulnerability, together with socio-cultural vulnerability problems.

The editors, May 1999

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Introduction and Overview

R.K. Turner · W. Salomons

Coastal Management Principles and Practice

Coastal areas are currently experiencing intense and sustained environmental pressures from a range of driving forces which have been increasing in their intensity over many decades. Responsible agencies are seeking better ways of managing the causes and consequences of the environmental change process in coastal zones. This volume contains chapters which discuss the basic principles underpinning a more integrated approach to coastal management, as well as other chapters which highlight practical obstacles to its implementation in both developed and developing countries. Governments are now committed to the policy goal (variously defined) of sustainable development. But the fulfilment of the sub-goal of sustainable utilisation of coastal resources via integrated management is likely to prove to be an especially difficult task. Any successful strategy will have to encompass all the elements of management from planning and design through financing and implementation. It also requires an interdisciplinary scientific and operational approach, combined with a more flexible and participatory institutional structure and emphasis to account for multiple stakeholders and their different resource demands. The importance of historical, socio-economic, cultural and ethical contexts should also be more fully recognized.

All coastal areas are facing a growing range of stresses and shocks, the scale of which now pose threats to the resilience of both human and environmental coastal systems. The pace and extent of change in coastal areas is controlled by an increasingly complex set of biogeochemical and socio-economic interrelationships and feedbacks, such that some analysts refer to the concept of coevolution in their analysis of coastal problems (Turner et al. 1996). In order to scope the many issues, problems and arguments surrounding the scientific analysis, valuation and management of coastal areas, a simplified organisational and auditing framework can prove useful. In this volume such a framework, the Pressure-State-Impact-Response (P-S-I-R) approach (Fig. 0.1), has been adopted to underpin the various chapter contributions. The P-S-I-R approach although simple is still flexible enough to be conceptually valid across a range of spatial scales. It also highlights the dynamic characteristics of ecosystem and socio-economic system changes, involving multiple feedbacks within a possible coevolutionary process (Turner et al. 1997).

Environmental pressure builds up via socio-economic driving forces – demographic, economic, institutional and technological – which cause changes in environmental systems 'stakes'. These changes include increased nutrient, sediment and water fluxes across drainage basins and into the marine environment; land cover and use changes, fragmentation and degradation of habitats; pollution of soil, water and atmosphere; and climate attention. The severity of some of the resulting damages is increased be-

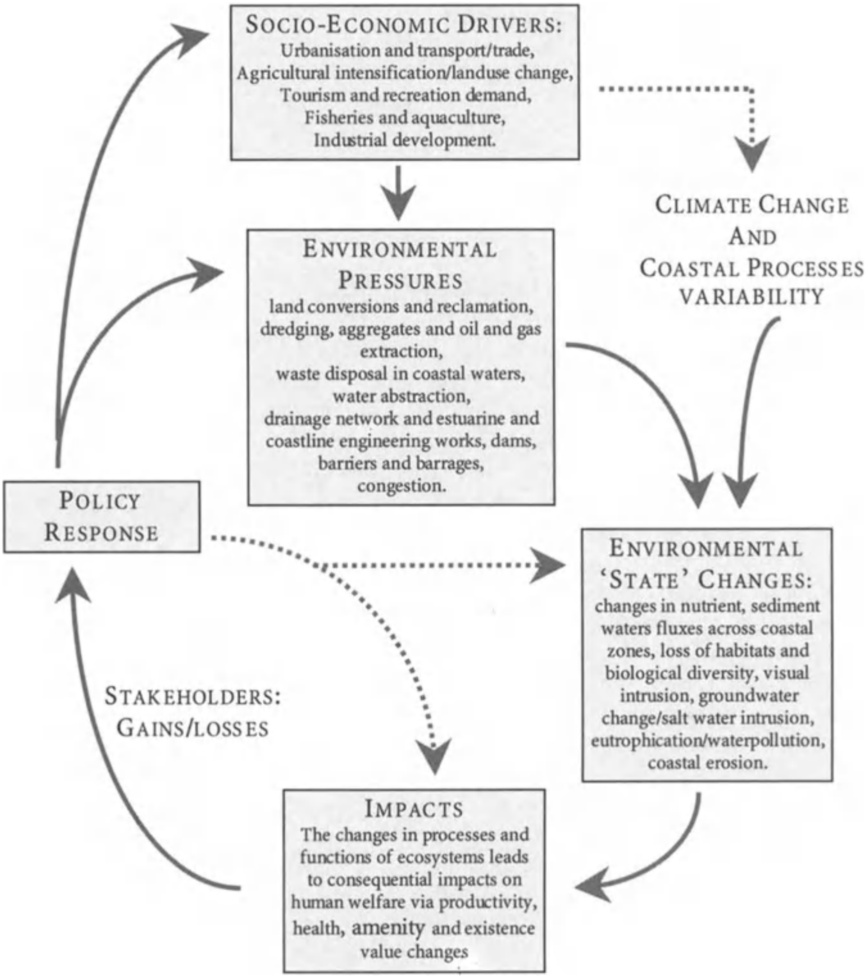

Fig. 0.1. P-S-I-R framework: continuous feedback process in coastal areas (*Source:* Turner et al. 1998b)

cause of the variability (natural and induced) of coastal processes. In situations where the processing and functioning capabilities of ecosystems are affected, human welfare consequences are felt. Social welfare losses occur because of productivity, health, amenity and other value changes. These impacts impose welfare losses and gains across a spectrum of different stakeholders, depending on the spatial, socio-economic, political and cultural setting. Policy response mechanisms will then be triggered within this continuous feedback process.

Understanding the interactions between the coastal zone and global changes cannot be achieved by observational studies alone. Modelling of key environmental processes is a vital tool that must be used if coastal management is to achieve its overall goals and objectives, particularly in view of the fact that many of the uncertainties in global carbon flow models may represent unquantified processes occurring within the coastal zone. For any group of researchers wishing to investigate and model a particular local coastal system (or aspects of that system) for subsequent up-scaling into larger models or wider regional estimates, there are initially two types of information required:

- estimations of biogeochemical fluxes in the system as it is now, for eventual incorporation into global estimates of flux through the coastal zone; and
- dynamic simulations of processes in the coastal system which can be used to explore the consequences of environmental change, and produce forecasts of future fluxes.

The second type of information set will require the integration of socio-economic and natural science data and models in two basic analytical contexts:

- to provide an understanding of the external forcing effects of socio-economic changes such as, for example, population growth, urbanisation, and other land use changes on fluxes of C, N, P and sediment; and
- to assess the human welfare impacts of flux changes due to of consequent processes and functions changes in coastal resource systems. Such assessments of the social costs and benefits involved will provide essential coastal management intelligence based on social science and possible resource and value trade offs.

The second analytical context poses a more formidable research task, not just because of the data requirements and the integration problem involving data which differs in form and in spatial and temporal scale, but because the long term goal is the development of an integrated prognostic assessment capability.

The assessment of the impact of changes in the coastal zone on human use of resources (wealth creation) and habitation (quality of life aspects) requires the application of socio-economic research methods and techniques in the context of coastal resource assessment and management. A particular contribution of socio-economic research is the incorporation of evaluation methods and techniques which can be applied to specific resource damage and utilisation situations (projects, policies or courses of action which change land use/cover, alter or modify residuals from point and non-point sources etc.) because of C, N and P flux changes and related consequences, including loss of functions and even habitats. Again most of these valuation studies will be at a local/regional level and the same scaling-up problem presents itself. However, the transfer of economic valuation estimates (known as benefits transfer) across time and geographical and cultural space is controversial (Turner and Adger 1996; Turner et al. 1998a).

The first chapter by Turner and Bower expands on the P-S-I-R framework in a discussion of the basic principles of integrated coastal management. Turner and Bower place considerable emphasis on a model based on the concept of functional diversity, which links ecosystem processes and functions with outputs of goods and services, which can then be assigned monetary economic and/or other values (Folke et al. 1996). Functional diversity can be defined as the variety of different responses to environmental change, in particular the variety of spatial and temporal scales with which organisms react to each other and to the environment (Steele 1991). This diversity concept encourages analysts to take a wider perspective and to examine change in large-scale ecological processes, together with the relevant socio-economic driving forces causing loss. The focus is then on the ability of interdependent ecological-economic systems to maintain functionality under a range of stress and shock conditions. Marine and terrestrial ecosystems differ significantly in their functional responses to environmental change and this will have practical implications for management strategies. Thus although marine systems may be much more sensitive to changes in their environments, they may also be much more resilient (i.e. more adaptable in terms of their recovery responses to stress and shock).

The sustainable utilisation of resources principle will be a key component of any future coastal management strategy. A real challenge will be to demonstrate in practical ways both the Total Economic Value (TEV) of coastal resources (use and non-use values) and capture mechanisms by which local people can participate in an equitable sharing of income and assets connected to the management of coastal zones under development pressures. Turner and Bower argue that the rate of social return derived from environmental conservation – motivated activities needs to be compared with the rate of return available from alternative development options, allowing for the prior correction of any existing market and institutional failures. Their approach is not reductionist in the sense that it neglects the overall systems perspective that is key to the understanding of the environmental change process. Rather it is narrowly drawn initially, at the level of individual ecosystem-functions), only in order to provide analytical rigour, as well as practical regulatory/policy relevance. At no time is the overall value of a healthy evolving set of environmental systems lost sight of. The term TEV is meant to describe, when appropriate, an aggregation of use values and other non-use (option and existence) values, in cases where it is feasible and meaningful to quantify such values in monetary terms, see Fig. 0.2. TEV is therefore less than total system value which incorporates the life support function and maybe other dimensions of environmental value such as intrinsic value i.e. the value of a saltmarsh or mangrove, for example, that resides in itself rather than of itself (Turner and Pearce 1993).

The second chapter by Burbridge focuses on the management challenges posed by the sustainable utilisation of coastal resources principle. It advocates the adoption of multiple-use management approaches in coastal areas i.e. where the choice of management boundaries for coastal systems is again based on functions and critical linkages with other systems, similar to approaches adopted in watershed management. According to Burbridge the management of processes is more important than management of uses and the relevant management institutions need to move beyond their traditional sectorally-based approaches. Developing the political will to improve the sustainability of the process of planning for, and management of coastal ecosystems is also he believes proving to be problematic. One of a number of requirements for such an improvement will be increased scientific understanding of the working of coastal systems.

The chapters by Underwood and Wolanski deal with aspects of CZM from the ecology and the physical science viewpoint respectively. The necessity for including the ecological sciences in a bottom-up approach is stressed in particular. However, the popular focus on key species to "charismatic" animals or plants does not do justice to the complexity and dynamic nature of an ecosystem. The best current approach is to

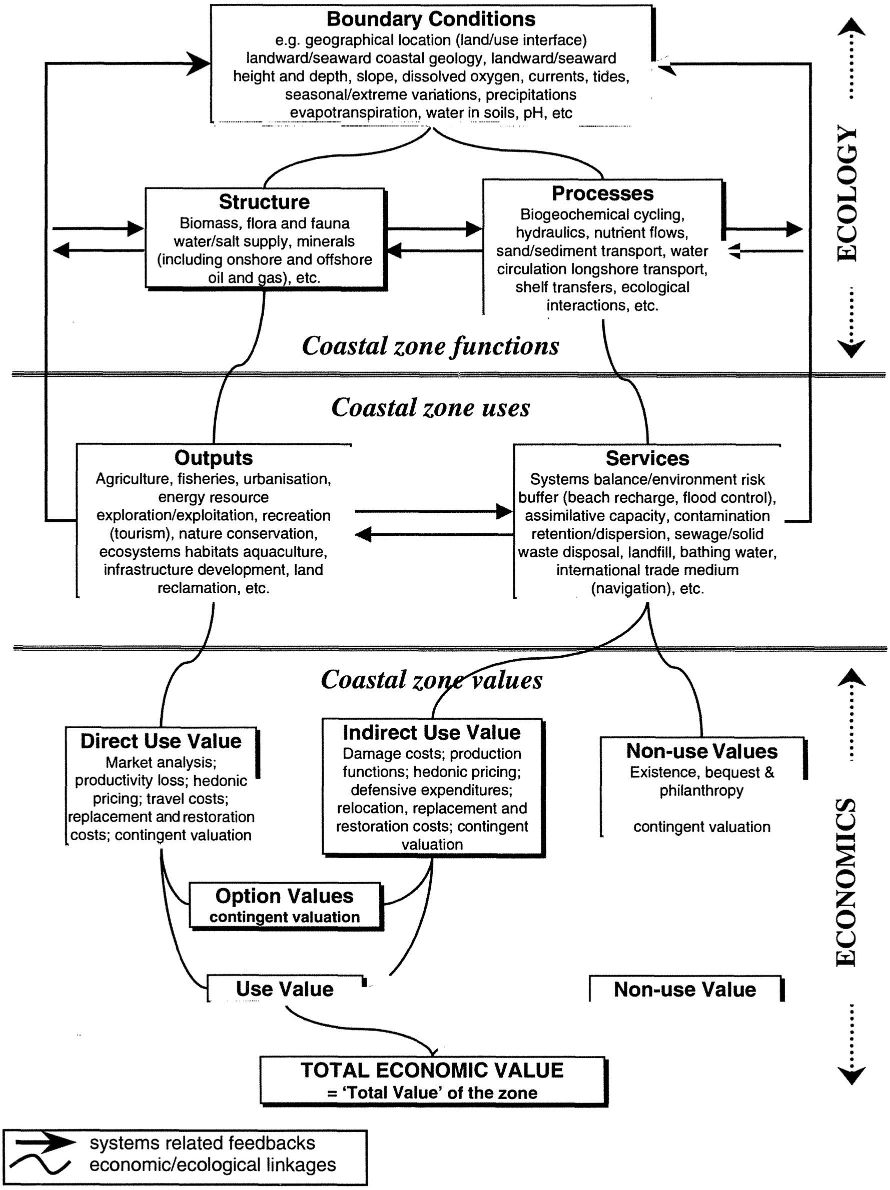

Fig. 0.2. Coastal zone functions, uses and values

treat the ecosystem as a web of demonstrated functional relationships. The biophysical sciences have to deal with patchiness at various scales which makes prediction of environmental effects at a particular location very difficult. both authors advocate detailed measuring and sampling methods to increase predictability. In particular what is called by Underwood "manager experiments" e.g. changes brought about by coastal management, should be accompanied by detailed sampling surveys of the ecosystem in order to learn from those changes and determine their applicability at different locations. In particular transfer of knowledge from a sandy coast line like the North Sea, about which an extensive scientific knowledge base exists, to rocky coastlines like those in Australia is hampered by difficulties both from ecological and physical viewpoints.

The chapters by Weide and Vrees and by Lange provide more details of the new methods and tools (or adapted versions of established ones) necessary to support integrated coastal management. Both chapters reinforce the importance of the systems analysis approach. Lange demonstrates the usefulness of Natural Resource Accounts (NRA). These accounts record stocks of natural resources and changes in stocks, together with use of resources and the environment. They are linked to economic accounts (national income, output and expenditure data) via the use of a common classification of economic activities. NRA can be compiled in both physical and monetary units for monitoring and/or policy analysis purposes. NRA is also a tool which facilitates a pro-active approach to policymaking, involving the use of "what if?" scenario simulations. Given the degree of uncertainty present in coastal management situations such an approach has much to recommend it.

No management prescriptions can possibly anticipate all the vagaries of the environmental change process. Flexibility and adaptability will be necessary characteristics for any future successful management strategy. Nevertheless since fundamental uncertainty over climate variability and change and the effects of coastal processes change and consequent losses will remain. There is generally considerable uncertainty about the threshold values of either populations of organisms or biogeochemical cycles for many of the most important ecosystems. Further, if a threshold is breached the implications are completely unknown (Perrings and Pearce 1994). Some judgement about the socially acceptable margin of safety (the 'precautionary principle') in the exploitation and protection of coastal resources will be required. The chapter by Stebbing and Willows explores the issues surrounding the application of such a precautionary approach by an analysis of the North Sea's assimilative capacity for wastes and effluents. Stebbing and Willows see assimilative capacity as a cross disciplinary concept that describes a resource of considerable economic value which, if it is exceeded, represents a limitation on the sustainable use of the marine environment. They advocate the use of biological techniques to monitor environmental quality and argue that the more traditional regulatory approach based on a predominantly chemical approach is deficient. Their approach uses measures of biological impact of contaminant loading, rather than an assessment of the health of the system based on the monitoring of single chemicals, or class of chemical containment.

Some judgement about the socially acceptable margin of safety (the degree of precaution that should be exercised) in the exploitation and protection of coastal resources is unavoidable. This is essentially an ethical judgement and there are a number of ways in which such an ethical dimension can be reflected in the decision-making process. The chapter by Ruijrock and Vellinga covers some of the cultural/ethical issues connected with resource management. They distinguish between three possible world views – weak, moderate and strong sustainability – and draw out the different resource management implications. It may therefore be possible more generally to discern a hierarchy of economic and ethical considerations, from immediate self-interest and resource use efficiency, through possible self-interest (reflected in a preference for more rather than less risk avoidance measures and policies), to care for and obligation towards future generations. An important task will be to further clarify where conventional economic values are sufficient for sustainability decisions and where broader human values – including non-monetary values – and criteria are more important.

It seems fair to conclude that the actual practice of coastal zone management around the globe is lagging well behind the emerging principles for sustainable actions and policy. The experiences of a number of developed and developing countries are recorded in several chapters in this volume. The studies cover a number of different contexts from individual coastal ecosystem management through to whole zone planning.

A number of chapters examine the coastal zone management issues associated with one particular pressure or coastal resource. Drude and Kjerfve report on the status and importance of mangroves in coastal Latin America. They note that a detailed inventory and classification of mangrove areas in Latin America is far from complete and this is inhibiting the further development of sustainable management strategies. The chapter by Conde and Rodríguez discussed the pressure from the oil industry on the Maracaibo system. Tourism is a major economic factor in many areas in the world, and the chapter by Sarda and Fluviá discusses the pressures, impacts and responses to such development in the Costa Brava region in Spain.

The regional practise and case studies on the one hand illustrate the various mechanisms, which are in place for coastal zone management and on the other hand highlight specific priority issues in coastal zone management. In most cases the issues connected to sea level rise are rather low on the agenda, more attention is given to the short to medium term problems stimulated by industry, tourism, fisheries and housing. For India (Ramachadran) a survey picked out population pressure and environmental degradation such as destruction of mangroves along with pollution and urbanisation, as the upcoming major problems. Sea level rise together with agriculture are not considered major issues. Also in Indonesia (Sukardjo), where 2/3 of the population already lives in the coastal zone, the pressure from population increase, in combination with associated increases in impacts from industry, sewage outfalls, etc., is singled out again as the major issue. Both authors give an overview of the various international agreements that have been signed and the judicial institutions in each of these countries. In both countries implementation of existing regulation is difficult, although the case study on a power plant in the Danahu region in India (Khanna et al.) shows the various regulatory phases and options deployed to control the power industry.

In Bangladesh which is downstream of rivers whose sources are in India and Nepal, receives a transboundary pollution loading, furthermore increased erosion in the Himalayas and Assam Hills causes high sediment load in the rivers and siltation and high turbidity problems in the coastal region.

Specific issues in South Asia are coral mining for the cement industry and its use as building material in certain parts of India, Sri Lanka and the Maldives.

The tourist industry will be a world leading economic sector by the year 2000, representing in 1997 already some 12% of the world GDP. Tourism brings income and jobs, increased understanding of other cultures, investment in infrastructure, which in turn brings social and cultural benefits. However, on the other hand, it can cause destruction of habitats, degradation of landscapes, and competition of scarce resources and services, such as land, freshwater, energy and sewage treatment. The chapter by Sarda illustrates the experience of 40 years of tourism development on the Spanish Coast. Aspects of this experience that should provide lessons for other areas. In particular, three areas along the Coast Brava can be distinguished with different development policy. The one focusing on short-term gains and rapid development resulted in a loss of attractiveness of the area for tourists. Better sustainability was observed for the other regions with policy and planning which exerted less pressure because of a lower relative priorities on immediate economic gains. A common problem of these tourist areas is the strong seasonal demands on the infrastructure, with populations rising more than 10-fold in the tourist season.

The chapter by Harvey on the Great Barrier is an illustration of coastal zone management developing over a period of more than 20 years. The major sanctioned activities are tourism and fishing and the only activities that are prohibited are commercial mining and oil drilling. In particular the tourism industry is growing, as elsewhere in the world, at a fast rate. Extensive zoning is practised for the Great Barrier Reef ranging from preservation zones and scientific research zones where only controlled scientific experiments are allowed, to "General Use" zones. In the general use zones activities are held at levels that will not jeopardize the ecosystem. Generally commercial and recreational fishing is allowed but bottom trawling is not permitted. Coastal zone management of the system involved a three tier system of government involving the Commonwealth (national) government, state and territory governments and local governments. However, local government authorities carry out much of the day to day coastal management. Harvey concludes that each dimension of integration in coastal zone management has been addressed including interactions among sectors, between regions, among government levels, and the wider community, and between disciplines. As such, in principle, all the requirements for integrated management have been met.

Coastal zone managers dealing with Lake Maracaibo system in Venezuela, discussed in detail by Rodríguez, have not only to cope with the pressure of the oil industry, but additionally with conflicts between artisanal and commercial fisheries and between fisheries and the oil industry. The oil industry has generated a large population increase and further industrialisation of the coastline. It has been estimated that over the last four decades almost 90% of the mangroves have been lost. Pollution and water availability problems are also generated upland. Construction of reservoirs has resulted in a reduced water flow. Large water consumers are electric power generation plants and cane sugar mills. The use of pesticides, fertilizers, herbicides and soil amendments is wide spread in the upland drainage basins. A complicating factor, as in the case of Bangladesh, is the transboundary nature of the management issues. Close to one quarter of the population living in the watershed of the lake are in Columbia. The success of an ICZM programme depends strongly on cooperation of the Colombian government. The activity of powerful guerrilla groups active in blasting oil pipe lines, makes life even more difficult for resource managers, the industry itself and government regulations.

The Tokyo Bay case study by Takao and Bower provides a detailed analysis of a very intensely utilized coastal area. Multiple usage has led to heavy pollution and habitat alteration in the bay area over a long period of time. In order to assess the costs and benefits of a range of management strategy options, the authors have simulated three possible future economic/policy scenarios and their implications for the bay and its environs. In practice, a key issue turned out to be the future provision of water-based recreation in the bay and the benefits of such a policy. The costs of implementing the recreation plan were dominated by liquid waste disposal costs at sewage treatment plants and industrial facilities; together with the costs associated with the recreation itself e.g. conversions of old port facilities, construction of artificial beaches etc. The simulation results suggested that two conditions were required for achieving significant net benefits from management of Tokyo Bay – improved and maintained ambient water quality and increased provision of recreation facilities.

The final chapter by Glaeser brings together many of the concepts and issues discussed in earlier chapters, in the context of an integrated coastal zone strategy for Sweden. He surveys the multiple resource uses that are pressurising the Swedish coastal zone and then examines the institutional options for the management of the coast.

If one picture arises from these contributions it is that the scientific and management foundations for integrated coastal region management are reasonably well understood. But this merely informs us how the coastal region management should function in an ideal world. Reality is both more complex and beset by uncertainty.

The impacts on the coastal region are very well identified by the biophysical sciences. A large knowledge base exists but in many cases it is not possible to transfer the insights from one region to another. The integration of the findings of the biophysical sciences with those of the socio-economic sciences is still in need of improvement. Considering the international science efforts in the field of climate change and sea level rise it is remarkable that these issues are not high on the agenda of coastal region managers. More pressing and important for the short and medium terms are all the issues associated with population increase; an increase that is disproportionate for the coastal zone. Particular issues within this context are industrial development, tourism, recreational and commercial fisheries and traffic in general. Although schemes exist for coastal region management, the issue of transboundary impacts through watersheds has not been fully addressed.

Solutions will require at the science level a stronger cooperation and integration of the natural and social sciences in order to derive the necessary predictive tools. On the management side all contributions advocate better incorporation of all stakeholders in the decision making process. Again, very few examples exist on how this could be done successfully (O'Riordan and Ward 1997). In the main time we have to learn from each others experience and determine whether and how one solution working in region A can or cannot be applied to region B.

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Part I

Methodological Principles

Chapter 1

Principles and Benefits of Integrated Coastal Zone Management (ICZM)

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1.1 Introduction

In many ways coastal zones typify the problems and policy challenges presented by the process of Global Environmental Change (GEC). These zones are under increasing environmental (resource usage/over-usage) pressure and are exhibiting unacceptable environmental state changes as a consequence of population growth, urbanisation, tourism and other multiple and often conflicting resource usage trends. The mitigation of the resource conflict problems and the practical adaptation of the sustainable economic development policy objective requires innovative policy responses. Integrated Coastal Zone Management (ICZM) is such a comprehensive policy/management response option. At its core should be a process which enables policy makers to strike a socially acceptable balance between conflicting stakeholder resource demands as they manifest themselves in different economic, socio-political (and institutions), cultural and environmental contexts.

ICZM has to embrace a range of general principles (also highlighted in UNCED's Agenda 21 action programmes);

- E *Economically efficient resource usage* – supplemented by principles such as polluter pays and proper resource accounting;
- S *Sustainable resource usage* – supplemented by intragenerational and intergenerational equity concerns and transboundary responsibility;
- P *Precautionary action* – involving a more sophisticated recognition of the problems and issue posed by both scientific and social uncertainties.

Again the concept of "balance" is paramount because even these basic (E, S, P) underlying principles are not necessarily all complimentary across all situations, trade-offs will be inevitable.

This paper outlines a methodology for the assessment of the social benefits to be gained from implementation of integrated coastal zone management (ICZM). The methodological approach that is recommended is based on economic efficiency principles, and involves cost-benefit/cost-effectiveness analytical methods combined with scenario analysis. The economic efficiency object is modified where necessary to account for other objectives by imposing constraints on the net benefit criterion. The basic approach has to be modified to fit the particular conditions, e.g. multiple resource outputs and competing resource demands, usually found in coastal zones.

ICZM is a continuous, adaptive, day-to-day process which consists of a set of tasks, typically carried out by several or many public and private entities. The tasks together

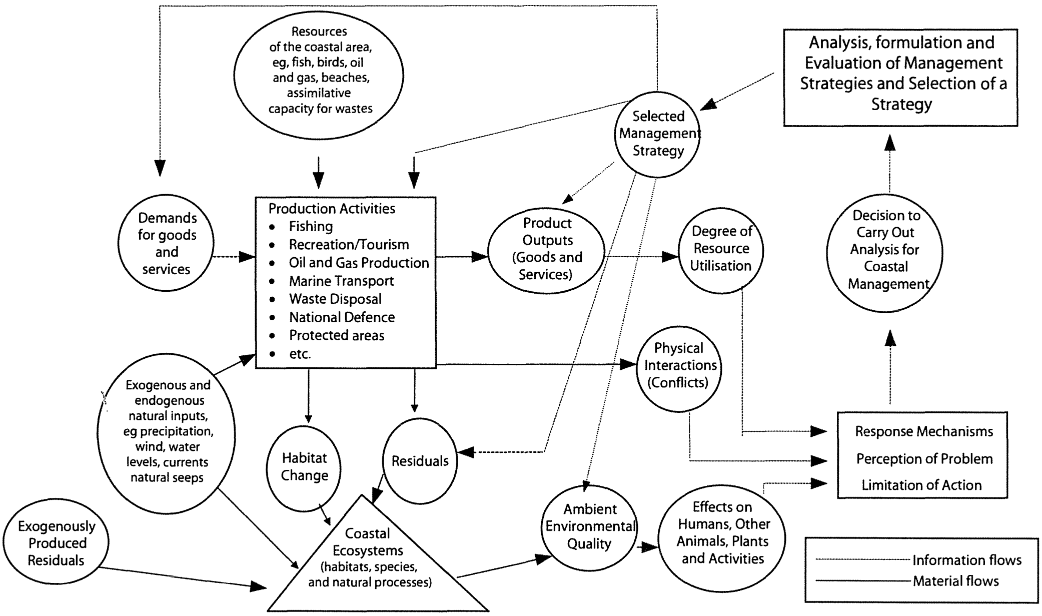


Fig. 1.1. Coastal management system

produce a mix of products and services from the available coastal resources. ICZM involves continuous interaction between human systems and natural systems, among human systems, and among natural systems, as these systems "coevolve" over time (Turner et al. 1997a). The management process must therefore be dynamic and adaptive in order to cope with changing circumstances, changing social tastes, increased knowledge of the behaviour of coastal processes and of human behaviour and "value" of coastal ecosystems, as well as, changing technology, changing factor prices and changing governmental policies (Ehler and Bower 1995; Turner and Bower 1995). The coastal system to be managed is shown conceptually in Fig. 1.1.

Because the resources of a coastal zone can generate a range of different products and services, not all of which are naturally compatible, conflicts are likely and trade-offs necessary. This situation is exacerbated by the variety of different stakeholders that are usually present in any given coastal zone. Moreover, the coastal zone resource base is now under severe pressure from the sheer "scale" of the resource demands that are being generated. Parts of the coastal zone have become increasingly susceptible (more vulnerable) to stress and shock and consequent environmental/economic damage by climate and other natural geophysical factors, together with population, urbanisation, waste generation and disposal pressures. This is exemplified by projections for Chesapeake Bay (USA), indicating that the substantial expenditures over the last 10–15 years to improve water quality will be negated by uncontrolled growth in population and economic activity (Anonymous 1996). These pressures, the consequent changes in the "state" of the coastal environment and human response options need to be evaluated in a consistent and systematic fashion (Turner et al. 1996).

1.2 Pressure-State-Impact-Response (P-S-I-R) Framework

A particular characteristic of modern economic development (encompassing population and population density increases, urbanisation, intensification of agriculture and industrial processing) is that it has led, among other changes, to the progressive opening of biogenic nutrient cycles e.g. much increased mobility of nitrogen and phosphorus. The increased mobility of nutrients has meant increased exchanges between land and surface water and consequent impacts on ecological functioning of aquatic systems. Other process changes involving water and/or sediment movement together with the transport of heavy metals and other substances have also added to the cumulative changes experienced in coastal systems.

The coastal areas interface between the continents and the ocean is comprised of a continuum of aquatic systems including the network of rivers, the estuaries, the coastal fringe of the sea, the continental shelf and its slope. These interdependent systems are characterized by very significant biogeochemical processes – primary productivity generation, organic matter and nutrient sinks etc. The major flux of nutrients from land to sea occurs through river transport, via the drainage basins network. The network contains various "filters" (e.g. wetlands) retaining or eliminating nutrients during their downstream passage to the sea. The effectiveness and selectivity of these filters depend on the strong biogeochemical coupling existing between carbon, nitrogen, phosphorus and silica circulation and they are also affected by hydrology and land use/cover (Billen et al. 1995).

A useful starting point for both natural and social science research would be to seek (via a more integrated modelling and assessment process) to better describe and understand the functioning of the ecosystems forming the coastal interface, and in particular the filter effect it exerts for nutrients, in response to environmental pressures, both anthropogenic and non-anthropogenic – climate change, land use/cover change, urbanisation and effluent treatment from both point and non-point sources. But first we need some broad analytical framework (rather than a specific model) in which to set the more detailed analysis.

The P-S-I-R cycle offers such a generalized context – see Fig. 1.2. For any given coastal area (defined if necessary to encompass the entire drainage network) there will exist a spatial distribution of socio-economic activities and related land uses – urban, industrial mining, agriculture/forestry/aquaculture and fisheries, commercial and transportation. This spatial distribution of human activities reflects the final demand for a variety of goods and services within the defined area and from outside the area.

The production activities result in different types and quantities of residuals, as well as goods and services measured in Gross National Product (GNP) terms. Environmental processes will transform the time and spatial pattern of the discharged/ emitted residuals into a consequent short-run and long-run time and spatial ambient environmental quality pattern. Thus we need to know more about the impacts of, for example, C, N and P flux changes on systems (including socio-economic systems).

These state environmental changes impact on human and non-human receptors resulting in a number of perceived social welfare changes (benefits and costs). Such

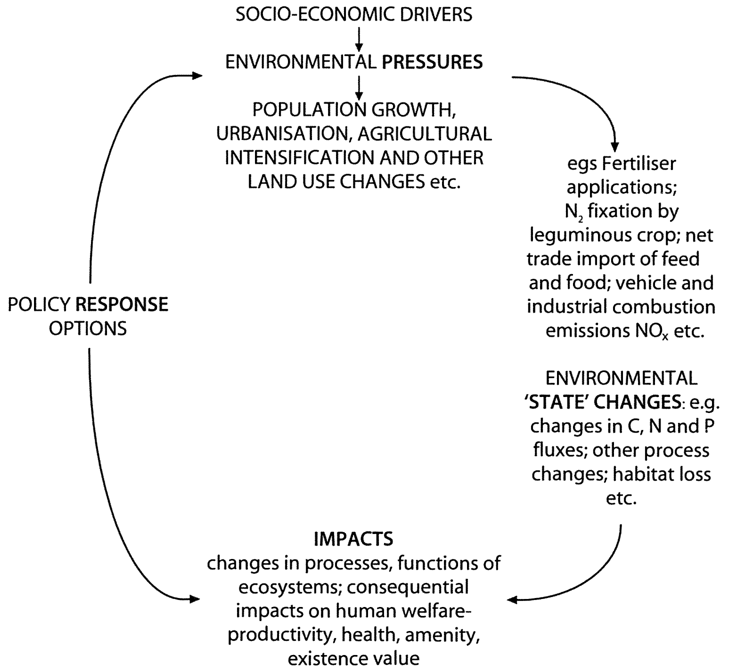


Fig. 1.2. P-S-I-R cycle, continuous feedback process (*Source:* Turner et al. 1997b)

welfare changes provide the stimulus for management action which depends on the institutional structure, culture/value system and competing demands for scarce resources and for other goods and services in the coastal zone. An integrated assessment approach will need to encompass within its analytical framework the socio-economic and biophysical drivers that generate the spatially distributed economic activities and related ambient environmental quality, in order to provide information on future environmental states. The elements required in an integrated coastal zone management process will be outlined in Section 1.4, but first a more detailed examination of the causes of environmental damage in the coastal zone is presented.

Table 1.1 presents a typology of market and intervention failures which have been identified in coastal zones. A marked feature of the pollution and resource overexploitation problems in coastal zones is the significance of "out of zone" activities and their effects. Most of the damage occurring in the coastal zone is related to activities that have taken place within the wider drainage basin areas and beyond. Thus around 12% of the nitrogen and ammonium loads entering the Baltic Sea, for example, are due to atmospheric deposition linked to emissions from as far away as Belgium, Netherlands, Norway, France and the UK. Other examples include:

- *San Francisco Bay:* Major modification of inputs to the coastal zone have resulted from consumptive use of water and discharge of pollutants upstream and from major diversions of water out of the basin south to Southern California.

Table 1.1. Market and governmental intervention failures in coastal zones (*Source:* Bower and Turner 1997)

Market failures		
1.	Pollution externalities	
a	Air pollution, outside catchment sources	Excess levels of nitrogen, phosphorus and ammonia contributing to eutrophication of water bodies;
b	Water pollution, land-based with-in catchment sources	Excess nitrogen and phosphorus from sewage and agricultural sources; industrial wastewater and toxic effluent pollution particularly from the pulp-and-paper and chemical industrial operations, nuclear power plants and research installations, military installations;
c	Water pollution, coastal and marine sources	Excess nitrogen and phosphorus from coastal sewage outfalls; oil spills and contaminated bilge water from ships; outside catchment pollutants transported via longshore currents.
2.	Public goods-type problems	
a	Ground-water depletion/surface-water supply diminution	Over exploitation on-and-off-site of water supply;
b	Congestion costs, on-site	Recreation pressure on beaches, wetlands and other sensitive ecosystem areas;
c	Fisheries yield reduction	Over exploitation due to open access, loss of habitat, water pollution.
Intervention failures (including lack of intervention)		
3.	Intersectoral policy inconsistency	
a	Competing sector output prices	Agricultural price fixing and associated land requirements;
b	Competing sector input prices	Tax breaks or outmoded tax categories on agricultural land; or tax breaks for non-agricultural land development, including forestry; land conversion subsidies; state farming subsidies (historical) and other waste, wastewater and energy subsidies.
4.	Counterproductive factors	
a	Inefficient policy	E.g. strategies that lack a long-term structure; wastewater and industrial effluent combined treatment practices; general lack of enforcement of existing policy rules and regulations;
b	Institutional failure	Non-integrative agencies structure, non-existent agencies; lack of monitoring survey and enforcement because of capacity inadequate resources such as trained personnel, equipment and operating funds; lack of information dissemination; lack of public awareness and participation;
5.	Conflicting perceptions	Different perceptions of a problem among stake-holders and management officials, e.g. local inhabitants and local governments do not consider hurricane or coastal storm flooding a major hazard, in contrast to specialists and state/federal/national government officials; or fishermen who do not think overfishing is a problem when state/federal/national agencies do.

- *Chesapeake Bay:* About 5 years ago, it was estimated that around 30% of the nitrogen inputs into the bay were from sources outside the bay via atmospheric transport. A recent study (Blankenship 1995), yielded an estimate of about 75%.

- *Lake Superior:* Analysis by Cohen et al. (1995) showed that about 90% of several pollutants of concern, are being brought into the lake from outside the drainage basin by atmospheric transport.
- *Bay of Sengal, Jakarta Bay:* Both water bodies are stressed significantly by pollutant materials from agricultural and forest areas upstream.
- Perhaps the epitome of effects on a coastal zone from activities outside the coastal zone is represented by the *Gulf of California*. Since about 1950, essentially no water from the Colorado river has reached the Gulf of California. What little water which is in the river from return irrigation flows after the last diversion in Mexico, simply evaporates in this desert country.

The objective of coastal zone management is to produce over time a "socially desirable" mix of coastal zone products and services. This mix is likely to change over time with changing demands, changing knowledge and changing pressures. Fulfilment of this objective will require the mitigation of current market and intervention failures; continuous monitoring of performance and of coastal zone conditions; and application of research findings over time. The desired social mix can be most effectively and efficiently provided by an integrated approach to coastal zone management. The analysis required for ICZM performs an overall resource management auditing role; it forces decision makers to ask relevant questions relating to coastal ecosystems and processes, coastal zone pressure trends, trade offs, environmental impacts and various aspects of response strategies, including sources of finance and human/institutional capital resource potential. In macro-policy terms, ICZM can be seen as a component of sustainable resource management within a regional/national economic development strategy.

1.3 The Elements of Integrated Coastal Zone Management (ICZM)

What does "integrated" in ICZM mean? Our experience suggests that, at a minimum, *integrated* coastal zone management should include:

- integration of programmes and plans for economic development, environmental quality management, and ICZM;
- integration of ICZM with programmes for such sectors as fisheries, energy, transportation, water resources management, disposal of wastes, tourism, and natural hazards management;
- integration of responsibilities for various tasks of ICZM among the levels of government – local, state/provincial, regional, national, international – and between the public and private sectors;
- integration of all stakeholders in all aspects of the management process;
- integration of all elements of management, from planning and design, through implementation, i.e. construction and installation, operation and maintenance, monitoring and feedback, evaluation over time;
- integration among disciplines, e.g. ecology, geomorphology, marine biology, economics, engineering, political science, law; and
- integration of the management resources of the agencies and entities involved.

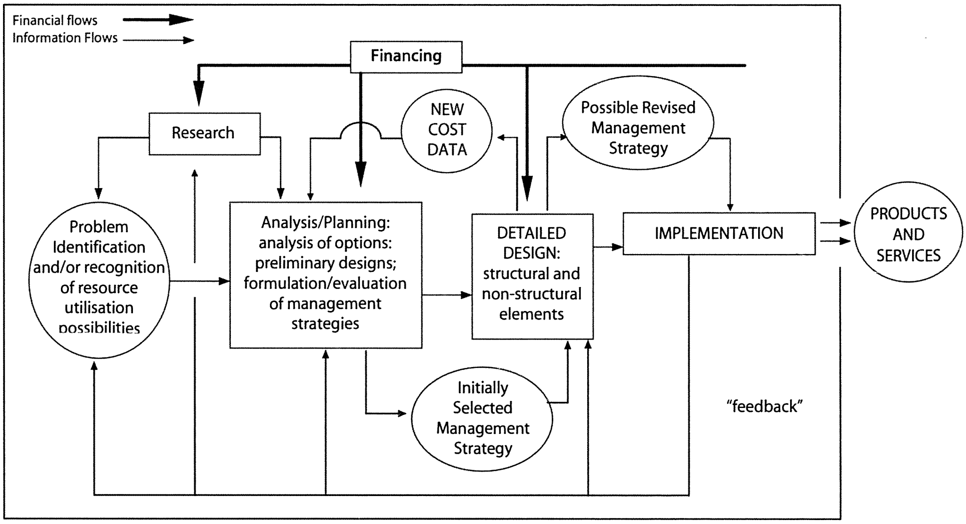


Fig. 1.3. Simple schematic of the elements of ICZM (*Source:* Bower and Turner 1997)

The hypothesis is that there is a positive correlation between the degree of integration achieved and the probability of achieving the estimated benefits.

Figure 1.3 depicts the elements of ICZM. Analysis generates the information which is subsequently utilized in planning decisions, which are made at various points in time in any given management context/area. A planning decision determines the distribution, timing and location of the coastal goods and services produced, the methods of delivery, and the receivers and payees.

This analysis/planning process will therefore be a significant component of ICZM. It is underpinned by biophysical research and data relating to various processes, structures, stocks, flows, and dose response relationships. From an economic perspective it should be based on the cost-benefit/economic efficiency criterion and evaluation method tempered by any relevant equity considerations, other precautionary environmental (e.g. ambient quality) standards, and regional economic constraints. In the standard cost-benefit method the traditional decision criterion is, maximize net economic benefits. This criterion is too narrow, however, in situations when not all resource values can be translated into monetary terms and when criteria other than economic efficiency are deemed important by the relevant decision makers. Operational trade off relationships can nevertheless be developed by imposing constraints (e.g. ambient environmental quality, regional employment/income targets, conservation of designated nature reserves etc.) on net economic benefit estimation.

In many coastal areas, maintenance or expansion of a regional economy is a major, often a primary, objective. Adverse effects on coastal economies, e.g. tax revenues, tourist expenditures, employment, can occur as a result of degraded water and/or beach quality or loss of or damage to unique natural features, such as a coral reef. Thus, beach replenishment programmes are typically justified on the basis of the need to maintain local economies dependent on tourism. In the context of regional or area economic development, the objective of ICZM can be expressed as:

Maximize the present value of:

$$GRP - C_p - C_{cm} - D + B - C_a$$

where:

- GRP = gross regional product;
- C_p = normal production costs;
- C_{cm} = net coastal management costs, discharge reduction costs/beach replenishment costs/coastal protection costs;
- D = remaining damages;
- B = benefits from improved environmental quality; and
- C_a = administrative costs of ICZM.

The "design" segment of ICZM will encompass both preliminary designs of physical/biophysical facilities such as effluent treatment facilities, hard and soft sea defence/coastal protection engineered structures, construction of artificial marsh areas, and subsequent more detailed designs. But the design activity is also not restricted to structures and will include specifying the components and procedures of non-structural measures such as inspection and monitoring systems, charging systems and land use planning and implementation provisions.

To be able to manage requires proper resource assessment, involving the evaluation of (including costs of, and, wherever feasible, monetary evaluation of the benefits) multiple resources exploitation in the coastal zone and the interactions between and among the competing resource uses. The *first* management problem is that of deciding among the possible sets of outputs of goods and services which can be produced. Various combinations of outputs are possible, involving marine transport, waste disposal, fisheries yield, recreation, national defence, amenity, and preservation of unique coastal ecosystems. The different combinations will reflect different trade-offs among the feasible outputs.

Because of the dynamic and "open system" nature of coastal zones, analysis for planning and management must consider at least three areas (multiple foci for ICZM). These are:

- *The politically designated management area.* The political process in any given country, or in an international setting, will designate the boundaries of the management area, and will assign the management responsibilities to one or more public and private agencies.
- *Ecological areas.* A designated coastal management area may be within the boundaries of an identified ecosystem. More likely, the area will encompass, or be encompassed by, several ecosystems or catchment areas.
- *Demand areas.* Demand areas are those from which demands are exerted on the resources of the designated coastal area. These demands comprise: demands from within the designated management area; demands from outside the designated management area but within the catchment area; demands from outside the catchment area, with respect to, e.g. waste disposal of pollutants transported into the area

via atmospheric transport, demands for coastal recreation, including visits to unique marine resource areas; and internationally determined demands, such as for global shipment of crude oil and oil products.

Thus, ICZM involves *multiple* regions, the boundaries of which rarely – if ever – coincide. For example, governmental boundaries for counties, states and provinces are rarely contiguous with watershed or ecosystem boundaries. In analysis, explicit consideration must be given to cross-boundary flows – in and out, upwind and downwind. However, the management structure established for a designated coastal area is not likely to have jurisdiction over activities beyond its area.

1.4 Establishing Priorities for Management Actions

Given multiple problems and virtually always limited resources with which to "tackle" them, a major problem in ICZM is to establish priorities, i.e. what to do first. Criteria for establishing priorities include

- benefits in relation to costs, cost effectiveness,
- distribution of benefits and costs, i.e. who gains and who pays,
- political concern for some segment of the population, e.g. artisanal fishers, or other low income groups in a given region,
- physical, chemical, biological effects on the environment,
- effects on institutional/administrative structure,
- relative importance of problems, regardless of how "relative importance" is measured,
- feasibility of financing,
- time to first returns,
- accuracy of estimates of benefits and costs, i.e. how likely are they to be achieved.

The significance of each individual criterion and the relative importance of the criteria vary from area to area and over time.

Because the coastal zone is the most biodiverse zone, it may be prudent to impose a "zero net loss" principle or constraint on resource utilisation (affecting habitats, biodiversity and the operation of natural processes) in the zone, at least at the start of the analysis. The adoption of such a precautionary approach (Gray 1997) with its accompanying set of constraints will probably conflict with some other human needs. A typical multiple objective and value conflict problem is posed, for example, by: the need of local people to increase fisheries yield in a given zone; the increasing use of the same or nearby waters for waste disposal; improving conditions for marine transport; an increasing need to raise the quality of bathing waters/beaches: and a political desire to increase the stringency of pollution controls on dischargers to coastal waters. A difficult sustainability balance (E versus S versus P) will need to be struck depending on the real and full economic value of the various resource management options, the extent to which sustainable human livelihoods can be fostered with alternative income sources substituting for unsustainable current usages, and the actual resilience of various natural systems and processes.

It is important to note, with respect to ICZM, that none of the desired outputs can be achieved without financing. This involves not only the financing of analysis and planning, but also the financing of capital investments, Operation/Maintenance/Replacement (OMR) costs (including monitoring and enforcement) and an allocation for contingencies. With regard to capital investments, it is essential to investigate:

a how governmental agencies involved will raise the annual "cash flow" required for repayment of loans for capital investment, as well as covering OMR costs and a contingencies fund; and
b whether or not the activities allocated to private entities, can be financed by those entities.

1.5 Characterising the Benefits of ICZM

The benefits of ICZM can be most readily discerned if they are related to baseline conditions in the given coastal zone i.e. coastal area A at time T_0. The condition of the coastal resources at T_0 reflects the effects of various human activities and of natural events over past time to T_0. Examples include

- damage that has been incurred from coastal storms, hurricanes, eroding shorelines,
- loss of habitat, e.g. wetlands that have been filled and mangroves removed,
- water quality that has been degraded by discharges of various materials, e.g. heavy metals, synthetic organics, suspended solids, faecal matter,
- sedimentation that has occurred in navigation channels and in harbour areas, and on spawning beds and coral reefs,
- offshore sand and gravel mining that has affected fisheries and the wider ecosystem,
- salinity intrusion that has occurred as a result of excessive withdrawals from ground water aquifers,
- both finfish and shellfish yield declines,
- residential and commercial facilities that have continued to be constructed in hazardous areas in relation to coastal storms, hurricanes, shoreline erosion,
- conflicts among different types of recreation users of beach areas that have become more prevalent,
- conflicts between commercial and recreational fishers that have escalated,
- exotic species that have inadvertently been introduced into the coastal waters, resulting in damages to physical structures, e.g. water intakes, and to indigenous species.

ICZM benefits are achieved by: reducing damages; mitigating pollution and resource overexploitation problems; enhancing coastal zone outputs; and preserving unique coastal ecosystems. It is important to recognize that benefits comprise the *net* effects on coastal zone resources – processes, functions and outputs – linked to a management measure or set of measures. Any given measure often generates multiple effects not all of which will be positive. Thus a measure which reduces "pollutant" discharges into a coastal water body can reduce damages to recreation at the same time improving the environment for finfish, but also increasing borer populations which result in increased damage/maintenance costs of wooden structures such as piers. Benefits can be classified and defined as follows:

Resource utilization benefits. These benefits stem from production of goods and services not currently being produced in the coastal area e.g. oil and gas, aggregates and recreation.

Mitigation benefits. These benefits are comprised of damage reduction and restoration benefits. Examples include reducing damages from: point and nonpoint residuals disposal, coastal storms, hurricanes, shoreline erosion, non-coastal soil erosion, salinity intrusion, excessive withdrawals from ground water aquifers, sedimentation in navigation channels and harbours, breeding areas for vector-borne diseases, over exploitation of fish species, water fowl and water animals. Examples of restoration benefits include actions which return the coastal system toward original ecosystem productivity, such as: replanting wetlands, constructing "artificial" wetlands, removing exotic species, restocking with native species, improving water quality by various means to reduce water intake treatment costs, increase water species productivity, increase availability of swimming and decrease fish advisories.

Enhancement benefits. These benefits are achieved by *increasing* the outputs from a coastal water body from current levels, as long as the costs involved are less than the potential gains. They are comprised of two subcategories:

a *increasing* the output of some product or service by, e.g. constructing artificial reefs to provide habitat for fisheries thereby increasing fish output, constructing recreation facilities such as ramadas, parking areas, outhouses and beaches, installing shark protection devices in coastal swimming areas, increasing the depth of navigation channels and harbours;
b *reducing conflicts* among or between various users of the coastal resources, such as competing uses among beach recreationalists, e.g. dunebuggies, surf fishers, swimmers; competing use of navigation channels by commercial and recreational vessels; or conflict between oil/gas exploitation and recreation or non-use ecosystem preservation benefits. Conflict reduction can be accomplished by, for example, some combination of pricing schemes and time and spatial scheduling of activities.

Preservation benefits. These benefits stem from setting aside and managing particular areas in order to preserve the natural ecosystem e.g. marine sanctuaries or preserves in order to counteract or preclude increasing "consumptive use" pressure on such resources. Two types of benefits are involved: (1) use benefits; and (2) non-use benefits. The former involves activities which produce benefits as a result of actual visits to the preserved area for observing natural ecosystems, for scuba diving, for taking photographs. In contrast, the latter subcategory of preservation benefits does *not* involve actual visits to an area. Rather, the benefits are estimated as a function of "option demand" and "existence value".

Indirect economic benefits. This category is comprised of benefits stemming from "second round" effects of measures applied to produce direct economic benefits. The

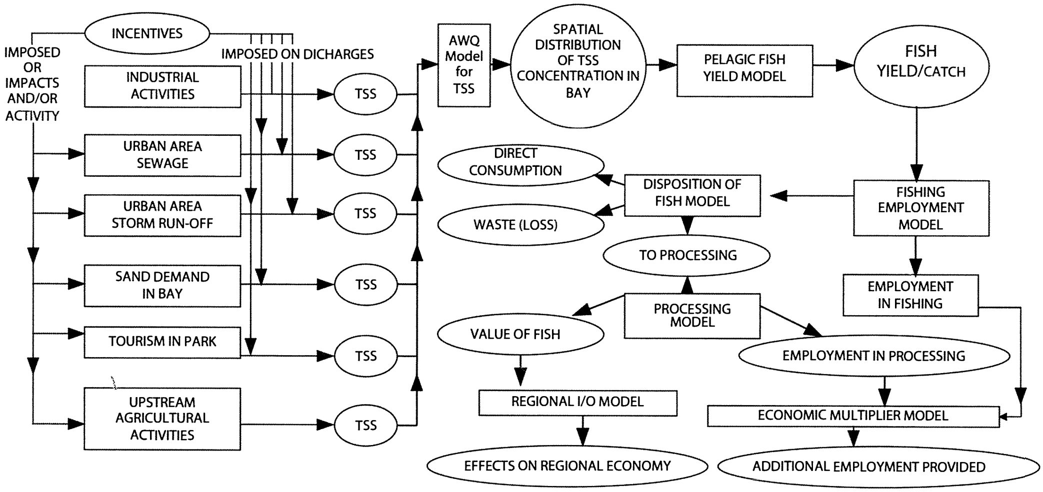


Fig. 1.4. Sequence of analyses to evaluate direct and indirect monetary effects: relationship between fish yield and distribution of total suspended solids concentration

context for the analysis and estimation is the regional economy (and/or the national eco-nomy), as the *direct* economic benefits result in additional economic activities in the region (which may or may not be *net* to the nation). Discussion of methods for estimating these benefits, and the problems in doing so, fill multiple pages in the literature on analysis for planning water resources developments in the period circa 1950 to circa 1980, primarily under the rubric "secondary benefits". Figure 1.4 illustrates the sequence of analyses involved in estimating the indirect benefits in relation to restoration of fish yield by reducing suspended sediment concentration in waters of a given coastal area.

"Option" benefits. These benefits refer to the potential gains from an ecosystem conservation policy which seeks to retain as extensive a set of future coastal resource use options as is practicable. *"Existence" benefits* refer to the non-use values that coastal ecosystems might possess. Some individuals would be willing to spend money just to be assured that the resource is preserved even though they have no intention of visiting or using the resource.

The estimation of benefits takes place as part of the analysis for planning for ICZM in the context of continuous integrated coastal zone management. This means that the analysis is done at some "point" in time, or over some finite time period. This in turn means that the analysis must be based on some "baseline conditions". Those conditions, e.g., contamination in sediments, land use in the coastal area, represent (a) present conditions (hopefully some relatively recent year for which data are available), and (b) the factors which have operated over time to result in those conditions. For example, PCBs in the Lower Hudson river and in the Lower Fox river (Wisconsin) are a function of discharges which occurred some time ago. In both cases, no discharges of PCBs have occurred in at least 10–15 years. But concentrations are still significant and result in current damages. Baseline conditions for estimating damages from hurricanes, for example, must include the changes that were made, e.g. in building construction, as a result of the most recent hurricane. In addition, the "baseline conditions" will change over time, as a result of increased information about coastal ecosystems, increased accuracy of forecasting hurricane landfalls and changing governmental policies.

Thus, a critical problem in estimating benefits from ICZM is defining what would happen in the absence of ICZM, i.e., what is the "baseline scenario".

ICZM benefits over time are also a function of the research and monitoring components of ICZM. These components provide information on which to base benefits estimates. For example, having monitored the Florida shoreline in the Pensacola area before Hurricane Opal enabled determining the effect of the hurricane on shoreline erosion by remeasuring after the hurricane (Stone et al. 1996). Investigations to determine reasons for damages to residential structures in Florida by Hurricane Andrew lead to changed building codes and construction methods, thereby reducing damages from subsequent storms. Studies of recreation behaviour in coastal areas provide data for developing estimates of demands, and hence of benefits associated with coastal recreation. But the provision of continuous research and monitoring activities requires an institutional arrangement (a) to organize and finance the research and data collection; and (b) to make use of the results of those activities.

1.6 Demonstrating the Benefits of ICZM

From a pragmatic decision-making perspective, there needs to be a method for demonstrating to decision makers and other stakeholders what the benefits of ICZM could be. However, there also must be an understanding that achievement of benefits requires implementation of a coastal resources management strategy. The components of a strategy are shown in Fig. 1.5. These components are related to the set of tasks of coastal management mentioned earlier.

The analytical approach suggested for demonstrating the benefits of ICZM is based on a "without ICZM" versus "with ICZM" comparison. The *net benefits*, i.e. benefits minus costs, associated with (attributable to) ICZM are then represented by the difference between the two "states of the world" in a given coastal area. The benefits and costs of ICZM will be determined by the range of processes, functions, products and services found and produced in the coastal area and their interrelationships with factors external to the coastal area. The "without-with" comparison is combined with the application of "scenarios" of conditions extended to whatever points in the future are considered to be of interest, i.e. "alternative futures". The structural scenario analysis is indicated in Fig. 1.6.

A scenario comprises some combination of values of three sets of linked variables:

a Economic and demographic conditions over the time horizon of interest;
b Environmental conditions; and
c Non-coastal governmental policies and programmes, technological changes, and factor prices.

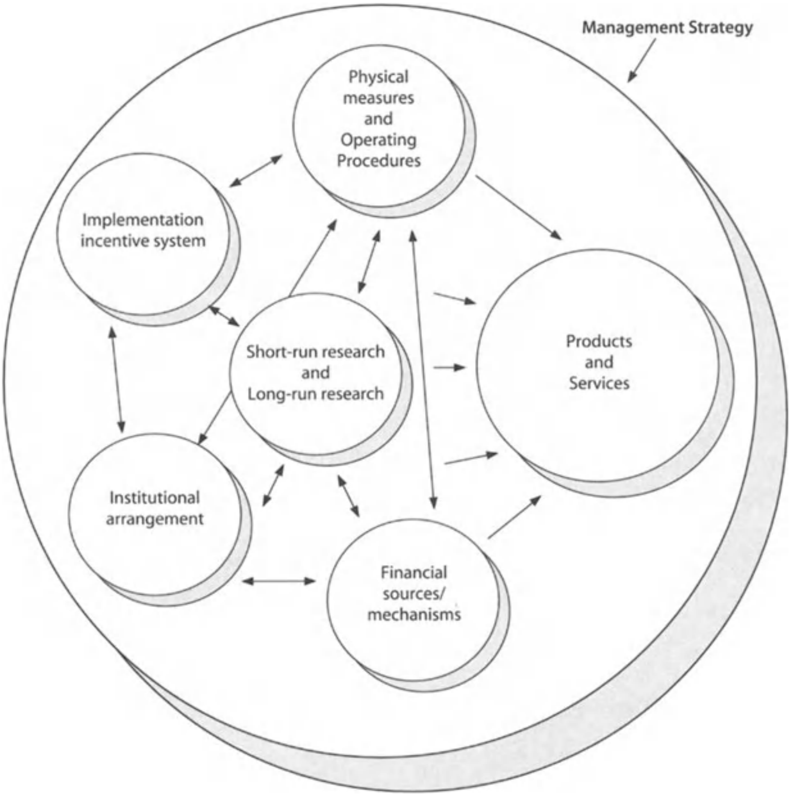


Fig. 1.5. Components of a management strategy (*Source:* Bower and Turner 1997)

Clearly the third "variable" could be divided into three separate variables. However, each additional variable added multiplies the possible number of permutations and combinations of the variables.

1.6.1 Without ICZM

For any given scenario, i.e., a combination of (a), (b), and (c), what is termed the "base case" involves the estimation of net benefits for the given scenario with the "trend" management strategy, termed the "without ICZM" situation.

The zone's aggregate future production (i.e. feasible array of products and services) is evaluated both in terms of input requirements and residuals generation and discharge impacts, and the effects on the regional economy. The benefits and costs will be determined by the "trend" management strategy, which in turn is a function of the institutional structure. All these socioeconomic activities and systems will of course be underpinned by the coastal ecosystems and their interrelationships with the abiotic environment.

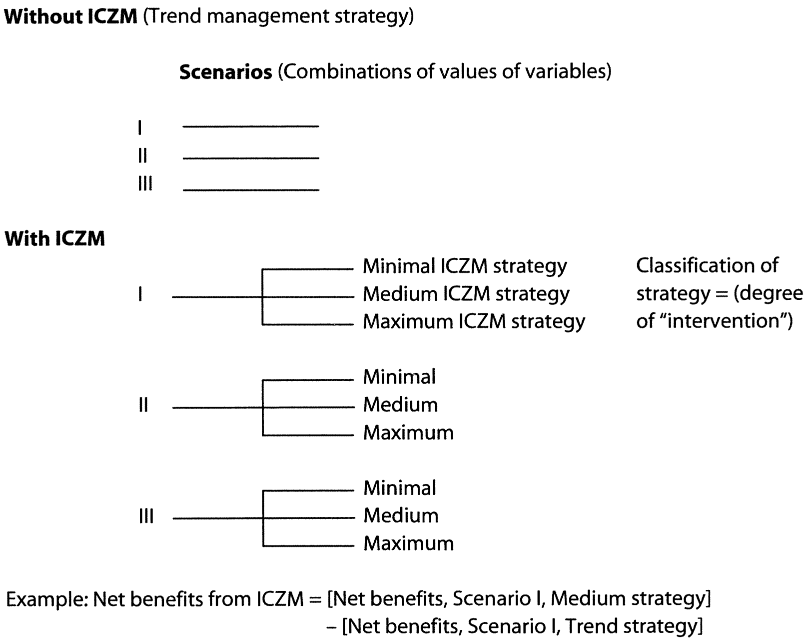


Fig. 1.6. Role of scenarios in estimating benefits of ICZM (*Source:* Bower and Turner 1997)

Characterising the "without" situation is not straightforward, as a "business as usual" management strategy is not realistic because the biophysical and socio-economic systems in the zone are not likely to be static. Rather such systems will be subject to an almost continuous process of adaptive change as socio-economic systems learn from past experiences. These adaptations may then generate feed back effects in bio-physical processes and functions and so on. Changes, for example, were made in response to the last three hurricanes in Florida, USA. Building codes were tightened, particularly for mobile homes, and insurance companies became more particular about what they insured in relation to storms and hurricanes. When salinity intrusion was recognized in Southern California 50–60 years ago, a recharge scheme was established and water withdrawal charges imposed to prevent any further intrusion. Regulations have been established, and in some places actually enforced and fines levied, preventing the filling of wetlands. "Artificial" wetlands have also been constructed in various areas, to compensate for previously filled wetlands and consequent loss of habitat.

The rate and scale of the adaptive behaviour will be conditioned by, among other things, human perceptions of environmental change. Perception of the nature, extent and severity of a problem affects the response of users to incentives imposed to change behaviour. Net benefits are a function of responses to incentives; responses to incentives are a function of perceptions. There may well be significant differences between perception of a problem by federal and state officials and local government officials and land users, as in the case of wildfires in urban fringe areas. There typically is a difference in perception with respect to the implications of the decline in yield of a particular

Table 1.2. Environmental conditions and impact categories (Adapted from Turner et al. 1996)

Impact categories	**Climate-related events and human activities**						
	Erosion	**Flooding/ inundation**	**Saltwater intrusion**	**Sedimen-tation**	**Degraded water quality, e.g. eutro-phication, red tides**	**Storms, hurricanes, typhoons**	**Upwellings e.g. El Niño**
Tourism	$				$	$	
Fresh water supplies			$	$	$		$
Fishing/ agriculture	'$'	'$'		$	$	$	$
Coastal residences	$	$	$		$	$	
Commercial/ buildings	$	$		$		$	
Wetlands	$, nm	$, nm	$, nm	$, nm	$, nm	$, nm	
Agriculture and drylands	$	$	$	$	$	$	
Human health		$, nm			$, nm	$, nm	$, nm
Culture and heritage sites	nm	nm			nm		

nm: non-market impacts; *$:* market priced major impacts *'$'*:minor impacts.

fish species e.g. over the last 15–20 years' among fishers, regulatory authorities and scientists. There is a difference between fishers and responsible governmental agencies in the perception of the efficacy of a particular method for allocating fishing "rights". There is also often a difference between the view of federal and state officials of the nature of the hazard of locating in the coastal zone and of the individuals who have located in the coastal zone, even those who have been through floods and hurricanes.

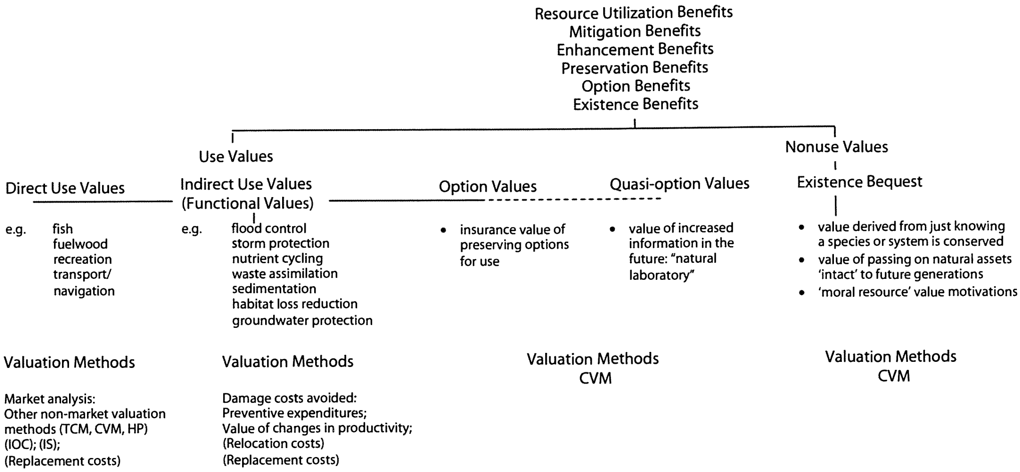
Thus, the perception by different "parties at interest" of the danger/risk related to a problem is a key variable in implementation of ICZM, and hence in the achievement of net benefits of ICZM.

The environmental impacts generated by human activities combine with "natural" variability in coastal zone biophysical processes to produce an array of effects, only some of which can be valued in monetary (economic value) terms. Some combinations of environmental conditions and impacts are shown in Table 1.2.

1.6.2 With ICZM

For the *same* scenario analyzed for the without ICZM case, one or several ICZM strategies are posited. Each strategy is a combination of physical measures and nonstructural measures. Examples of measures which can be elements of an ICZM strategy include:

- land use controls, i.e., precluding certain types of land use in specified areas of the coastal zone,



Notes: *Market Analysis* : based on market prices; *HP* = hedonic pricing, based on land/property value data; *CVM* = contingent valuation method based on social surveys designed to elicit willingness to pay values; *TCM* = travel cost method, based on recreationalist expenditure data; *IOC* = indirect opportunity cost approach, based on options foregone; *IS* = indirect substitute approach. The benefits categories illustrated do not include the *"indirect"* or *"secondary benefits"* provided by the coastal zone to the regional economy, ie the regional income multiplier effects.

Fig. 1.7. Methods for valuing coastal zone benefits (*Source:* Turner 1988; Barbier 1989)

- land use controls in terms of setbacks,
- beach replenishment,
- extensive evacuation, temporary sheltering, resettlement procedures,
- intensive storm/hurricane forecasting procedures, coupled with extensive system of conveying warnings to coastal occupants,
- differential property tax rates, with higher taxes imposed on higher hazard areas,
- construction specifications in building codes, e.g., roof tie-downs to frames, shingle tie-downs; constructing facilities on "stilts",
- refusal by insurance companies to write damage insurance, except at very high rates.

Net benefits are estimated for the specified ICZM strategy for the given scenario. These net benefits are compared with the net benefits for the scenario without ICZM. The difference represents the net benefits attributable to ICZM.

In principle on the benefit side of the net benefit estimations it is possible to conceive of a total economic value (TEV) of the coastal zone's output of products and services. TEV will consist of both use values (direct and indirect) and so-called non-use values, as shown in Fig. 1.7. A range of valuation methods is available, but it will not be possible to place meaningful monetary values on all the benefits (and some of the costs) of outputs from the coastal zone.

The benefits of ICZM are linked to four environmental impacts/effects categories:

- Direct and indirect productivity effects;
- Human health effects;
- Amenity effects; and
- Existence effects such as loss of biodiversity and/or cultural assets.

Table 1.3. Coastal zone impacts and valuation methods

Valuation methods

Market orientated benefit valuation
Benefit valuation using actual market prices of productive goods and services based on changes in value of output, or loss of earnings. Examples include loss of fisheries output due to pollution, or value of productive services or recreational benefits loss, through increased illness caused by coastal waters pollution.

Surrogate markets benefit valuation
Environmental surrogates may include marketed goods, property values, other land values, travel costs of recreation, wage differentials, compensation payments. Examples of such proxies are entrance fees to national parks as a proxy for value of visits to protected areas, changes in commercial property values as a result of water pollution, or compensation for damage to fisheries.

Cost valuation using actual market prices of environmental protection inputs
Preventive expenditures, replacement costs, shadow projects, cost-effectiveness analysis. For example the cost of environmental safeguards in project design, cost of replacing resource damage by pollution or conversion, cost of supplying alternative recreational facilities destroyed by development activities, or cost of alternative means of sewage sludge disposal in marine waters can be used as cost indicators.

Survey orientated (hypothetical valuation)
Contingent valuation or contingent ranking questionnaire-based surveys of individuals to elicit willingness-to-pay or to-be-compensated valuations.

Effects categories	**Valuation method options**
Productivity E.g. Fisheries, agriculture, tourism, water resources, industrial production, marine transport, storm buffering and coastal protection.	Market valuation via prices or surrogates; Preventive expenditure; Replacement cost/shadow projects/cost-effectiveness analysis; Defensive expenditure.
Health	Human capital or cost of illness; Contingent valuation; Preventive expenditure (avertive behaviour); Defensive expenditure.
Amenity Coastal ecosytems, wetlands, dunes, beaches, etc., and some landscapes, including cultural assets and structures.	Contingent valuation/ranking; Travel cost; Hedonic property "value" method.
Existence Values Ecosystems; cultural assets.	Contingent valuation.

Different valuation techniques are appropriate for each of the four broad effects categories. Choice of technique will depend on the magnitude and significance of the effects, on the availability of data and on the analytical/institutional capability in any given context. Table 1.3 summarizes both the characteristics of the valuation methods and the valuation options available in each environmental effects category.

The choice of resource valuation approach will need to be adapted to fit the spatial scale of the cause and effect relationship that is being assessed. Barbier (1993) identifies three forms of assessment:

- *Impact analysis:* related to identified impacts generated by a project, policy or course of action usually within a restricted spatial area, but sometimes requiring more extensive drainage basin-wide data and analysis;

- *Partial valuation analysis:* of given ecosystems, their functions and valued outputs, normally requiring extensive spatial analysis; and
- *Total valuation analysis:* of a defined and perhaps very extensive coastal marine area, sometimes with its coupled terrestrial drainage basin.

All the valuation work must be underpinned by sound natural science. Such an integrated assessment in the coastal zone should be guided by the following basic analytical rules:

- *Problem orientation*
  Any assessment should take account of the prevailing political economy context, equity issues and possible "stakeholder" interests. Data limitations must be acknowledged and recommendations made conditional upon these.
- *Typology*
  A useful common terminology regards *functions* as relationships within and between natural systems; *uses* refer to use, potential use, and nonuse interactions between human and natural systems; and *values* refer to assessment of human preferences for a range of natural or non-natural "objects" and attributes – see Fig. 1.8.
- *Thresholds*
  These relate to the scale and frequency of impacts. Their occurrence can be presented in a simple three part classification: no discernible effects; discernible effects; discernible effects that influence economic welfare.
- *Economic valuation*
  Three broad approaches to a valuation exercise: impact assessment; partial analysis; and total valuation. For each function or impact, a number of techniques exist for attributing economic value to environmental benefits.
- *Scale*
  The drainage network should be the spatial unit for assessing ecological variables, with possible zonation within this. In terms of benefit estimation, the minimum scale is determined by the relevant population affected by any impacts. Temporal scale of analysis is also fundamentally important.
- *Transferability*
  Transferring scientific results across sites is required for global scaling but transfer of some economic benefits is problematic. Accuracy of benefits transfer may be improved if based on scientific variables divided into separate components depending on processes, functions, and "state variables".

1.7 Steps in Estimating ICZM Net Benefits

Operationally, the following are the basic steps in estimating net ICZM benefit:

1. Define the problems in quantitative terms. This typically involves developing various physical-chemical-biological relationships, e.g. pollutant discharge-water quality relationships, dose-response functions, environmental conditions-species response relationships, damage vs. intensity of storm relationships, level of water quality vs. water intake treatment costs.

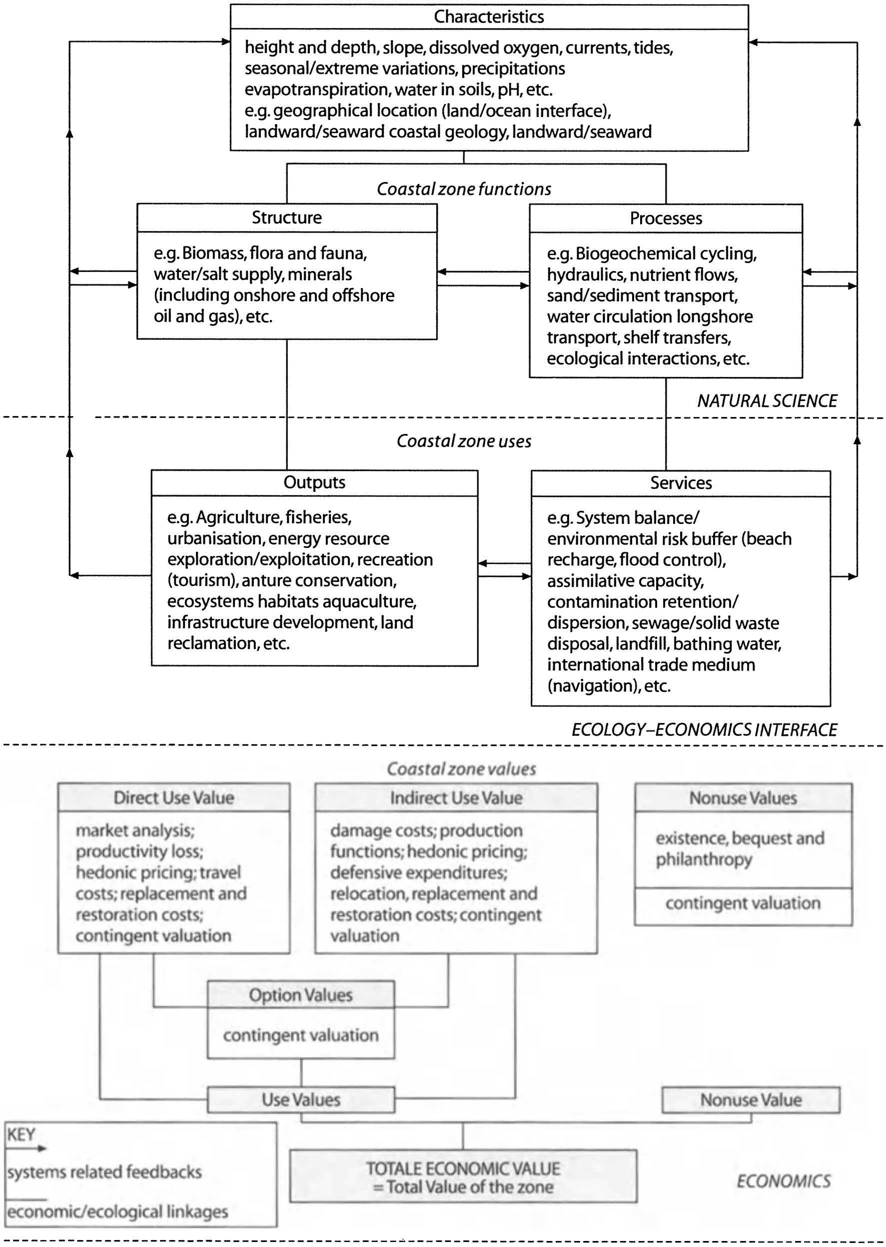


Fig. 1.8. Coastal zone functions, uses and values

2. Select a scenario and tabulate the related spatial pattern and levels of population and economic activities, for the time horizon specified in the scenario.

3. Based on (a) the relationships defined in N° 1; (b) the demographic conditions specified in N° 2; (c) the sequence of meteorologic/hydrologic events selected in the scenario; and (d) changes, if any, in factor prices and technology specified in the scenario, estimate the extent of various problems and the damages associated therewith for the "trend" management strategy, and the associated benefits and costs (where costs represent the incremental costs in addition to existing costs at time T_0). This yields the net benefits for the "without ICZM".
4. Define an ICZM strategy, which involves – as noted above – some combination of physical (structural) measures and non-structural (charges, land use regulations) measures, and the capital, OMR, and administrative costs associated therewith.
5. For the *same* scenario as selected in N° 2, estimate the benefits from applying the ICZM strategy defined in N° 4, remembering that explicit consideration must be given to the extent to which the coastal occupants actually behave as "assumed" in response to the various incentives imposed.
6. Calculate the net benefits associated with the ICZM strategy defined in N° 4.
7. Compare the net benefits estimated in N° 6 with the net benefits estimated in N° 3. The result represents the net benefits from ICZM.

The method for estimating benefits from ICZM can be illustrated by applying the method to a prototype or actual coastal system. The prototype system has characteristics analogous to real coastal systems. Data on costs, various relationships involved in the performance of natural systems, values of unit discharges, and so on, are based on data from the "real world". The prototype contains a variety of typical uses of coastal resources and the competitions between and among those uses. It may be useful in order to test a range of general relationships and/or in cases where the actual coastal systems under review are particularly complicated or for which data is severely limited.

1.8 Conclusions

Coastal zones are under increasing pressure from the scale of the multiple resource demands that are impinging on them. Multiple usage of the goods and services provided by coastal systems reflects a variety of stakeholder interests and perceptions. A number of these uses and interests and perceptions conflict with each other and are themselves changing over time. The management process deployed in order to maintain an acceptable mix of outputs from the coastal zone into the future must therefore be both a dynamic and an adaptable process. Past and current market and government intervention failures will need to be corrected if pollution and resources loss trends are not be exacerbated. An integrated approach to coastal zone planning and management (ICZM) is necessary in order to produce (effectively and efficiently), and/or enhance the mix of goods and services that society wants, and to ensure an equitable distribution of the benefits of ICZM.

Integration in ICZM includes its integration across broad policy objectives and plans, with different sectoral plans and management, with different levels of government and with the public and private sectors. ICZM itself must encompass all the elements of management from planning and design through financing and implementation. It also requires an interdisciplinary analytical and operational approach. Because of the dynamic and "open system" nature of coastal zones' analysis for planning and management has to encompass multiple regions i.e. politically designated management area, ecological areas and socio-economic demand areas, the boundaries of which rarely, if ever, coincide.

The benefits of ICZM, which take a variety of forms, can be demonstrated by comparing a coastal resources management strategy "without ICZM" versus a management strategy "with ICZM". The net benefits of ICZM are then represented by the difference between the two "states of the world" in a given coastal area. Human perception of the nature, extent and severity of a problem or risk of a problem, conditions responses and adaptive behaviour. It is therefore a key variable in implementation of ICZM and hence in the achievement of net benefits of ICZM.

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Chapter 2

The Challenge of Demonstrating the Socio-economic Benefits of Integrated Coastal Management

P.R. Burbridge

2.1 Introduction

The concept of Coastal Management has been with us for more than 30 years. In that time there have been major advances in developing information on coastal areas and the unique ecosystems that characterize the zone of transition from purely marine to purely terrestrial environments which has been termed the "Coastal Zone". There have also been major advances in the development of practical tools for improving the planning and management of human activities in coastal areas and in the management of resources generated by coastal ecosystems. However, there have been mixed results in the success of coastal management initiatives and the conservation of productive yet fragile coastal ecosystems. Part of the problem that hinders the success of coastal management lies in the difficulty of convincing politicians, and senior managers responsible for sectoral agencies that there are significant advantages to be gained by investing time, effort and funds in developing coastal management.

During the process of developing the concepts, principles and methodologies for coastal management there has been a major change in emphasis away from "Coastal Zone Management" and towards "Integrated Coastal Management". Initially people were concerned with raising awareness of the unique ecological features of the ecotone or zone of transition from marine to terrestrial environments and the need for special management arrangements to control human activities to protect fragile coastal ecosystems. Experience has shown that, no matter how the boundaries of the "Zone" were defined, there would always be external environmental processes or economic and social influences that would transcend the boundaries of that zone. For example, the increasing incidence of flooding in coastal districts is often the result of poor land management practices in upland areas many miles away from the coast.

There has also been increasing recognition of the need to focus on the integration of sectoral development policies in order to promote more sustainable development of coastal resources, as exemplified by the international demand for shrimp which has led to major conversions of coastal wetlands into aquaculture ponds in tropical developing nations. Sectoral agencies promoting this form of highly profitable aquaculture have generally failed to recognize the economic and social costs resulting from the loss of wetland habitats, including reduced support for stocks of fin fish and crustaceans which sustain capture fisheries.

With the passage of time and the growing recognition of the strategic importance of coastal areas and ecosystems in sustaining a wide range of human economic activities, there has been a move towards integrated planning and management of human activities as a means of improving the economic efficiency of coastal resources utilisation while attempting to ensure that the resulting development is socially equitable and environmentally sound. In other words, to manage for sustainable development of coastal areas and resources. However, attaining sustainable utilisation of coastal areas requires far more sophisticated social, economic and environmental information, and the effective use of that information in development planning and management, than is the case for purely marine or purely terrestrial environments. This is due to the highly productive and diverse nature of coastal ecosystems and the corresponding diverse forms of economic activity that have developed. Many of these activities can be sustained by coastal ecosystems at the same time without unacceptable effects while others are often mutually exclusive and their development imposes external economic, social and environmental costs on other activities. Thus many of the most complex sustainable development challenges facing mankind are associated with coastal resources.

In theory the use of coastal ecosystems should be planned and managed so that local communities, nations and the global economy gain the maximum benefit by optimising various sustainable uses. However, we must ask ourselves if such a goal can be achieved given the practical problems of assessing what forms and level of human use of coastal systems can be sustained. Many of these uses may be incompatible and there will be those who will gain and those who will lose even with multiple use management or other means of promoting optimal mixes of uses.

We therefore need to enhance peoples' awareness of the benefits and disbenefits associated with different forms of coastal development. Many of the values associated with coastal ecosystems, such as their contribution to the control of carbon cycles, their bio-diversity or their aesthetic beauty, are difficult to assess. Such values mean little to coastal communities which may be burdened by poverty and consider that development is passing them by. If we focus on the global ideal of sustainable development of coastal ecosystems and neglect the interests of local people we will be in danger of neglecting forces that will undermine policies, plans and other measures designed to achieve national and international sustainable development objectives.

One way to achieve sustainable development of the multi-faceted resources derived from coastal ecosystems is to adopt multiple-use management of coastal ecosystems and their resources. With sound management, multiple-use management can improve the efficiency and equity of resource allocation and can help managers optimize the total economic benefit to activities which depend upon coastal resources. Multiple-use is an organising principle where the choice of management boundaries for coastal systems is based on functions and Critical Linkages with other systems similar to approaches adopted in watershed management. The management of processes is more important than management of uses. While uses have to be managed in terms of areal extent and intensity of use, it is more important to base the management of uses on criteria such as complementarity of uses in respect to services or functions (forest harvesting versus nutrient flows to support fisheries in Mangrove), in respect to opportunities to make better use investment on infrastructure or other cost reducing opportunities, and non-consumptive forms of complementary use – e.g. conservation of mangrove for sustainable capture fisheries development supporting the maintenance of coastal erosion control of benefit to navigation.

Given the broad and diverse array of human activities that are directly or indirectly supported, there is more to be gained in both economic and social terms by maintaining the health and productivity of coastal systems than can be normally achieved through their allocation to single purpose and exclusive uses, or their conversion to alternative uses. This does not mean that all coastal systems must be left in an undeveloped state free from human disturbance. In some cases there will be no alternative but the conversion of natural coastal systems to some alternative purpose.

Many economists would argue that market mechanisms are efficient in allocating scare resources to the highest and best use. However, where coastal systems generate a wide variety of economic and environmental goods and services, we should be looking for the optimal mix of uses that generates the greatest aggregate economic benefit to society – not the maximum financial gain to one form of activity. Arguably, we can only begin to optimize the use of increasingly scarce coastal resources if we develop multiple-use based approaches to the allocation and use of coastal systems that are balanced with the ability of those systems to sustain the desired mix and intensity of uses. This must incorporate a basic understanding of the mutual dependence of coastal ecosystems and the consequences of treating individual ecosystems in isolation.

This provides a strong case for the development of techniques to promote beneficial multiple-use strategies such as integration of activities and coordination of policies and investment strategies. Once the concept of multiple use has helped achieve improvements in national thinking concerning the broad management objectives for coastal resource systems, we will be in a better position to develop regional and local investment strategies and strategies for investment in infrastructure, and resource allocation objectives for land and water use. For a more full explanation of the multiple use management approach to coastal ecosystems and how it could be applied to fisheries see "Planning Processes for Integrated Coastal Zone Management" by P. R. Burbridge, Proceedings of the ICES Science Meetings, St. Johns Newfoundland September 1994.

There is no good reason why we cannot apply the concept of multiple-use to the management of coastal areas and renewable coastal resources. However, the coastal zones of the world are ecologically, economically and socially far more complex than most watersheds. Investment is therefore needed strengthen human resources and institutional arrangements to allow multiple-use management concepts, principles and techniques to be integrated into the thinking and actions of the myriad of agencies and resources uses with interests in promoting wise and sustainable coastal development.

No matter what scale of coastal management initiative is proposed there will be financial costs and adjustments to the authority, power and responsibilities of different interest groups. Unless these interest groups see that such adjustments will be to their advantage or at least will not disadvantage them, there will be little prospect of developing any cooperation, coordination or integration of policies, plans or management strategies required to achieve more sustainable and equitable development. This paper explores some of the dimensions of this challenge and presents a case for giving greater attention to the multiple use management of coastal ecosystems as a primary means of optimising the economic and social benefits that can be derived from integrated coastal management.

2.2 The Coastal Development Context

The management of human activities in coastal zones is one of the most complex and challenging tasks faced by man. Experience to date has demonstrated that it is very difficult to achieve rapid advances in promoting the sustainable use of coastal resources through large scale and fully integrated coastal zone management strategies for some very good reasons, namely:

1. *Nature of the system*
   a The coastal zones of the world generally contain a greater diversity of ecosystems than the purely terrestrial or marine environments that border the coast;
   b Associated with each coastal ecosystem there is a complex array of natural resources which provide both economic goods and services – i.e. those that are traded using market mechanisms, and environmental goods and services of equal value but which do not lend themselves to rational allocation via the market;
   c The resources development opportunities offered by these coastal resources are often far more varied and valuable than those found in purely terrestrial or marine environments. As a result, coastal zones support very complex patterns of human activity;
   d Damage to any coastal system can have an adverse influence on other systems and upon human activities based on those systems. This is illustrated in the following figure where the inter-dependent coastal ecosystems are represented as stone blocks forming the arch of a bridge in Fig. 2.1.

   Figure 2.1 illustrates the need to treat coastal ecosystems as inter-dependent and mutually supporting components whose combined contribution to the sustenance of human activities must be assessed before decisions are taken which could adversely influence their health and productivity. This requires an holistic perception of the environmental linkages among different coastal ecosystems as well as the potential support they give to economic and socio-cultural systems.
2. *Pressures*
   a These opportunities have attracted large numbers of people and in many nations more than one-half of the population is located close to the sea in coastal zones. The concentration of population and economic activity creates great demands for space for the expansion of settlements, industry and commerce and associated infrastructure. These pressures often lead to conflicts over access to land and water resources. Moreover, the future growth of the world population is expected to be concentrated in the world's coastal zones, most of this will occur in developing nations which are least well equipped to plan for and manage growth in a manner that promotes sustainable resources use and protection of coastal ecosystems and environmental process that are essential to their welfare;
   b There are less direct pressures on coastal regions resulting from human development pressures. One example is climate change associated with changes in carbon cycles which may increase the vulnerability of coastal regions to the effects of sea-level rise such as increased incidence and duration of flooding.
3. *Management issues and shortcomings*
   a Legal, administrative, planning and management arrangements have generally evolved to represent individual sectoral economic interests and do little to avoid conflicts of interest among different sectors many of which have a common dependence on the economic or environmental goods and services generated by one or more coastal ecosystems;
   b These same arrangements also tend to treat the marine and terrestrial components of the coastal zone as separate and unrelated entities when in fact they are interdependent;

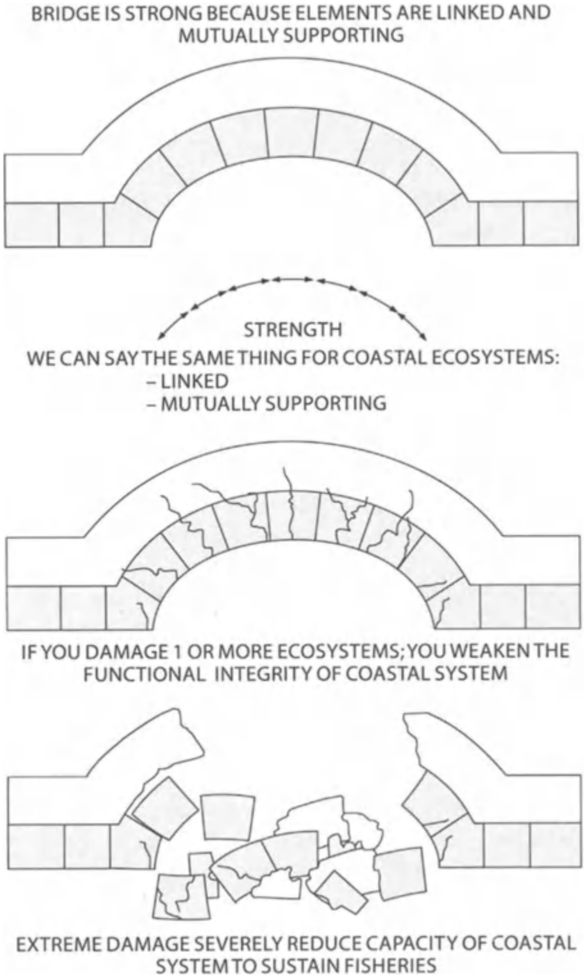


Fig. 2.1. Interdependence of coastal ecosystems and their carrying capacity

c It is very difficult to get the very many sectoral agencies with interests in coastal resources use to work together in developing coordinated policies and integrated development strategies and management programmes where they see no clear benefit and fear the loss of their decision making authority;

d Policy makers are often ill informed about the strategic value of coastal areas and resources in meeting the needs of current and future generations. Without the political will to improve the planning and management of coastal development, it is very difficult to achieve wise and sustainable coastal resources use.

Despite increasing international awareness of the strategic value of coastal resources, coastal planning and management is still dominated by sectoral approaches which favour single purpose and exclusive use of land and water resources. This approach favours the most financially profitable short-term returns and discounts to zero all alternative uses.

2.3 The Challenge of Optimising the Economic and Social Benefits Derived from Maintaining the Flow of Goods and Services Supplied by Coastal Ecosystems

2.3.1 The Need to Move Away From Current Sectoral Management Approaches

By paying increased attention to both the ecology and the actual use of coastal environments we have gained a clearer perception of the wide range of economic activities they support and the critically important environmental services they provide. Where the economic and environmental goods and services have been documented, the information serves as a means of illustrating their value to people responsible for allocation and use of different coastal systems. It also serves to illustrate the common dependence of different economic sectors on the same coastal ecosystems. This common dependence and the mounting competition amongst different economic sectors for access to and often exclusive use of coastal resources raises concerns over protecting socioeconomic equity in the absence of improved integration of sectoral policies and management plans. Socioeconomic equity is a key element in the concept of sustainable development, for example see Daily et al. (1995).

Although improved evaluations of the ecology and the actual use of coastal environments help illustrate the significance of the environmental systems, a basic problem which remains is that the multiple functions they provide and many of the corresponding goods and services are often not understood by central government officials responsible for the formulation of development policies, investment and the allocation of coastal resources systems. These policy and decision makers do, however, recognize the economic activities which seek to maximize the returns from specific resources through single purpose activities. Unfortunately, the establishment of strong government agencies to promote sectoral development activities reinforces single purpose approaches to the allocation and use of coastal areas. Single purpose, areas-based planning is the most common approach to coastal zone management in most developing countries.

A fundamental problem this creates is that agencies formed to provide leadership in one economic sector are put in charge of resource systems which may be equally important to other sectors of the economy. The classic example is the allocation of the responsibility for mangroves to departments of forestry. In comparison to upland forests, the sustainable extraction of timber and secondary forest products from mangrove is difficult and provides relatively modest revenues to forestry departments. The limited revenues earned provide little incentive or cash to manage mangrove forests well and virtually no incentive to manage them in a manner which will sustain other mangrove dependent uses such as fisheries.

Reliance on sectoral approaches creates a series of problems which make it difficult to make full use of coastal resources systems, namely:

1. A narrow range of economic activities dominate assessments of the potential use of coastal land and water resources by the sectoral agencies concerned;
2. Ddevelopment and investment plans are generally based upon exclusive, single purpose development;

3. Inter and intra-sectoral conflicts arise which detract from the effectiveness of development initiatives and investment, and
4. It is difficult to persuade sectoral agencies that multiple-use concepts are a logical alternative for fulfilling competing development objectives.

In effect, the sectoral agencies believe they are acting in the best interests of a nation and give priority to the efficient pursuit of their development remits at the cost of other activities.

2.3.2
The Need for Improved Information to Demonstrate the Benefits of Integrated Coastal Management

In both developed and developing nations there is growing awareness of the problems associated with sectoral approaches to the management of coastal environments held in the public domain. However, breaking away from sectoral control has proven difficult and attempts to establish special agencies at the national level and working parties at the international level have not overcome practical management problems. For example, the State Ministry of Environment in Indonesia has been charged with the responsibility of promoting sustainable development and reducing intersectoral conflict which can create environmental damage. In practice, the work of the ministry is hampered by the shortage of skilled staff with knowledge and experience in integrated resource management, lack of information on the functions and use of environmental systems, and resistance from powerful sectoral ministries who do not wish to have their activities subject to review by another agency.

Similar problems are experienced at the international scale. For example, the Association of East Asian Nations (ASEAN) was established to help resolve problems of common interest to the member states (Singapore, Indonesia, Brunei, Malaysia, the Philippines and Thailand). Cooperation among these nations provides opportunities to share scientific information, formulate management strategies to resolve issues such as the exploitation of shared stocks of marine fish and to establish treaties to enforce controls over marine pollution, etc. However, the resolution of problems is often hampered by different priorities being attached to common issues, such as marine pollution from land based activities, and the adoption of different standards to assessing their significance (Burbridge and Maragos 1985). This is also the case in Europe; where, for instance in the case of the Wadden Sea, unified agreement has not yet been reached in relation to conservation policies (WWF 1991).

The primary challenge we face is developing the *political will* to improve the *process* of planning for and managing coastal ecosystems and the use of their renewable resources. Developing *political will* will require improved communication between scientists and policy makers concerning the ecological, economic and social significance of coastal resources. Improving the *process* will require

- an improvement in our scientific understanding of the functions performed by different coastal ecosystems and the resources they generate,
- developing the awareness of decision makers, planners and managers from different sectoral agencies that they have a common interest in promoting the conservation of coastal ecosystems,

- achieving a shift in emphasis away from coastal development based primarily upon controlling the end use of coastal ecosystems and a shift toward a more balanced approach where emphasis is given to maintaining the health and productivity of coastal ecosystems so that they can continue to supply flows of resources that sustain different forms of activity,
- developing multiple use management approaches to the use of coastal ecosystems and resources which allows different sectoral agencies to meet their economic objectives without adversely affecting their respective economic objectives or the ecosystems that help sustain their economic activities,
- developing policies, plans and management strategies that seek to optimize the use of coastal areas and renewable resources to meet social and economic development objectives (Burbridge 1997).

2.3.3 The Basis for Integration

When we talk about integrated coastal management we must first consider the integration of three major sets of factors, namely:

- Environmental features which include biological, chemical, and physical aspects of coastal areas and component ecosystems;
- Economic features which relate to how human beings interpret and utilize the resources provided by coastal ecosystems;
- Socio-cultural features of the societies which condition the manner in which coastal areas and resources are utilized.

The interaction among these three sets of factors is illustrated in Fig. 2.2.

From Fig. 2.2 we can see that the three sets of very complex factors interact. This demonstrates the need for interdisciplinary analyses of how these interactions form

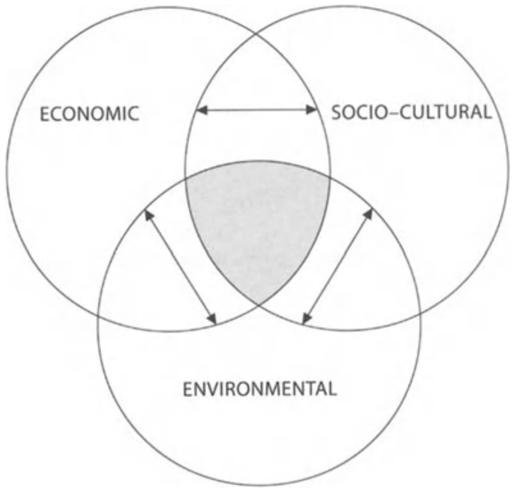


Fig. 2.2. Factors to integrate in coastal management

the unique characteristics of individual coastal areas. Traditional boundaries between disciplines such as ecology and economics are breaking down and there have been advances in developing methods for interdisciplinary analysis of these two sets of factors. For example, the development of environmental economics or ecological economics. This can be represented by the arrows linking environmental factors and economics factors in Fig. 2.2. However, a great deal of work remains to be done in developing conceptual frameworks and practical methods for integrating socio-cultural, economic and environmental factors. This is of great importance in developing integrated approaches to the organisation of human activities in coastal areas.

There are three basic areas in which greater effort is required in meeting the goal of protecting the health and productivity of coastal ecosystems so that they can con-

Box 2.1. Examples of the social and economic dis-benefits or costs associated with inappropriate development and use of coastal areas, ecosystems and natural resources

Associated with the concentration of population in many coastal areas there have been early innovations in land and water uses that today form the foundation for the relocation of people from overcrowded areas inland, and for major thrusts of investment common throughout many nations. One prime example is the development of brackish water fishponds many hundreds of years ago in Southeast Asia. This technology permitted the polyculture of wild species of fin fish and crustaceans and improved food security and opportunities for diversifying rural economies.

The culture of penaeid shrimp for export now forms a major thrust of economic investment throughout Asia and many areas in Latin America and more recently in Africa. The socio-economic impact of coastal aquaculture developments which require major alteration of coastal ecosystems can be far reaching. Apart from the direct loss of mangrove and other valuable coastal systems, there have been a number of corresponding impacts such as land subsidence, acidification of soils and estuarine waters and salinisation of groundwater and agricultural lands and the subsequent loss of economic and environmental goods and services generated by natural resources systems (1991). This has led to: the loss of agricultural productivity and farm incomes, reduced water supplies, loss of income from fishing and forestry and increasing hazards of coastal flooding (Huang 1990; Chua and Scura 1993). As is the case of agricultural conversion of coastal systems, great attention must be paid in planning and managing aquaculture to soils, tidal ranges, fresh water supplies, and natural hazards such as flooding if the investment is to generate sustainable and economically rational results. Where these factors are not built into management plans, investment capital is lost, natural resources degraded and coastal communities destabilized.

Unfortunately, extensive areas converted for pond development now lie idle, many sites have been abandoned and many people have lost their capital. Others have been adversely affected by the degradation of the mangrove and have lost the economic basis for their survival in traditional occupations such as fishing.

It is not possible to establish an accurate account of the total area of coastal wetlands and former agriculture sites which have been converted to non-sustainable aquaculture. The estimates that do exist suggest that very substantial areas are involved. For example, in Thailand it has been estimated that approximately 14% of the total area of mangrove forest has been destroyed as a direct result of shrimp farming (Phillips, pers. comm. 1996). The Bangkok Post for 20th February 1995 reports that some 24% of all shrimp ponds have been abandoned and that for each 16 000 ha of abandoned ponds there is economic loss on investment in shrimp farming equivalent to US $12 593 $ha^{-1} a^{-1}$ (Stevenson 1996). This estimate does not include the economic costs associated with increased soil and groundwater salinisation and consequent impacts on adjacent agricultural areas, or costs associated with loss of mangrove dependent fisheries, loss of control over coastal storm surges or other goods and services normally supplied by functioning mangrove ecosystems. The loss of value to capture fisheries alone is estimated to be equivalent to US $277 235 km^{-2} of mangrove (Kapetsky 1985). At the same time there are major costs associated with bringing these degraded lands into some form of productive use.

tinue to generate economic and environmental goods and services that sustain human economic and social needs and which can support new forms of development, namely:

1. Raising awareness among policy makers, planners, resources managers and coastal peoples of the value of coastal ecosystems and the need to seek the optimisation of uses rather than maximisation of the returns from exclusive uses of selected resources generated by coastal ecosystems;
2. Responding to changing economic and social perspectives within coastal communities without damaging the welfare of the international community;
3. Developing a cascade of international, national, regional and local sustainable development strategies, policies, plans and management strategies which respond to the needs and aspirations of coastal peoples while ensuring that development does not degrade the functional integrity of coastal ecosystems.

2.4 Means of Meeting the Challenge

When considering what means we have to address these issues it is important to consider two broad themes, namely:

1. Socio-cultural stability where people will continue to depend upon the sustained flows of economic and environmental goods and services provided by coastal ecosystems, and
2. The ability of the mosaic of interdependent coastal ecosystems to sustain creation of environmental and economic goods and services given the impact of human demands for resources.

Both of these themes need to be given greater attention in the formulation and implementation of coastal management strategies. One means of addressing these two themes is to develop improved means of valuing coastal ecosystems and the resources derived from them. This, combined with a basic understanding of the linkages between human activities and ecosystem functions, provides a basis for developing multiple use management of the ecosystem as a means of optimising the economic, social and environmental benefits derived from coastal systems.

2.4.1 Valuing Coastal Ecosystems and their Role in Sustaining Human Activities

Considerable effort has been given to the inventory and uses of selected resources derived from coastal ecosystems. For example, Hamilton and Snedaker (1984) list some 70 direct uses of tangible mangrove products such as fish trap poles. Many of the tangible products have economic values which can be calculated using local market prices. However, many of the less tangible goods, such as medicinal plants collected from a mangrove are not exchanged using traditional markets. These goods and most environmental services, such as flood attenuation by wetlands, are seldom represented in economic calculations associated with the evaluation of alternative forms of development. Text Box 2.2 looks at some of the approaches to placing a value on non-marketed values of environmental goods and services.

Box 2.2. Examples of the economic and social benefits derived from coastal areas and associated ecosystem functions

The progressive development of Resource Economics, Environmental Economics and more recently Ecological Economics has provided a means of developing increasingly sophisticated economic representations of the environmental and economic goods and services generated by coastal ecosystems. This has facilitated the demonstration of the environmental and economic importance of coastal ecosystems as well as the value of the flows of resources they generate. This means that we are in a better position to explain to politicians, policy makers and decision takers as well as the general public the economic value of environmental services such as the protection of agricultural crops from storms provided by the buffer function of mangrove.

We have the economic skills to represent the non-marketed value of environmental goods and services. The innovative use of economic valuation of the goods and services applied to wetlands and other complex environmental systems is well documented, for example see: Hufschmidt et al. 1983; Barbier 1989; Dixon 1989; Pearce and Turner 1990; Turner 1991; James 1991; Winpenny 1991; Pearce and Moran 1994; or Willis and Corkindale 1995.

The economic value of natural systems such as coral reefs, mangrove or salt marshes is gaining recognition. The actual value attributed to a coastal ecosystem will depend upon its area, its current condition and the number of resources that are incorporated into the economic calculation. For example, mangroves are considered as being particularly rich in terms of the economic and environmental goods and services they provide (Hamilton and Snedaker 1984; Dixon 1989; Burbridge 1990). The actual calculation of the economic value of the full range of these goods and services is rarely carried out.

Costanza et. al. (1997) calculate that the total global value of natural capital stocks and services provided by ecological systems such as wetlands is between US $16–54 trillion ($10^{12}$) per year with an average of US $33 trillion. Ecosystem services provided by the coastal realm are valued at US $12 568 $\times 10^9$ which represents some 38% of the total global value of all biomes. Costanza et al. (1997) argue that because ecosystem services are not fully captured by commercial markets or adequately quantified in terms comparable to economic services or manufactured capital they are "... too often ignored or undervalued, leading to the error of constructing projects whose social costs far outweigh their benefits". They further argue that "... this may ultimately compromise the sustainability of humans in the biosphere".

Figure 2.3 illustrates a simple economic model representing the different goods and services and whether they are normally marketed and whether they occur within the mangrove or in surrounding areas.

Quadrant 1 represents the products derived from a mangrove that are generally recognized using market values. *Quadrants 2, 3* and *4* represent goods and services that are generally excluded from analyses of the value of coastal ecosystems.

Ecological linkages among coastal systems must also be taken into consideration when valuing individual systems. There are linkages among systems in the form of nutrient exchange, migratory pathways, energy transfers, etc. These are not well documented. Never the less, the positive influence of one coastal system on other systems should be accounted for as part of any economic valuation exercise.

Attention should also be given to the value of the ability of coastal systems to compensate for changes caused by global environmental pressures and to continue to sustain human activities. Recent reviews of development pressures and the potential effects of major climatic and sea level changes (Jeftic et al. 1993; Pernetta and Elder 1993) conclude that the impact on coastal systems from predicted social and economic changes in coastal areas may outweigh the impact of climate change. It is therefore important to consider the value of coastal systems in sustaining human activities while

		Location of goods and services	
		On-site	Off-site
Valuation of goods and services	Marketed	1 Usually included in an economic analysis (e.g. poles, charcoal, woodchips, mangrove crabs)	2 May be included (e.g. fish or shellfish caught in adjacent waters)
	Nonmarketed	3 Seldom included (e.g. medicinal uses of mangrove, domestic fuelwood, food in times of famine, nursery area for juvenile fish, feeding ground for estuarine fish and shrimp, viewing and studying wildlife)	4 Usually ignored (e.g. nutrient flows to estuaries, buffer to storm damage)

Fig. 2.3. Illustration of the economic and environmental goods and services produced by a coastal ecosystem – a mangrove (After Hamilton and Snedaker 1984)

adapting to global environmental change. For example, in respect to the amelioration of coastal flooding hazards associated with predicted sea level rise a 10 m wide apron of salt marsh along parts of the coast of Britain is considered to serve the same purpose as a 1 m high artificial sea defence.

Apart from valuations of mangrove and other wetlands illustrated above and work by Spurgeon (1992) of coral reefs, there are few studies which attempts to quantify the total economic value (TEV) of coastal habitats. The study by Costanza et al. (1997) demonstrates that the value of all "potential" uses of individual coastal ecosystems should be included in TEV calculations. However, this may not be acceptable to some policy makers as it can be argued that some potential uses of resources will never be adopted by individual societies and should not be included in calculations of what may be lost versus what may be gained through alternative forms of development. This is essentially a question of social choice.

There are also questions of social equity and freedom of choice which need to be addressed in respect to dependence on coastal resources by local communities. It has been calculated that some 40% of all animal protein consumed in coastal communities is derived from the capture of fish, molluscs and crustaceans. Many of these animals depend upon coastal ecosystems for part of their life cycle. Therefore, the welfare of many coastal people in rural villages is intimately linked to and dependent upon the sustained flow of resources derived from or supported by the functions of coastal ecosystems.

Development activities, such as clear cutting coastal forests or conversion of wetlands to shrimp ponds can reduce the support that these coastal ecosystems provide to the sustained production of fish and other species. These developments can also alienate people from other resources such as fuelwood or medicinal plants which help sustain their economic and social welfare. Where coastal development alienates local populations from resources and reduces their livelihoods there can be a consequent breakdown in the cohesion of communities because people can no longer sustain themselves from coastal resources. This can lead to a movement of fishermen and others from rural communities to urban areas in search of employment where their little opportunity to use their skills and they are further impoverished. This breakdown of rural society in developing nations can also increase the burden on urban communities which are themselves striving to provide adequate housing, infrastructure and services to meet even basic human needs.

Alteration to one coastal system and the substitution by a man-made replacement can have a negative ecological impact upon other coastal systems with the potential result of reducing their productivity and ability to sustain human activities. These potential adverse environmental and corresponding social and economic effects should be taken into consideration when calculating costs and benefits.

Accurate and holistic valuation of coastal systems also allows decision makers to assess the benefits and costs associated with developments inland from the coastal zone which may have an adverse environmental and economic impact in the coastal zone. A good example is the work by Hodgson and Dixon (1988) that illustrates the disbenefits of upland logging in terms of the loss of valuable tourism and fisheries in Palawan.

The poorer people become as a direct or indirect result of non-sustainable development of coastal systems, the less incentive they have of investing in environmental management measures to sustain their activities. The more problematic survival becomes, the greater the incentive to seek short-term results (World Bank 1992). This leads to a breakdown of risk reducing, traditional approaches to the management of coastal areas which further exacerbates problems of environmental degradation.

Given the wide range of ecological, economic and social factors involved, the assessment of the costs or disbenefits associated with the conversion of coastal habitats to alternative forms of use is a very complex but very important challenge. We must therefore give greater attention to the economic, social and environmental costs associated with poorly planned and managed development in coastal regions.

This suggests that far greater attention needs to be given to the development of Social and Cultural assessment of coastal ecosystems and resources to ensure that the Ecological and Economic assessments are placed into perspective. There are a number of critical socio-cultural issues that need to be addressed in strengthening the Social and Cultural assessment of coastal ecosystems. Examples include:

- Understanding local knowledge and the dynamics of technical change in developing countries. This must be effectively linked to political and ideological objectives in development, such as poverty reduction, gender issues, empowerment and locally organized and accountable institutions, with locally appropriate, widely adopted and sustainable objectives for technical change (Blaikie et al. 1996);
- Developing methodologies for identifying and incorporating the needs, aspirations and viewpoints of stakeholders in the assessment of options and constraints for sustainable coastal resources development;
- Developing methodologies for analysing and improving the effectiveness of uptake pathways for renewable natural resources information and technology by local communities.

2.4.2
A Simple Conceptual Model for Illustrating Role of Coastal Ecosystems in Sustaining Human Activities

Figure 2.4 illustrates a coastal ecosystem, the different functions it produces, the resources generated by those functions and the different human activities that make use of those resources.

Points that should be noted from this figure are:

- The direct link between environmental functions and the generation of renewable resources;
- The use of one form of resource by more than one form of human activity;
- Sustainable use of the flow of renewable resources – this includes economic as well as environmental goods and services – requires management of the coastal ecosystem as well as the human activities.
- Overexploitation of one resource can have a corresponding effect upon other potential users of the resource;
- Adverse environmental effects resulting from the uses of the coastal ecosystem, or from external activities can reduce the functional integrity of the ecosystem, and production of resources and their use;
- The importance of environmental processes in maintaining the production of renewable resources. Like a factory, you cannot expect the system to continue produce products unless you pay attention to the amount and quality of inputs required to maintain the productivity and functional integrity of the system.

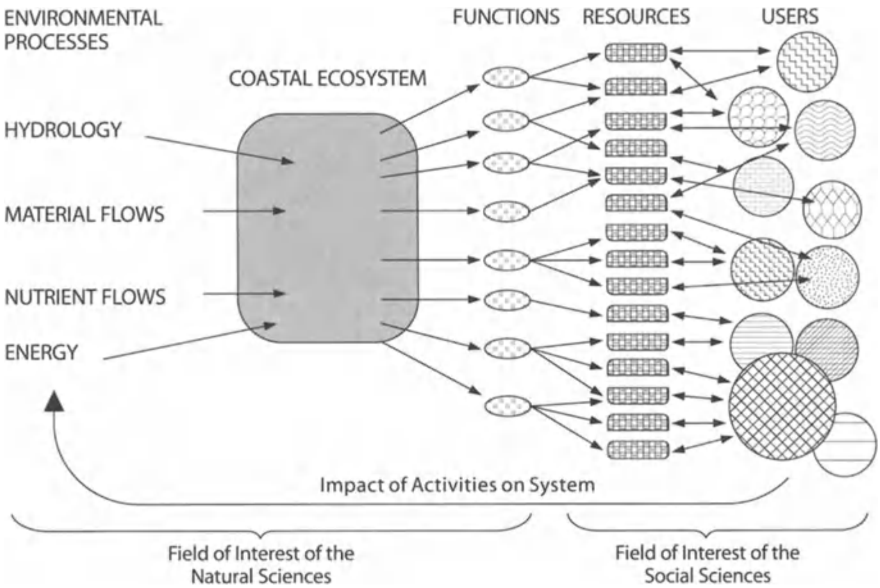


Fig. 2.4. A coastal ecosystem

This highlights one of the basic problems we face in promoting sustainable development of coastal resources, namely that economic planning and management systems are designed to manage human activities – not natural systems.

The sustainable use management of coastal ecosystems requires a creative fusion of a wide range of disciplinary skills and knowledge. Figure 2.4 can help to demonstrate this observation. Towards the *left* hand side of Fig. 2.4 disciplines such as hydrology, geomorphology, physics, and ecology have a major contribution to make to developing planning and management practices that will maintain the health and productivity of the coastal system. Towards the *right* hand side of Fig. 2.4 disciplines such as economics, sociology, business management, or spatial planning will make a major contribution to the development of resource utilisation strategies and planning and management arrangements that will help to ensure the sustainable use of the renewable resources produced by the coastal system.

With reference to Fig. 2.4 it can be seen that a variety of different economic activities can be sustained by the different resources generated by one coastal ecosystem. There may be competition among different users for the same resource and there will be corresponding economic links among the different users. For example, there may be a finite supply of mangrove poles to make fish traps. If one user exploits the resource heavily there will be less poles for other users.

In theory there is a point of Maximum Sustainable Yield (MSY) for each renewable resource produced by an ecosystem beyond which production declines (see Fig. 2.5). MSY of one resource cannot be viewed in isolation from the MSY of other resources from the same ecosystem. Maximum exploitation of one resource can have a negative influence on other resources. For example, if a mangrove is clear cut to maximize the extraction of timber there can be a reduction in leaf litter production which enters the estuarine food web. This can reduce secondary production of organisms which form the catch of local fishermen.

In economic terms, there are decreasing financial returns per unit effort expended for the extraction of the maximum sustainable yield of a renewable natural resource, such as mangrove timber, by individual competing for that resource. This means that there is a point on a curve of production (point "m" in Fig. 2.5) beyond which there are decreasing returns per unit effort/investment.

Fig. 2.5. Single sector perspective

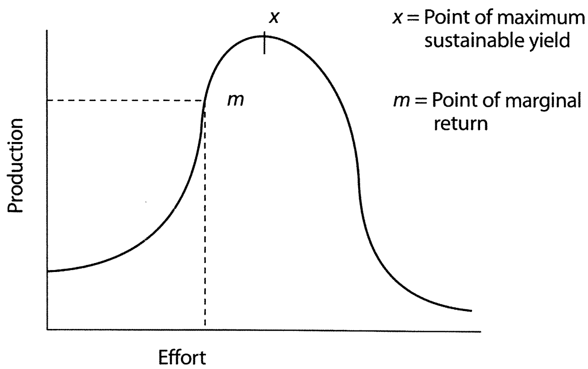
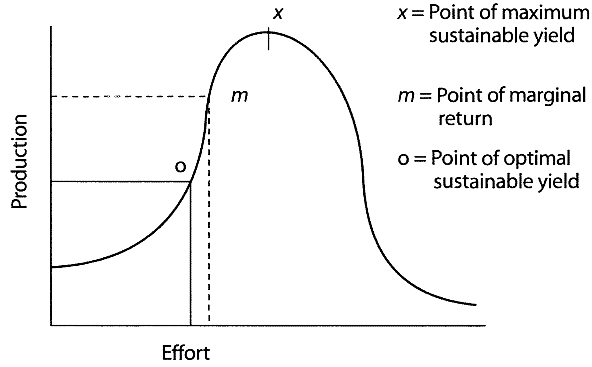


Fig. 2.6. Illustration of optimum sustainable yield



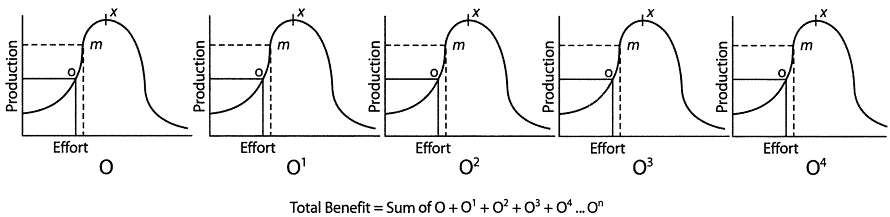


Fig. 2.7. Optimal sustainable yield from integrated, multiple uses of coastal resources

The same logic can be applied to the production of a series of resources generated by a coastal ecosystem where the exploitation of one resource will have a corresponding effect on the production of other resources and on potential users of those resources. If it is considered economically and socially desirable to maintain production of the mix of resources, then a level of exploitation of individual resources will have to be found which will minimize adverse effects on the production of other resources. This level of exploitation can be termed the Optimal level of Sustainable Yield (OSY). This is illustrated in Fig. 2.6. It is interesting to note that in theory the total area under the production curve at OSY for a specific resource may not be a great deal less than that for the point "m" at which increasingly marginal returns on investment or effort. However, this must be worked out in practice and the calculation of the economic interactions among different multiple uses will require sophisticated economic modelling. It may be possible to build upon the economic models developed for multiple species fisheries to better represent the potential interactions among different economic activities sustained by one or more coastal ecosystems.

Figure 2.7 illustrates a series of uses of different resources generated by a coastal ecosystem where Optimum Sustainable Yields are maintained. Note that the *sum* of the benefits is equal to the sum of the individual levels of OSY for all direct uses of resources. To this can be added a multiplier resulting from secondary economic activities sustained by the direct resource uses.

To actually achieve the total benefits illustrated in Fig. 2.7 will require a very good information base on the maximum sustainable yield of individual resources and how different forms and levels of exploitation of those resources will affect the health and productivity of the entire ecosystem. It will also require good information on social preferences for different resources, including the sustained availability of environmental goods and services which may not be extracted or consumed. This is a very complex challenge indeed and reinforces the idea that we need to find better ways of integrating environmental, social and economic information to help us develop the skills required to manage complex coastal systems in a sophisticated manner.

2.5 Multiple-use Management of Coastal Areas and Associated Ecosystems Utilising the Concept of Integrated Coastal Management

The achievement of even modest levels of sustainable and integrated development of coastal resource systems requires intersectoral cooperation, coordination of plans and the integration of development activities. This is not easy, however the concept of multiple-use has been used world-wide to successfully coordinate and integrate activities in watershed management programmes because significant benefits can be derived from interactions among, rather than the segregation of, resource users.

The concept of multiple use of land and water resources is not new. Many coastal societies in Asia have been utilising coastal resource systems, such as mangrove, for a variety of purposes for centuries. Unfortunately the sophistication and risk reducing character of these traditional, multiple-use systems are being destroyed before we have properly studied them. Their destruction is brought about by concentrated economic pressures, such as the conversion of mangrove to produce highly valued shrimp for export, and by sectoral approaches to economic development which displace them. These can result in the foreclosure of development options, increased risk of adverse environmental effects, loss of employment, and accelerated rural to urban migration.

The sustainable, and wherever possible optimal, use of complex coastal systems therefore requires a management approach equally sophisticated as traditional multiple use approaches and which is capable of maintaining the multiple functions of the environmental systems, guiding public and private sector investment and avoiding the foreclosure of future development options. Slavishly mimicking traditional systems which may not be the solution to coping with the scale and rate of change evident in most developing nations. However, careful observation of traditional management systems can provide a wealth of information on the ecology of coastal environments, utility of resources, limits to exploitation, and economic, social and cultural values which need to be taken into consideration in formulating management plans. In essence there is information available which can be used to fill in the large gaps in our knowledge of coastal ecosystems.

2.6 Conclusions

For the foreseeable future, most coastal nations will remain heavily dependent upon coastal resources to meet the needs of expanding populations and the need to expand and diversify their economies. The degradation of coastal areas, declining availability of coastal resources and the loss of future development options are avoidable. Most of these issues have come about as a result of a gross underestimation of the value of coastal land and water resources and the sophisticated policy making, planning management skills required to fulfil development objectives without destroying renewable resources. Some authors argue that it is the development pressures that are the principle issue, an alternative view would be that these pressures have to be dealt with and the answer lies in developing improved management systems that can handle these pressures and make more effective use of available capital, bio-geophysical and human resources. This presents a major challenge in creating the knowledge and management skill required to overcome constraints which hinder the development of multiple-use management of the flows of economic and environmental goods and services generated by coastal ecosystems. This suggests that a key issue is how to promote greater investment in interdisciplinary studies to develop the information and management guidelines to support integrated management for sustainable coastal resource development.

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Chapter 3

Strategic Planning for Sustainable Development in Coastal Zone Regions: Using Natural Resource Accounts

G.-M. Lange

3.1 The Need for a Comprehensive Framework to Represent Socio-economic Systems

Supporting nearly two-thirds of the world's human population and much of its biological productivity, sustainable management of coastal zones represents the most complex challenge we face. Integrated coastal zone management (ICZM) is an action-oriented approach to this challenge which combines scientific analysis and planning, stakeholder participation, and institutional reform under the umbrella of a single activity (Post and Lundin 1996). ICZM takes a multidisciplinary, systems approach in which the essential, distinguishing feature is the understanding and representation of the interdependencies among ecosystem functions, socio-economic activities, and institutions. In this way, ICZM differs from other methods which are based on incremental, sector-by-sector approaches (Hatziolos et al. 1996; OECD 1993; Pernetta et al. 1993).

Since sustainability is both a socio-economic and an ecological problem, a unified analytical framework is needed that fully integrates models of ecological systems and models of socio-economic systems. Much progress has been made in ICZM to develop a comprehensive analytical framework to represent ecosystems. This strength of ICZM may reflect, in part, the origins of ICZM with natural scientists and physical planners such as marine biologists, transportation engineers, and land use planners. For the economic component of the analysis, important work has been done in the area of designing appropriate user fees, pollution charges, and policy changes such as the removal of subsidies for agricultural chemicals, and changes in land use zoning (e.g., Linden and Lundin 1996; Panayotou et al. 1995). However, much less progress has been made in applying the holistic modelling approach, which is the hallmark of ICZM, to socio-economic systems.

Economic activities and population growth are the major driving forces for change in coastal zones. Because of sectoral interdependencies, cross-sectoral impacts of economic activities and the far-reaching influence of upstream activities on coastal zones, it is widely recognized that ICZM must be integrated with National Development Plans, but there is little discussion in the ICZM literature of how to build a framework for systems analysis of socio-economic activities and the ecosystem-economy linkages. In this paper, I will discuss a new economic tool which is of particular relevance to ICZM because of its ability to bridge ecosystem models and economic system models: Natural resource accounts (NRA), also known as environmental accounts. This paper begins with a brief description of NRA, then provides an example of the use of NRA for strategic planning in Indonesia. While the application of NRA to Indonesia is not exclusively for coastal zones, the analytical method reported here is appropriate for ICZM and may be used for such work in the future. The paper will also describe some of the institutional elements required for successful implementation of NRA.

3.2
Natural Resource Accounting

NRA record stocks of natural resources and changes in stocks as well as use of the environment and resources and are linked to economic accounts through the use of a common classification of economic activities; they are constructed as a set of satellite accounts to the System of National Accounts (SNA) (United Nations 1993). The SNA are particularly important because they constitute the primary source of information about a country's economy. Though NRA are relatively new and a number of conceptual and practical issues are not yet resolved, the use of NRA is spreading (Bartelmus et al. 1997). NRA can be compiled in both physical and monetary units and used for the following purposes:

1. To monitor the state of the environment and economy. The NRA as a monitoring framework can provide both detailed and aggregate physical indicators and an improved indicator of macroeconomic performance, environmentally-adjusted domestic product, which adjusts for net degradation or depletion of natural capital. This system represents economic activities, including households, that use resources or cause environmental degradation as well as those activities that are affected by degradation.
2. For policy analysis and planning. NRA provide the environmental and natural resource input to economic tools and models for analysis at the regional and national levels, or for sectoral and project management.

The emphasis of NRA, compared to other sorts of data about the environment, is the direct linkage with economic accounts to facilitate integrated environmental-economic analysis (Lange and Duchin 1994). The contribution of NRA has been primarily at the macroeconomic (either economy-wide or regional, including watershed or coastal regions) and sectoral levels as a tool for coordinating policies in different Ministries, tracking cumulative impacts and upstream/downstream effects across sectors and over time, evaluating trade-offs, and setting policy that can only be determined at the regional or national level.

In addition to the ability to address specific policy issues, the construction and use of NRA has made several important contributions to the *process* of policy-making itself (Lange 1996a), which are relevant to the decision-making process of ICZM:

1. NRA require a way of thinking about resource management based on a *systems approach* in which the key feature is to understand the interdependence of activities, of economic and environmental considerations, and consequently of trade-offs. In addition, the use of NRA is based on a *pro-active approach* to policy-making rather than a reactive one, an approach to policy based on anticipation of possible future situations through a series of "What if?" scenario simulations.
2. NRA provide a transparent system of information about the state of the environment and relationships between human activities and the environment in situation. The power of the SNA for economic information is that it has become an information system to which all parties agree (despite recognized limitations). The NRA organizing framework could play a similar role in searching for common ground to

describe the environment-economic linkages in a potentially conflict-ridden situation.

3. A formal, structured framework such as the one offered by NRA facilitates consistent analysis which, in turn, provides a concrete basis for productive dialogue among line Ministries about alternative, multi-sectoral development strategies and the associated policy trade-offs.

3.3 Using Natural Resource Accounts in Strategic Planning for Sustainable Development in Indonesia

A study undertaken by the author and her colleagues over several years for Indonesia's Planning Ministry provides a concrete example of the use of NRA for strategic analysis at the national and sectoral levels (for more detail, see Duchin et al. 1993; Lange 1997). NRA were constructed and incorporated as the environmental module in an ecological-economic model in order to calculate the demand on the natural resource base of Indonesia's Second Long Term Development Plan (1994–2018). In particular, the analysis sought to anticipate emerging conflicts between economic development and sustainable resource management and to identify the kinds of technological changes that might make it possible to achieve Indonesia's development objectives within the constraints posed by the natural resource base.

Indonesia's long-term development strategy is based on increased industrialization and a transition away from dependence on oil with a strong emphasis on sustainable management of resources in order to avoid the degradation of the resource base which occurred during the rapid economic growth of the past 25 years. Over the next 25 years, economic growth will intensify competition for land. Some of the most fertile rice land is being converted for residential, industrial and commercial use, especially land near urban areas. Forests and coastal wetlands are being converted to agriculture production. While Indonesia has abundant water resources, there are large seasonal variations in water availability and it is already in short supply in some areas. Water pollution and air pollution have become a major threat both to human health and welfare and to industrial productivity in urban areas. Increasing urbanization of the population and the continued concentration of industry in urban areas over the next 25 years make dealing with these problems a priority.

Conflict over resource use and the deterioration of the environment may force Indonesia to make some difficult decisions concerning trade-offs between economic growth and the possible exhaustion or serious degradation of its natural resources. However, through the use of more efficient and cleaner technologies, Indonesia may be able to achieve substantial economic growth without sacrificing its natural capital. The major issues which were addressed with the ecological-economic model include:

- Feasibility of continued food self sufficiency;
- The compatibility of sustainable management of natural forests and the large-scale expansion of the pulp and paper industry;
- Availability of an adequate amount and quality of water for agriculture, industry and households;
- Management of air pollution.

Food self sufficiency. Over the next 25 years, economic growth will intensify competition for land. Rice, the staple crop of Indonesia is extremely water-intensive, accounting for 90% of current water use. Even moderate increases in rice production would require large amounts of water and some increase in land area at a time when some the most fertile paddy land is being converted for residential, industrial and commercial use, especially land near urban areas. As incomes increase, the average diet can be expected to include more meat, fruit, and vegetables. Increases in livestock production require a great deal of land either directly if livestock is raised on rangeland or indirectly to provide the feed if livestock is raised on feedlots.

Forestry and the paper industry. Indonesia accounts for a significant share of the world's remaining rain forests. Its forests are barely able to meet current levels of demand. The scale of operation of wood-using industries over the next 25 years is likely to place demands on Indonesia's forestry sector which would decimate its forests, especially with a large expansion of the pulp and paper industry. Plantation forests may be able to alleviate the timber shortage and allow the preservation of natural forests.

Water and air pollution. The provision of clean water for household use and for industry is also a major objective over the next 25 years. While Indonesia has abundant water resources, there are large seasonal variations in water availability and it is already in short supply in some areas. Both water pollution and air pollution have become a major threat both to human health and to industrial productivity in urban areas. Increasing urbanization of the population and the continued concentration of industry in urban areas over the next 25 years make dealing with these problems a priority.

The issues raised by Indonesia's development strategies require an analytical framework that is *multi-sectoral* and *cumulative*; the former in order to identify spillover or intersectoral effects and the potential conflict for resources or inconsistencies among sectoral objectives; the latter in order to keep track of the cumulative economy-wide environmental degradation and demands on the resource base. The development strategies and environmental concerns determine the kinds of variables to be included in the NRA and the type of economic model to be used.

The NRA include the major constraints to development in Indonesia: water, land suitable for different crops and forests, and factors affecting the quality of water and land: soil erosion and three types of water pollution, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and suspended solids. Three types of air pollutants are also included, carbon dioxide (CO_2), sulphur dioxide (SO_2), and nitrogen oxides (NO_x) for each economic sector and for households. A 30-sector dynamic input-output model was used to represent the economy, based on the dynamic model developed by (Duchin and Szyld 1985) and implemented in (Leontief and Duchin 1986). NRA were constructed for the base years of 1985 and 1990 (see Table 3.2). The NRA were converted to sectoral parameters for using with the IO model and NRA were projected under alternative scenarios for the year 2020.

The impact of the economy on the environment will depend in part upon the technologies in use in each sector. Four scenarios were constructed to represent alternative development paths, focusing on potential technological change. The scenarios were first defined in terms of broad objectives like rates of GDP growth (a high rate of 7% and a moderate rate of 5%) and the direction and rate of technological change. (Scenario S1 continues present trends toward more efficient use of resources and environmental protection; S2 includes much stronger resource conservation measures.) Then the IO case-study methodology (Duchin and Lange 1994) is used to project and quantify future production technologies for the 15 sectors of the economy most closely related to the four strategic development issues identified earlier (Table 3.1).

The case studies project changing parameters governing resource efficiency and pollution generation as well as other inputs expressed as changes in sectoral inputs coefficients relative to the value of the coefficients in the base year. Some of the most important environmental aspects of the case studies are briefly described below.

Agriculture. Increases in yields (greater under S2 than S1), reducing land requirements per unit of output, are projected for all agricultural sectors due to improved seed varieties or cultivars and improved farm management. For Paddy, greater multiple cropping is projected which further increases annual yields and reduces land requirements. The farming techniques currently used for other food crops result in serious soil erosion which undermines the potential gains in yields from improved cultivars by reducing soil fertility. Under S2, soil conservation measures are introduced to preserve soil fertility. In total, land requirements per unit of output in paddy decrease by 35% under S1 and 56% under S2; for other food crops the land requirements drop 29% and 24% under S1 and S2, respectively. The slightly higher land requirements under S2 reflect soil conservation measures. The land input for Estate crops declines 46% under both scenarios.

Under current practices, Paddy needs only about 25% of the water it actually draws through the irrigation system; improvements in water efficiency are needed

Table 3.1. Sector codes and names

Sector codes and names	
1	Rice
2	Other food crops
3	Estate crops
4	Livestock
5	Forest products
11	Food, beverages, tobacco
13	Pulp and paper
15	Chemicals
16	Cement
17.2	Textiles, leather, apparel
17.5	Iron and steel
20	Electric power
26	Transportation services
	Household energy use
	Industrial energy conservation

Table 3.2 a. Natural resource accounts for Indonesia in 1985 (*Source:* Duchin et al. 1993)

A 1985		Sector	Air pollution CO_2 10^3 t	SO_2 10^3 t	NO_x 10^3 t	Water: Water uptake 10^6 m^3	BOD 10^3 t	COD 10^3 t	Susp. solids 10^3 t	Land: Land use 10^6 ha	Soil erosion 10^6 t
Agriculture	1	Rice	1	0.0	0.1	363 251	0	0	0	7.8	0
	2	Other food crops	18	0.0	1.1					6.2	170
	3	Other agr. crops	133	0.2	7.7					10.0	62
	4	Livestock	126	0.2	7.2	4	n.a.	n.a.	n.a.		
	5	Forest products	134	0.2	7.8						
	5.1	Natural forests									
	5.2	Plantations									
	6	Fisheries									
Mining	7	Coal	92	2.7	0.6						
	8	Crude oil	3 865	46.2	26.9						
	9	Natural gas	1 597	0.3	15.3						
	10	Other mining	267	7.2	1.0						
Manu-facturing	11	Food and tobacco	352	9.4	1.3	124	24	35	59		
	12	Wood products	256	6.9	0.9						
	13	Pulp and paper	53	1.4	0.2	164	43	142	49		
	14	Fertilizer	1 717	10.0	14.3						
	15	Chemicals	244	7.0	1.5	1	0	0	0		
	16	Cement	509	13.9	2.3						
	17	Other manufact.	1 033	27.1	4.0	339	68	271	339		
	18	Petrol. refining	908	11.9	5.7						
	19	LNG	283	2.1	2.0						
Utilities	20	Electricity	3 132	102.2	41.6						
	21	Gas utilities	285	6.9	1.3						
	22	Water utilities	40	0.3	0.1						
Services	23	Construction	6 582	43.2	23.7						
	24	Trade	624	4.0	2.3						
	25	Rest. and hotels	580	3.6	2.2						
	26	Transp and comm.	4 772	67.5	303.0						
	27	Business services	101	0.6	0.4						
	28	Public admin.	0	0.0	0.0						
	29	Services	363	2.1	1.4						
	30	Unspecified	14	0.1	0.1						
Households	31	Households	5 807	5.5	116.2	8 757	n.a.	n.a.	n.a.		
Total			34 157	383.0	608.2	372 640	135	449	448	60.2	311

if rice production is to expand in the future. Modification of the irrigation infrastructure to allow greater control of the flow of water and to reduce water leakage and losses reduce water requirements per unit of output by 63% under S1 and 73% under S2.

Forestry. Earlier analysis (Duchin and Lange 1992) showed that the natural production forests would not be able to satisfy Indonesia's domestic demand for wood products in the near future on a sustainable basis. The study now focused on the extent to which plantation forests would need to supplement natural forests and on measures required to manage natural forests sustainable.

Table 3.2 b. Natural resource accounts for Indonesia in 1990 (*Source:* Duchin et al. 1993)

B 1990			Air pollution			Water				Land	
	Sector		CO_2 10^3 t	SO_2 10^3 t	NO_x 10^3 t	Water uptake 10^6 m^3	BOD 10^3 t	COD 10^3 t	Susp. solids 10^3 t	Land use 10^6 ha	Soil erosion 10^6 t
Agriculture	1	Rice	1	0.0	0.1	392 298	0	0	0	8.3	0
	2	Other food crops	21	0.0	1.2					7.6	208
	3	Other agr. crops	162	0.2	9.4					10.8	67
	4	Livestock	173	0.2	10.0	4	n.a.	n.a.	n.a.		
	5	Forest products	210	0.3	12.3					49.4	109
	5.1	Natural forests								47.9	109
	5.2	Plantations								1.5	0
	6	Fisheries	401	0.5	23.4						
Mining	7	Coal	116	3.4	0.8						
	8	Crude oil	4 230	50.6	29.4						
	9	Natural gas	2 183	0.4	20.9						
	10	Other mining	200	5.4	0.7						
Manu-facturing	11	Food and tobacco	431	11.5	1.6	152	30	43	73		
	12	Wood products	589	15.8	2.1						
	13	Pulp and paper	57	1.5	0.2	177	47	155	54		
	14	Fertilizer	1 962	11.4	16.3						
	15	Chemicals	71	2.0	0.4	1	0	0	0		
	16	Cement	442	12.1	2.0						
	17	Other manufact.	455	11.9	1.7	149	30	119	149		
	18	Petrol. refining	1 004	13.2	6.3						
	19	LNG	443	3.3	3.1						
Utilities	20	Electricity	3 629	118.4	48.2						
	21	Gas utilities	335	8.0	1.5						
	22	Water utilities	53	0.3	0.2						
Services	23	Construction	6 156	40.4	22.1						
	24	Trade	724	4.6	2.7						
	25	Rest. and hotels	755	4.7	2.8						
	26	Transp and comm.	6 088	86.1	386.5						
	27	Business services	130	0.8	0.5						
	28	Public admin.	0	0.0	0.0						
	29	Services	465	2.7	1.8						
	30	Unspecified	3	0.0	0.0						
Households	31	Households	7 589	7.1	151.8	9 744	n.a.	n.a.	n.a.		
Total			339 078	416.9	760.4	402 526	107	317	276	76.1	384

Plantation forests on a 15 year cycle are projected to account for 40% of log production under S1 and 68% under S2. Plantations are to be established on degraded land not suitable for other crops and, consequently, will not compete with agriculture for land. Some soil erosion will occur when the plantations are first established, but erosion is expected to be negligible thereafter. Changes in methods of road building, felling, and transportation of timber from natural forests are introduced to reduce soil erosion and deforestation. The net impact of plantation forestry and improved practices in natural forests is to reduce land requirements per unit of forestry output by 35%, soil erosion by 80%, and deforestation by 65% under S1. The figures under S2 are 60%, 92% and 81%.

Manufacturing, transportation, and electricity. Projections for manufacturing include increases in energy efficiency, reduction in water requirements, and the introduction of measures to reduce the emission of water pollutants in line with current or likely future regulations. In some sectors the energy mix will change; coal, gas, or purchased electricity will substitute for oil, presently the most widely used energy source. Motor vehicle fuel efficiency increases by 25% under S1 and 50% under S2.

In Electricity, transmission and distribution losses are reduced, thermal conversion efficiency increases, and the fuel mix shifts. Under S1, oil, the fuel most commonly used at this time, is largely replaced by coal and gas. Under S2, a greater share of natural gas is used, burned in highly efficient, gas combined cycle generators. All other sectors not subject to case studies are projected to improve energy efficiency between 1985 and 2020 by an average of 20% through a variety of means from simple improvements in energy "housekeeping", such as regular tune-ups, to more complex methods like waste heat recovery and cogeneration of electricity.

Household energy use. Households accounted for 20% of commercial fuel consumption in 1985. In the future, commercial energy use will increase due to population and income growth and the substitution of cleaner and more convenient commercial fuels and electricity for non-commercial fuels. At the same time households will increase the shares of natural gas and coal (mostly in briquette form), reducing the share in fuel consumption of petroleum, currently the most widely used commercial fuel. Moderating this trend toward increasing energy use are substantial improvements in energy efficiency of goods used by households. Motor vehicle fuel efficiency increases 25% under S1 and 50% under S2 and electrical appliances are 10% more efficient under S1 and 25% under S2. Even with these efficiency gains, households are projected to use more than 20 times the electricity used in 1985 under S1 and 15 times the 1985 level under S2. Fossil fuel use increases more than four-fold under S1 and just under three-fold under S2.

Table 3.3. GDP, investment, and employment for Indonesia in 1985 and 2020 under moderate growth scenario (*Source:* Duchin et al. 1993)

	1985	**2020**
GDP (10^{12} Rps. in 1985 prices)	98	542
Per capita GDP (10^3 Rps. in 1985 prices)	611	2065
Investment (% of total GDP)	25.3	23.3[a]
Employment, full-time equivalent, 10^6	54	145
Employment as a share of labor force	0.80	1.08
Sectoral distribution of employment (%)		
Agriculture	53	26
Manufacturing	13	23
Services	33	51

[a] average over the period; figures for employment and investment are virtually the same for scenarios 1 and 2 with moderate growth. Figures for the high growth are not reported since they were considered not feasible.

3.4
Results of Scenario Analysis

Under the moderate (5%) GDP growth scenarios, total GDP increases more than 5 times between 1985 and 2020 (Table 3.3). Since population grows more slowly than GDP over the period (less than 2% a year), per capita income increases substantially from 611 000 rupiahs per capita in 1985 to 2 065 000 rupiahs in 2020 (in constant 1985 prices), which will contribute to a significant reduction in the incidence of poverty in Indonesia. Investment as a share of total GDP does not change much between 1985 and 2020, suggesting that investment may not be a serious constraint to development. Labor demand more than doubles and slightly surpasses the expected labor supply in 2020 even with significant projected gains in labor productivity, especially in agriculture, the major source of livelihood for Indonesians in 1985. The sectoral distribution of employment is projected to change as fewer people are employed in agriculture (26% in 2020 compared to 53% in 1985) and more find work in manufacturing and service sectors. While moderate economic growth is projected to provide full employment, high growth (sustained 7% annual GDP growth) requires labor far in excess of the projected supply and, for this reason, is not considered feasible; the scenarios associated with high GDP growth are not discussed further in this paper.

The impact of the alternative development scenarios on the natural resource base is indicated by the projected NRA (Tables 3.4, 3.5, and 3.6). In some instances, conflicts between economic growth and sustainable use of resources can be reconciled through the use of appropriate technology. In other instances, development objectives will need to be modified or reconsidered. In addition, substantial changes in existing policies may be required to create incentives to bring about the changes in behaviour necessary for implementing many of these changes. For example, future food self sufficiency appears technically feasible only for rice, but not for other food crops. Detailed results include:

- Rice self sufficiency is feasible only with vast improvements in the efficiency of irrigation and the introduction of incentives for farmers to conserve water, such as appropriate water pricing. Land required in 2020 under S1 is only 2% more than supply and under S2 it is considerably less than supply (Table 3.6). In 2020, rice still uses most of the water in the economy, but much less than the amount used in 1985 and 1990. In addition, much of the land for rice production in the future will be located on Irian Jaya replacing rice production on Java where land is steadily being lost to urban encroachment posing a major settlement policy challenge. In the absence of such changes, the required land and water inputs will far outstrip supply, cutting into land and water needed for other activities or requiring a reconsideration of the policy of rice self sufficiency.
- Even under optimistic assumptions about potential increases in yields, the production of other food crops faces tight land constraints because of the rapid growth of demand associated with rising incomes and an increased meat consumption. Land requirements exceed supply under both scenarios. Under the more realistic scenario, S2, in which soil conservation measures necessary to maintain improvements in yields are undertaken, land requirements are 18% higher than supply in 2020. Land

Table 3.4. Natural resource accounts for Indonesia in 2020 under scenario 1 with moderate economic growth (*Source:* Duchin et al. 1993)

Sector			Air pollution			Water				Land	
			CO_2	SO_2	NO_x	Water uptake	BOD	COD	Susp. solids	Land use	Soil erosion
			10^3 t	10^3 t	10^3 t	10^6 m^3	10^3 t	10^3 t	10^3 t	10^6 ha	10^6 t
Agriculture	1	Rice	2	0.0	0.1	112 255	0	0	0	9	0
	2	Other food crops	43	0.1	2.5					10	440
	3	Other agr. crops	637	0.8	37.0					27	180
	4	Livestock	1 048	1.3	60.6	24	n.a.	n.a.	n.a.		
	5	Forest products	694	0.8	40.5					109	64
	5.1	Natural forests								106	64
	5.2	Plantations								3	0
	6	Fisheries	1 563	1.9	91.4						
Mining	7	Coal	3 898	115.0	26.4						
	8	Crude oil	6 855	82.0	47.7						
	9	Natural gas	14 092	2.8	135.0						
	10	Other mining	978	26.5	3.6						
Manu-facturing	11	Food and tobacco	1 034	27.4	3.9	121	6	9	8		
	12	Wood products	1 377	36.9	5.0						
	13	Pulp and paper	876	25.9	6.5	429	76	299	25		
	14	Fertilizer	6 092	31.0	51.7						
	15	Chemicals	2 717	79.0	18.1	19	0	0	0		
	16	Cement	2 437	72.2	17.8						
	17	Other manufact.	1 736	44.8	6.9	688	55	220	172		
	18	Petrol. refining	2 893	39.2	18.4						
	19	LNG	3 301	25.9	23.4						
Utilities	20	Electricity	18 445	314.5	299.2						
	21	Gas utilities	2 266	53.5	10.5						
	22	Water utilities	244	1.6	0.9						
Services	23	Construction	26 409	173.3	94.9						
	24	Trade	2 900	18.4	10.8						
	25	Rest. and hotels	2 557	16.0	9.6						
	26	Transp. and comm.	22 251	314.4	1 412.1						
	27	Business services	559	3.4	2.2						
	28	Public admin.	0	0.0	0.0						
	29	Services	2 091	12.2	8.3						
	30	Unspecified	20	0.1	0.1						
Households	31	Households	41 328	446.0	534.6	18 494	n.a.	n.a.	n.a.		
Total			171 343	1 966.9	2 979.7	132 030	138	528	205	264	684

required for Estate crops exceeds supply by 37%. Indonesia will probably have to consider importing a significant share of its food requirements, despite its desire for food self sufficiency.

- To meet timber requirements without decimation of Indonesia's remaining natural forests, large-scale plantation forests must be rapidly expanded to meet up to two-thirds of the timber demand. However, in order to expand plantation forests without conflicting with, these plantations must be established on degraded lands and not on land suitable for food or estate crops. Incentives would have to be designed carefully to ensure that plantations are established on these lands. Plantation for-

Table 3.5. Natural resource accounts for Indonesia in 2020 under scenario 2 with moderate economic growth (*Source:* Duchin et al. 1993)

Sector			Air pollution			Water				Land	
			CO_2 10^3 t	SO_2 10^3 t	NO_x 10^3 t	Water uptake 10^6 m^3	BOD 10^3 t	COD 10^3 t	Susp. solids 10^3 t	Land use 10^6 ha	Soil erosion 10^6 t
Agriculture	1	Rice	2	0.0	0.1	81 476	0	0	0	6	0
	2	Other food crops	43	0.1	2.5					11	200
	3	Other agr. crops	619	0.8	36.0					27	180
	4	Livestock	1 045	1.3	60.4	24	n.a.	n.a.	n.a.		
	5	Forest products	689	0.8	40.2					62	35
	5.1	Natural forests								58	35
	5.2	Plantations								4	0
	6	Fisheries	1 562	1.9	91.3						
Mining	7	Coal	2 999	88.5	20.3						
	8	Crude oil	6 075	72.7	42.3						
	9	Natural gas	13 777	2.7	132.0						
	10	Other mining	898	24.3	3.3						
Manu-facturing	11	Food and tobacco	1 033	27.3	3.9	121	6	9	8		
	12	Wood products	1 370	36.7	5.0						
	13	Pulp and paper	854	25.2	6.3	418	74	291	24		
	14	Fertilizer	5 739	29.2	48.7						
	15	Chemicals	2 535	73.7	16.9	18	0	0	0		
	16	Cement	2 350	69.7	17.2						
	17	Other manufact.	966	24.9	3.8	383	31	123	96		
	18	Petrol. refining	2 356	31.9	15.0						
	19	LNG	3 298	25.9	23.3						
Utilities	20	Electricity	12 770	183.1	212.2						
	21	Gas utilities	2 425	57.2	11.3						
	22	Water utilities	242	1.6	0.9						
Services	23	Construction	26 187	171.9	94.1						
	24	Trade	2 808	17.8	10.4						
	25	Rest. and hotels	2 542	15.9	9.5						
	26	Transp. and comm.	17 509	247.3	1 110.6						
	27	Business services	552	3.3	2.1						
	28	Public admin.	0	0.0	0.0						
	29	Services	2 072	12.1	8.2						
	30	Unspecified	4	0.0	0.0						
Households	31	Households	27 817	321.4	328.4	18 494	n.a.	n.a.	n.a.		
Total			143 139	1 568.8	2 356.4	100 934	111	423	128	168	415

ests and improved management of natural forests also require significant increases in labor and capital inputs per unit of output. Preliminary calculations indicate that the costs of timber from plantation forests will be roughly 50% greater than timber from natural forests. Fee and pricing policies should be reviewed to provide incentives for the establishment of the more expensive plantation forests.

- Prospects for reducing water pollution are good if current regulations are enforced. In the absence of stringent regulations, air pollution will increase three- to five-fold. Recognizing that current concentrations of air pollution are unhealthy in major urban areas, the government has begun to introduce regulations for air pollution.

Table 3.6. Resource demands and constraints in 2020 under alternative, moderate economic growth scenarios (*Source:* Duchin et al. 1993)

		Ratio of land required to land available in 2020	
Land	**Land available (10^6 ha)**	**S1**	**S2**
1. Rice	8.3	1.02	0.7
2. Other food crops	9.8	1.06	1.13
3. Other agr. crops	19.6	1.37	1.37
4. Livestock			
5. Forest products			
Natural products	61.0	1.74	0.94
Plantation	19.8	0.13	0.22

1990 Level.

		Ratio of land required to land available in 2020	
Water	**10^6 m^3**	**Ratio of 2020 to 1990 levels**	
Total water uptake	402 526	0.33	0.25
Total BOD	107	1.29	1.04
Total COD	317	1.67	1.33
Total suspended solids	276	0.74	0.46
Air pollution	**10^3 t**		
Total CO_2	39 078	4.4	3.7
Total SO_2	417	4.7	3.8
Total NO_x	760	3.9	3.1

3.5 Institutional Factors Critical to Successful Implementation of Natural Resource Accounts

A major purpose of the Indonesian study was to stimulate policy dialogue within the ministries responsible for planning about their objectives for different sectors and the means to achieve them given their natural resource constraints. The success of this and other NRA demonstration projects in Indonesia is reflected in the decision by the government of Indonesia to institutionalize the compilation of NRA. Despite the apparent advantages of NRA, countries have been slow to adopt NRA; this is a matter of particular concern for developing countries who rely heavily on their natural capital and are undergoing rapid economic change and population growth. Broadly speaking, there are three elements required for successful construction and use of NRA (Lange 1996b):

Technical feasibility. Some environmental and natural resource data as well as economic data should be available, though initially this need not be collected by a central statistics office. The data requirements for NRA are often viewed as overwhelming, especially in countries that have few resources for the compilation of even the basic SNA. However, a great deal of information is already available for many countries, including developing countries, albeit scattered in various Ministries and in case studies or project documents. While the quality of the data may vary considerably, it is often adequate for policy analysis.

Clearly defined policy applications. To ensure that the NRA will be used by decision-makers, the problems NRA will be used to address need to be identified from the outset. NRA need to be demand-driven to avoid becoming just an "accounting exercise".

Institutional leadership capacity. The construction and use of NRA cuts across ministries and professional disciplines. While many ministries may support the construction of NRA, they may not see it as their primary responsibility. It is crucial to identify a ministry which is viewed by other ministries as having responsibility for NRA and which can provide effective leadership in coordinating inter-Ministerial participation (as well as NGO/PVOs, international donors, etc.).

3.6 Relevance of Natural Resource Accounting to ICZM

With ICZM, the planning challenge is always multi-sectoral and, at least in theory, is based on a systems approach to understanding complex human and ecological interactions. In practice, however, a piecemeal, rather than systems approach has often prevailed, especially in the integration of economic and ecological phenomena. With growing pressure on coastal zones, largely the result of economic and population growth, and the proliferation of coastal zone management efforts (Sorenson 1993), this approach is increasingly unsatisfactory. NRA provide one approach to improve dramatically the representation of economic system in ICZM. The NRA framework has special relevance to ICZM because it provides a comprehensive analytical framework that can explicitly represent the systems approach to the economy in a fair amount of detail.

To date, most NRA have been constructed for national economies though there have been a few applications of this technique at the regional level (within a nation) for watershed management and even at the village level. One of the major policy applications of NRA was to assist in the development of a management strategy of the Chesapeake Bay in the USA (Grambsch et al. 1993). The work presented here for the Indonesian economy could well be extended for any number of regions within Indonesia and provides a model for a formal, structured approach to linking ecological and economic systems in a manner that is suitable for quantitative analysis.

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Chapter 4

Methods and Tools to Support CZM

J. van der Weide · L. de Vrees

4.1 Introduction

Presently, a large number of Coastal Zone Management (CZM) programs are being implemented (Sorensen 1993) and successes and failures of some of these programs were evaluated in the Xiamen workshop. This has resulted in recommendations for good practices in the formulation. Design, and implementation of integrated coastal zone management (ICZM) initiatives (GEF/UNDP/IMO 1996). Recommendations can be divided into three categories:

- Recommendations regarding the approach used to ensure the quality and consistency in developing and implementing (ICZM projects and programs).
- Recommendations regarding the process of ICZM to ensure participation of all stakeholders in this process.
- Recommendations regarding the political, legal, institutional and technical instruments needed to support this process and to implement the output of the process.

Obviously, the ability to meet these requirements strongly differs between various countries, depending on the political, technical and financial context in which ICZM has to be implemented. Still, developing countries may benefit from experiences of the industrialized countries, if the above constraints are observed and appropriate techniques and tools are proposed.

The present paper tries to convert the requirements formulated in the Xiamen workshop into practical recommendations for planning, management and control of coastal zones, using experience obtained in the Netherlands and abroad.

4.2 The Approach

4.2.1 General

The Xiamen workshop recommended to use a systematic, incremental approach in developing and implementing ICZM projects and programs. Such an approach should take into account the following "dimensions" of ICZM:

- The issues: the objectives for ICZM and the criteria to be met;

- The process: the planning, development, implementation and control of programs and projects;
- The actions: the initiatives to facilitate planning, development, implementation and control.

4.2.2 The Issues

The management issues are manifold, throughout the world there is a wide variety of CZM objectives, therefore. Starting as a reactive effort to mitigate adverse effects of natural development or human interventions, the objectives have developed into a more precautionary approach to the planning processes which ultimately may result in a proactive coastal zone management policy, aiming at a sustainable production of goods and services required by the society. Reference is made to Sorensen 1993 showing the objectives and extent of CZM programs throughout the world.

The UNCED conference has marked the beginning of a new era in which sustainable development of land and sea resources is the leading issue. Its objective is to foster economic development without jeopardizing the integrity of vital ecosystems and their functioning. Though clear as a concept, implementation of the concept in real world cases is less obvious. New methods, techniques and tools have to be developed to provide the scientific basis for the approach and new administrative and governance structures have to be established to ensure its implementation.

4.2.3 The Process

Notwithstanding this large variety of objectives, it can be observed that most, if not all of the projects and programs, follow a more or less similar step by step approach to structure the CZM process. This so-called framework identifies planning, development, implementation, monitoring and evaluation as more or less explicit phases. Numerous attempts have been made to make this framework operational and in literature a number of guidelines for CZM are presented based upon this systematic approach. Examples may be found in the "The Guidelines for Integrated Coastal Zone Management" (The World Bank 1993), "Coastal Zone Management, Integrated Policies" (OECD 1993) and "Guidelines for Integrated Management of Coastal and Marine Areas" (UNDP/MAP 1994).

The basic elements of integrated coastal zone management are shown in Fig. 4.1. The elements can be grouped in three levels:

- The level of governance;
- The level of management tasks;
- The level of tools, instruments and capacities to support the management tasks.

On the *level of governance*, institutional arrangements and the legal arrangements should be considered. There is no universal approach, but the organisation will be based on tradition and social norms of a nation. Also, on the political level, objectives have to be formulated. In fact, there are three typical governmental tasks that cannot be organized by the private sector: safety for people; the access to or the division of resources over the users; and, finally, the stimulation of desired developments. Finally an ethical approach should be anchored on the level of governance through integration or harmonisation (horizontal and vertical) and by stimulating participation. If the government in different sectors and at different levels do not get its act together, there is little hope that people will understand the management program. Governmental policy is basically influencing people's behaviour.

On the *level of coastal management tasks* a typical cyclic approach exists, from problem recognition of planning, implementation and evaluation. Here, the coastal manager has to consider programs for research, data collection, policy development, decision making process for plan execution, the operation and maintenance and for monitoring of the developments in relation to the set objectives and criteria. In conclusion, or as a beginning of a new cycle, a programme for evaluation and outlook can be distinguished.

Finally on the *level of coastal zone management instruments and capacities*, a long check-list can be developed (Fig. 4.1). Some efforts also have been undertaken to define guidelines for coastal zone management. In general, the development of a program is site-specific and setting specific. Problem recognition can be supported by education and awareness programme coupled with research programmes and public participation. A multi-disciplinary approach in system analysis and decision making processes can avoid make-do solutions.

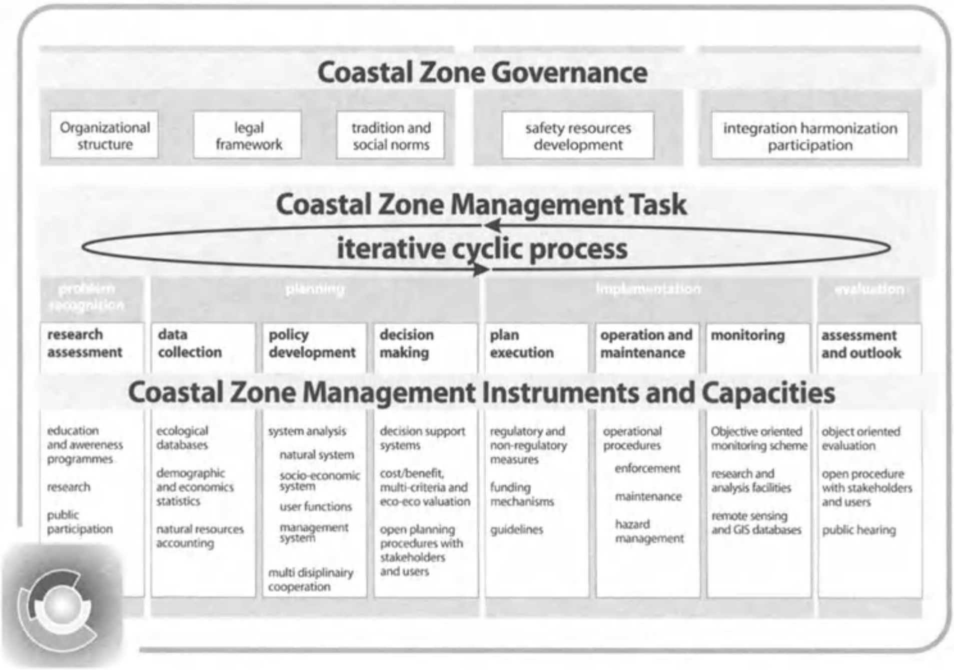


Fig. 4.1. The elements of coastal zone management

4.2.4
The Actions

The present paper focuses on the actions required to facilitate the use of the approach in the various phases of the process. Following the Xiamen recommendations, actions should guarantee:

- The active involvement of stakeholders;
- The integration of social, economic and environmental aspects;
- Policy instruments to coordinate administrative and governance initiatives at various levels and in different sectors;
- Technical instruments to support administrative and governance initiatives at various levels and in different sectors;
- The development of human resources.

The above aspects will be discussed in greater detail in the subsequent sections.

4.3
Active Involvement of Stakeholders

A crucial element in ICZM is the involvement of stakeholders in the process of establishing a programme. Most countries have a tradition to have a consultation process after the main decisions have been made. But as indicated before, governmental policy is basically about influencing people's behaviour. It is, therefore, essential that in an integrated process, already during the planning phase the stakeholders are consulted and participating. There are many forms in which this consultation process can be executed, depending on the traditions in a country. In western countries, the consultative process is used more and more. As an example a short description of this consultative process, used in the fourth integrated water management policy in *the Netherlands* will be given.

The philosophy for this process can be compared with the marketing of a product which needs to be sold. Therefore, it is essential that the potential "buyers" or customers are known, what their wishes are and how they consume. At first, a vision report called "Space for Water" was written and discussed with the customers (different authorities at different levels relevant ministries, provincial authorities, water boards), many user-groups like representatives of recreation sector, fisheries, farmers, drinking water companies, large industries, non-governmental organisations like nature groups, etc. Their reactions were combined and used in the second report: a rough outline of the policy plan. Again, a round of discussions and information sessions were organized, giving opportunity to the identified consumers to react on the way their first reaction had been dealt with. Although not all wishes could be honoured, the process should make clear what has been done with these wishes. This consultation round lead to the draft policy plan, which goes for consultation again. These reactions and the draft plan needs approval from central government before it is sent to parliament. Although the lead time for such a process is much longer than in the old manner (first making the policy plan, after which reactions are asked), it is the experience in the Netherlands that this time is re-gained again during the implementation phase.

In *Latvia*, another approach is used. Although the initiative for an integrated view on the coastal zone came from national level, the consultative process has been organized by local authorities. Five consultative bodies have been erected, with representatives of the different sectors. One national working group links the local plans to the national policies, procedures and legislation.

In *China*, the local authorities in the Yellow River Delta took the initiative to start the process of integrated management in the delta. But, having a strong central planning system with five year plans, it is essential that provincial and national authorities get involved and that links are made to these national planning strategies. In this project, a seminar was organized at the beginning of the process whereby all relevant authorities were invited. This led to the establishment of a Provincial Steering Group. Public hearings and consultation are not known phenomena in China. Therefore, representatives of stakeholders like the oil company and the nature reserve were especially invited to join the integrated process.

4.4 The Integration of Social, Economic and Environmental Aspects

4.4.1 General

It is common to describe the coast in terms of two interacting systems:

- The natural system which provides space, substratum, renewable and non-renewable resources and which regulates physical, biological and chemical processes in the coastal zone. In economic terms the value of this system is often categorized as the natural capital.
- The socio-economic system, the individuals, the public and private bodies who use the natural resource system for subsistence, economic and social activities. The importance of this system is expressed in economic terms as the human capital, which includes the human capital proper (the people), the social capital (its social infrastructure) and the industrial capital (the physical infrastructure).

Interaction is a two-way street. Man uses nature as a source to provide the resources for its activities and as a sink to dispose of its waste products. Both applications have a strong impact on the integrity of the natural system. For a sustainable exploitation of the resource system these impacts should be known.

In 1994, the OECD introduced the *pressure state response diagram* as a method to integrate economics and environment (OECD 1994). The method is schematically outlined in Fig. 4.2 obtained from the OECD publication. The upper part of the diagram describes the pressures, as a result of changes in the socio-economic system. For each group of actors pressures are defined in terms of resource use (in the diagram limited to land use) and waste emissions.

The central part of the diagram shows a set of matrices which are used to describe the effect of these pressures on the natural environment, the air, the water and the land. As shown in the diagram the method can be applied at various spatial scales, varying from local to supranational or even global scales. As a first step, the state of the natural

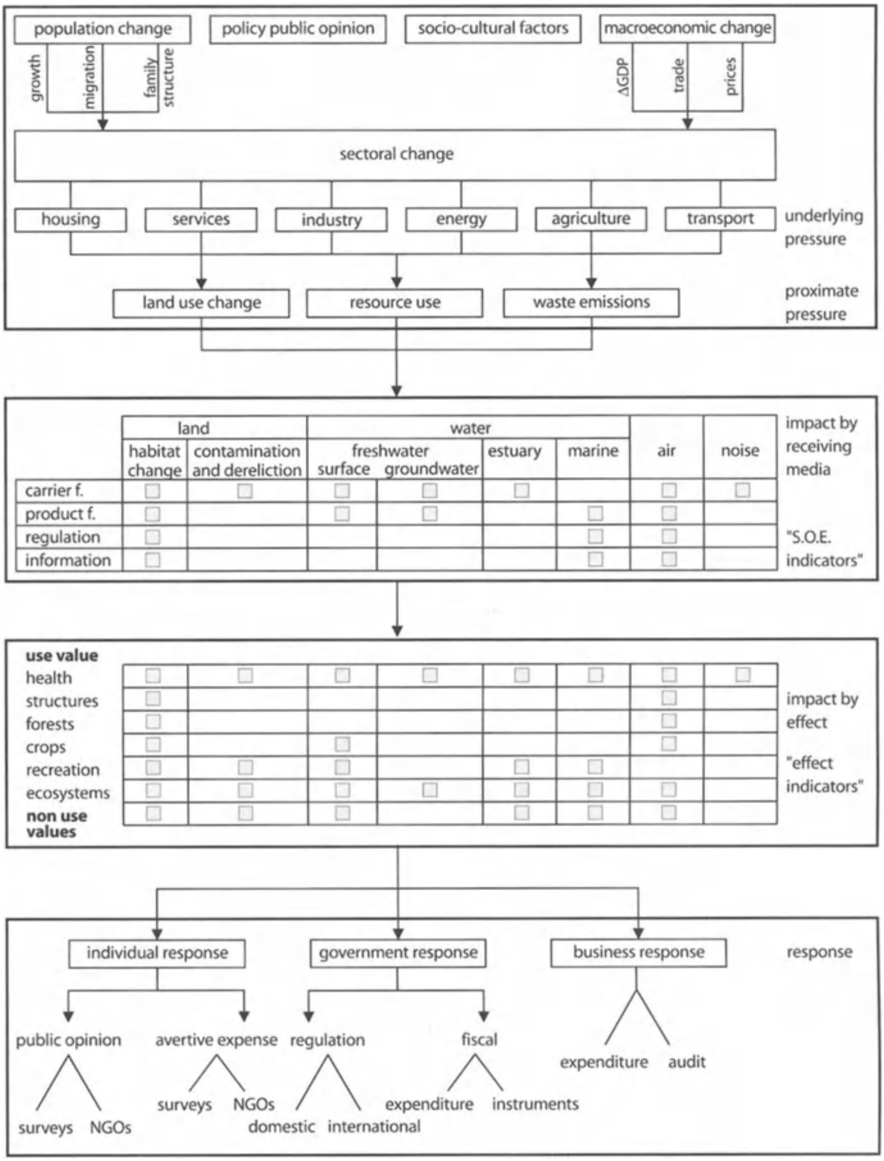


Fig. 4.2. Pressure state response diagram as applied by OECD

environment is described by means of relevant indicators, subsequent changes in these state indicators are converted into effect indicators, showing the effect on the natural and socio-economic system.

The lower part of the diagram shown schematically how individual, governmental bodies and industries can respond to these changes in order to mitigate adverse effects.

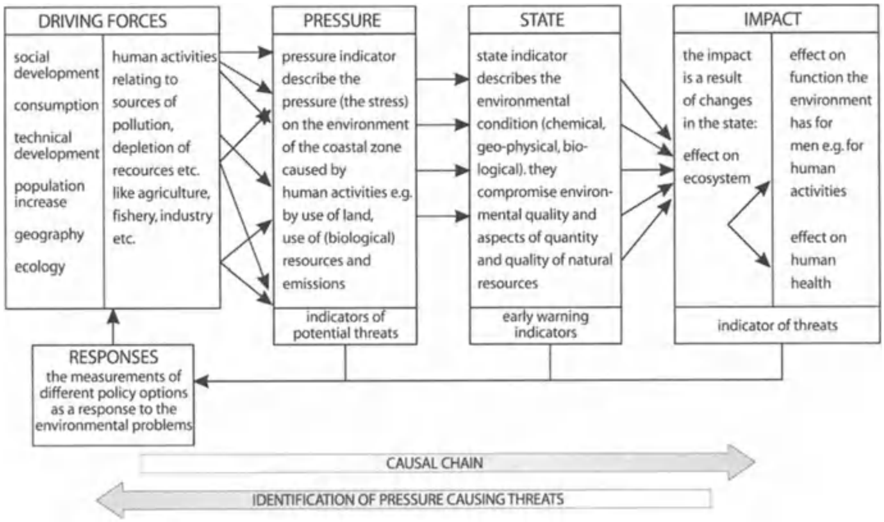


Fig. 4.3. Pressure state response diagram as applied by European Topic Centre (1996)

Obviously, the diagram is not complete as the effect of responses on the natural environment should also be taken into account as a feed back loop. A modified version of the diagram was used, therefore, by the European Topic Center on Marine and coastal Environment 1996, in order to quantify the state of the European Coastal Environment. Figure 4.3 gives a description of the modified PSR diagram used for this study.

Although not explicitly mentioned, both diagrams are implicitly using the concept of system analysis and system control as a theoretical basis for the analysis. The concept of systems analysis is explained in greater detail in "A systems view of Integrated Coastal Management" (van der Weide 1993).

The steps proposed to implement the Pressure State Response diagram will be described more in detail below, using the system concept as shown in Fig. 4.4.

4.4.2 Step 1: Driving Forces and Pressures

Pressures on the system are induced by driving forces, which may be either natural or induced by human activity. This paper focuses on the effects of human activity only. Schematically, this process is illustrated in Fig. 4.4a, where the natural system and the socio-economic system are combined into one production system. The inputs to the system are the objectives as formulated by the stakeholders, the outputs are the required goods and services. As resources are used to produce these goods and services, there is a negative feedback, characterized by the upper arrow. Obviously, also non product outputs have to be considered which have a negative impact on the production system. Most important in this respect is the disposal of waste back into the system. This is illustrated with the lower feedback arrow. Both feedback arrows will cause pressures on the production system.

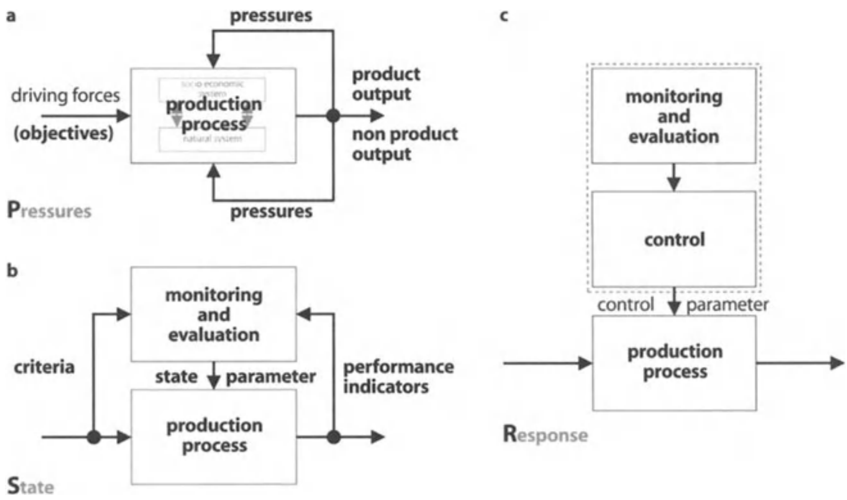


Fig. 4.4. System analogy of coastal system. **a** Pressures; **b** State of environment; **c** Response

In order to use this diagram for a practical case more specific information has to be collected:

- Firstly, the domain of the analysis has to be defined, as the study can be performed at various spatial and time scales: local, regional, national or supranational.
- Secondly, the actors in the process should be identified, e.g. the stakeholders which define the objectives and criteria for the production process. Together they should formulate what foods and services should be produced and in what quantities. Moreover, they should define the type of pressures, this will induce on the system. This includes pressures on the human, social, and industrial capital but also the impacts on the natural capital.
- Thirdly, environmental issues of interest for the study should be defined. in this respect only those issues should be considered which will significantly change under pressure. Due to the resilience of the natural system not all issues are of equal importance in this respect.

Once the study area has been defined, actors and issues can be combined into a matrix, showing the issue and the pressure induced by the various actors. Issues of importance are the functions of the natural system as defined a / o in "Functions of Nature" (de Groot 1992).

- The *carrier function*, the availability of suitable areas for settlement, subsistence and socio-economic activities. Aspects of importance in this respect are land loss due to erosion and increased inundation risks due to subsidence.
- The *production function*, the potential to provide resources for human activities. Key words in this context are depletion of resources due to mining of aggregates, ground water extraction, oil and gas exploitation, overfishing etc.

- The *regulation function*, the ability to create optimal living conditions for mankind. Typical examples of disturbances are pollution, deforestation and exploitation of mangroves.

For each actor, its effect on the various issues can be defined. These effects can be categorized in terms of volumetric units and concentrations, using appropriate pressure indicators such as volume of sand to be mined, volume and BOD of effluent discharges, chemical; content etc. In order to assess the state of the European coast, the National Institute for Coastal and Marine Management/RIKZ as part of the European Topic Center on Marine and Coastal Environment has proposed a list of issues to be used for a first assessment. This list is shown in Table 4.1.

4.4.3
Step 2: The State of the Environment

The Pressure State Response approach aims at an optimal use of the three sources of capital as a means to obtain a well balanced development, in which both economic and ecological values are equally well treated. To that end the performance of the production system ("statement of loss and profit") and the state of the production system (its "balance value") should be expressed in performance – and state indicators, which can be compared to criteria. In order to be able to define state indicators, the production system proper should be monitored and the monitoring results should be evaluated. This is shown schematically in Fig. 4.4b. Representative performance and state indi-

Table 4.1. Environmental issues of importance for coastal water quality

Issue	Criteria					
	General European coastal issue	Multiple source	Transboundary impact	Relevant issues	Data availability	Selection for the pilot study
Eutrophication/saprobiation	+	+	+	+	+, 1	+
Heavy metal pollution	+	+	+	+	+, 1	+
Antibiotics	–	–	–	–	–	–
(Persistent) organic compound pollution	+	+	+	+	–	–
Oil pollution	+	+	+	+	–	–
Introduction of foreign species		+	+	+	–	–
Loss and degradation of habitats	+	–	+	+	+, 5	+
– Thermal pollution	+	–	–	–	–	–
– Resource depletion groundwater	+	–	–	+	+, 3	+
– Resource depletion gravel	–	–	–	+	–	–
– Coastal erosion	+	–	(+)	+	–	–
– Physical disturbance of coastal waters	–	–	–	–	–	–
– Climate change	+	+	+	+	+, 4	+
Waste	+	+	–	+	–	–
Overfishing	+	+	+	+	+, 2	+
Loss of biodiversity and genetic resources	+	+	+	+	–	–

cators are monitored and the results are evaluated by means of the system shown in the upper box. Both natural and socio-economic aspects should be considered, indicating that the above indicators are of a "green" nature.

Unfortunately, natural and socio-economic indicators are expressed in different units, conversion of these units into monetary units is difficult if at all possible. Reference is made to the publication "Coastal Zone Resources Assessment Guidelines". LOICZ et al. 1995, for a detailed review of available and methods. It appears to be difficult to define one performance indicator which includes both economic and environmental values. It is common, therefore, to use a multi-criteria approach and to define indicators related to the natural system and indicators related to the socio-economic system.

Table 4.2. Environmental parameters of importance for the functions of nature

1	**Bedrock characteristics and geological processes**	**6**	**Vegetation characteristics**
1.1	Bedrock properties and lithology	6.1	Height, structure, density and roughness
1.2	Occurrence of distinct geological formations	6.2	Succsession stage/age/maturity
1.3	Volcanoes and areas of volcanic activity	6.3	Standing biomass/chlorophyll (see also 8.1)
1.4	Geotectonics and geophysical features	6.4	Surface covering/leaf area index (LAI)
		6.5	(Evapo)transpiration/water use efficiency
2	**Atmospheric properties and climatological processes**	6.6	Litter-production
		6.7	Root system and nutrient uptake/recycling
2.1	Chemical composition of the atmosphere		
2.2	Concentration of atmospheric dust	**7**	**Characteristics of flora and fauna (species properties)**
2.3	Concentration of water vapour/air humidity		
2.4	Precipitation/drought	7.1	Species composition and diversity
2.5	Clouds	7.2	Population size (rarity) and distribution (endemism)
2.6	Solar radiation input	7.3	Population viability/vulnerability (genetic diversity)
2.7	Temperature	7.4	Population dynamics (increase, decrease, etc.)
2.8	Winds	7.5	Dispersal and migration
2.9	Occurrence of lightning/fire	7.6	Special functional properties
			– Edibitity/nutritious value
3	**Geomorphological processes and properties**		– Useful genetic and biochemical properties
3.1	Topography (slope, relief, altitude)		– Role in biogeochemical cycles
3.2	Presence of distinct landform units		– Indicator value
3.3	Type and structure of surface (see also 6.4)		– Other (e.g. aesthetic value)
3.4	Albedo		
3.5	Weathering/erosion	**8**	**Life-community properties and food-chain interactions**
3.6	Sedimentation and fossilization		
		8.1	Biomass production/photosynthesis (see also 6.3)
4	**Hydrological processes and properties (at the surface)**	8.2	Consumption and respiration
		8.3	Decomposition
4.1	Water reservoires/availability (volume, area, depth)	8.4	Food-chain interactions
4.2	Interactions with atmosphere	8.5	Deposition of calcareous material
4.3	Runoff and river discharge	8.6	Bioturbation/activity of soil communities (see also 5.7)
4.4	Tides and ocean currents		
4.5	Groundwater tables	**9**	**Ecosystem parameters**
4.6	Water quality/BOD5	9.1	Naturalness/integrity/heritage value
		9.2	Uniqueness/distinctiveness
5	**Soil processes and properties**	9.3	Diversity/richness
5.1	Soil depth	9.4	Minimum critical ecosystem size
5.2	Texture/structure (physical characteristics)	9.5	Ecological fragility (carrying capacity)
5.3	Organic matter (humus content and litter)	9.6	Replaceability/renewability
5.4	Mineral content (fertility)	9.7	Information value
5.5	Soil moisture/humidity/drainage		– Amenity value/aesthetic qualities
5.6	Chemical characteristics/chelation		– Historic/cultural value
5.7	Biological characteristics (see also 8.6)		– Inspirational/spiritual value
			– Scientific and educational value

In the present paper we will not discuss the concept of performance indicators. We will concentrate on the definition of the state indicators, which characterize the value of our "green capital".

In order to use the method for a practical case more detailed information has to be collected.

- Firstly, the relevant indicators should be defined, and their monetary/non monetary units should be established;
- Secondly, a monitoring network should be established and selected indicators should be monitored depending on the issue concerned measurements should be taken intermittently or continuously;
- Thirdly, criteria should be established for recommended values of state parameters;
- Finally, actual values should be evaluated against these criteria and appropriate action should be initiated when needed.

As a starting point, the indicators described in de Groot (1992), for the various functions of nature can be used. The environmental parameters which influence the various functions are given in Table 4.2. Not all of these parameters are equally important for all functions. A more detailed matrix per function is given in the above reference.

4.4.4
Step 3: Impact and Response

Changes in the state of the environment will have an impact on the performance of the system. Often such impacts are inducing a sequential cause-effect chain. Changes in the state of the socio-economic system will induce technological developments which in turn will cause changes in the natural environment. If such changes are not properly managed they may affect human welfare and well being and may ultimately have an adverse effect on the production capacity of the system.

Therefore it is essential that changes should be detected well in advance so that mitigating responses can be initiated timely. To that end a control system should be integrated in the system analogy of the coast, as shown in Fig. 4.4c.

In first instance such a control system will be passive. The system will only monitor the state indicators and responses will be reactive. The coastal zone manager ill use the observed data to decide when, where and how he should react.

Once the system is better understood and cause effect relations can be established, such relations can be used to improve the control function. The control system is now more active, it will not only monitor the state indicators but can also predict the effect of impacts on the system. In this way a more active control strategy can be applied. A further improvement can be obtained when the governing processes are known and process models can be used to predict the effect of both impacts and mitigating responses. The control system can now be used interactively, so that a proactive anticipatory control strategy can be set up.

In order to use the method in a real-world case, an evolutionary an incremental approach should be used.

- Firstly, the actors responsible for the pressures and the resulting deterioration of the environment should be defined. To that end the Pressure State Response diagram should be used in reverse order.

- Secondly, practical control mechanisms should be defined for each group of actors. In this respect both social, technological and political interventions can be considered. Public awareness campaigns may be used to mobilize the general public. A change in societal attitude cost a little but may gain a lot. As a next step technological interventions should be considered which improve the state of the environment but which create at the same time an improved performance of the production system. This can often be achieved if technological means are supplemented by financial incentives. Finally, however, interventions have to be realized which are beneficial for the environment but have a negative effect on the coast of living and production. Laws, regulations and financial instruments are now required to enforce the required interventions.

4.5 Policy Instruments to Coordinate Administrative and Governance Initiatives at Various Levels and in Different Sectors

4.5.1 General

As indicated by the World Coast Conference, 1993, a basic element of an ICZM programme is the arrangement of management responsibilities. Management arrangements should comprise institutional arrangements and management instruments. Together they provide the framework which specifies the management tasks and the context in which these management tasks are carried out. This framework encompasses

- the structure of government and non-governmental organisations, including mechanisms for linking responsible agencies and organisations,
- the set of laws, conventions, decrees and standards for environmental quality, and
- the set of traditions and social norms such as customary laws.

Each of the responsible agencies has a set of management instruments in the form of structural, regulatory and incentive-based measures. These instruments need to be supported by legislation or other types of authorisation. Regulatory measures or implementation incentives that encourage the users of coastal environments to adopt desired patterns of behaviour include:

- Permits that stipulate gas and oil extraction rates or levels of waste discharges; such permits can be made subject to measure performance and to make results available to the public;
- Penalties and sanctions to penalize non-compliance with standard, permits and obligations to reduce discharges;
- Economic incentives to encourage desired changes in the behaviour of users of coastal resources such as taxes, quotas, subsidies, fees, etc.

Management arrangements are important components that need to be explicitly taken into account, when evaluating alternative plans or assessing the feasibility of a particular coastal zone management strategy. Such arrangements are part of the assessment of the manageability of a plan, which should also consider:

- Cross-boundary inter-dependencies, expressing the managers' degrees of freedom to develop and implement their own CZM policies and strategies;
- Sources of finance particular the possibilities to make the required investments, which are dependent on access to national savings, international funds or aid from donors;
- Technical capabilities, i.e. the level of technical information and expertize;
- Social acceptability, which will depend on, amongst others on the level of awareness, people's participation, access to resources, and traditional values and/or religious beliefs.

4.5.2 Institutional Arrangements

Some of the management actions selected will involve strengthening of institutional arrangements and empowerment of local authorities, a reiteration of customary rights and a strengthening of community organisation. Several different institutional approaches are possible to perform the task of interagency coordination such as:

- The national planning agency;
- The formal establishment of an interagency or inter-ministerial council;
- The creation of a special coordinating commission or committee;
- The formal designation of one of the line agencies or ministries to act as "lead agency" and to oversee an interagency coordination process.

4.5.3 Financing

The basis of a plan of execution is the funding of the management tasks. An overview of funding sources and mechanisms shows that internal sources of the state concerned is the most important source, much more important than external financial sources like grants and multi-lateral loans. Internal financial sources can comprise user charges to ensure that those who benefit contribute to the costs of the service. It may comprise of charging the polluter systems. Such money can be re-invested in subsidies to stimulate sanitation programs or be invested in technology to prevent pollution. The mentioned charges in combination with local or national taxes is the basis for every program. The private sector can be involved in some cases through borrowing, the set-up of a revolving fund or through private sector participation.

4.5.4 Monitoring

The results of the ICZM programme should be subject to regular monitoring and evaluation as a way of continually improving the process. It is especially important, therefore, that the goals and objectives of the ICZM programme be specified as clearly and as quantitatively as possible, otherwise assessments as how well they are being achieved are difficult. The monitoring procedure should include:

1. Identification of expected performance;
2. Assessment and/or measurement of the actual performance of the programme;
3. Establishment of performance variances (e.g. shortcomings or excesses);
4. Procedures for communicating variances to the appropriate management of enforcing and implementation authorities.

As an example of setting measurable targets in water management is the so-called "AMOEBA" a Dutch acronym which stands for a general method of describing and assessing ecosystems. The method is described in detail in "Speaking of Sustainable Development" (Ministry of Transport 1993). The National Policy Document on Water Management first introduced the AMOEBA approach. For example, some thirty plants and animal species were selected from the salt water habitats, and for each of these, their population during the reference situation – around 1930 – and today was traced. Counts, data on catches and hunting, comparison with other areas – in short, anything relevant was utilized to obtain a representative impression of a situation hardly disturbed by man and of the current situation. An appealing way to present the information gained is the application of a so-called radar diagram, a circle on which all species have been allocated a place in a fixed order (see Fig. 4.5).

The distance from the centre to the circumference represents the number of a species in the reference situation. Together, the thirty points on the circle represent the ecological situation of 1930. The numbers present today are drawn in the same manner from the centre. This gives a clear presentation of the shifts that have occurred since the reference period. In the case of the Netherlands the 1988 AMOEBA showed a shift from long-living to short-living species. The water systems are incomplete and unbalanced in composition.

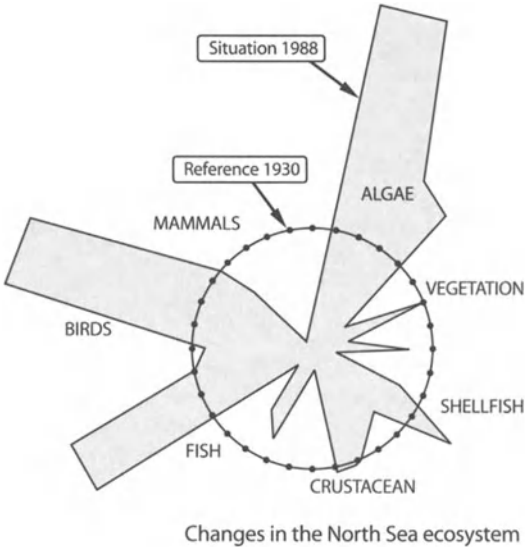


Fig. 4.5. The AMOEBA concept to describe the state of the environment

This way of presentation also gives the possibility to clearly quantify the objectives of future plans, like "all amoeba species should be between 75 and 200% of the reference situation". Measures can be developed to achieve this objective for example by reducing the dumping of waste, limiting disruption of the ecosystem, reducing harvest quota, etc. Various policy alternatives can be supported through different sets of measures.

4.6 Technical Instruments to Support Administrative and Governance Initiatives at Various Levels and in Different Sectors

4.6.1 General

There is a growing need to support policy makers, planners and engineers with information systems which can be used:

- to structure the decision making process,
- to facilitate the dialogue with stakeholders,
- to improve the quality of the decision.

Such systems should be able to integrate social, economic and environmental aspects and should apply modern information technology to generate, store and process the required information. Within the Netherlands such a system is now under development as part of the socalled LWI initiative. The main aspects of this system will be discussed in the following sections.

4.6.2 User Requirements

An information system should be able to support all phases of CZM, e.g. planning, development, implementation and control. Moreover, the system should be able to produce information on relevant aspects, such as geographic characteristics, abiotic, biotic and chemical parameters and processes and socio-economic indicators. In order to meet these requirements a system has been designed which combines a generic system architecture with a series of dedicated modules to cope with a broad spectrum of CZM issues.

4.6.3 The LWI Concept

4.6.3.1 *The System Functionality*

The principal functional components of the system are:

- GIS and Data Bases to describe the components of the system;
- Process models, to simulate processes in the natural and socio-economic system;
- Management support tools, to support the computational processes.

4.6.3.2
Dedicated Modules

For each management issue dedicated models can be developed. Presently systems are being developed for coastal zone management, estuarine management, river management and land reclamation.

For each of the above applications modules are developed for diagnosis (problem formulation), rapid assessment and comprehensive analysis of the relevance of the problems (planning and development phase) and operational management and control (implementation, evaluation and control).

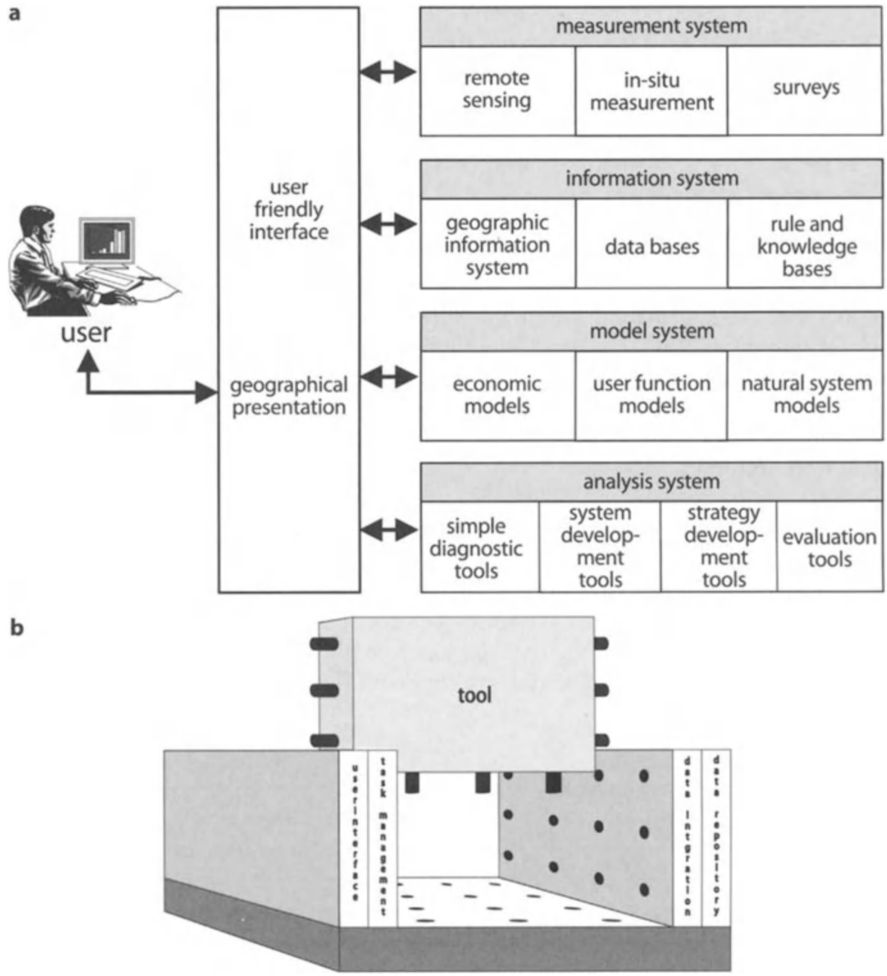


Fig. 4.6. System configuration and architecture of the DSS for LWI. **a** System configuration; **b** The "toaster" concept for the system architecture

4.6.3.3
System Architecture

The system applies the so-called toaster model, a shell in which the functional modules are embedded. The shell consists of the following components:

- User interface for communication with the users;
- Data management interface to handle external data input and output;
- Coupling modules for internal data handling.

The components of the shell can be visualized as three sides of a toaster, the dedicated modules fit in between these sides as sandwiches in a toaster. Schematically, the system set up is shown in Fig. 4.6a and b.

4.7
Human Resources Development and Technology Transfer

4.7.1
General

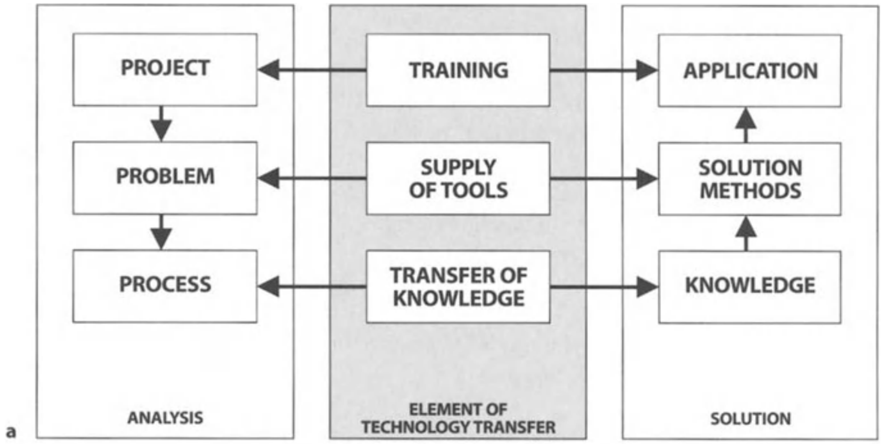
Human resources development is essential, in order to prepare the ground for a successful implementation of CZM techniques and tools. In many instances human resources development will involve technology transfer. Technology transfer implies the development of knowledge and skills of the receiving country, through education, training and the supply of tools to both individuals and organisations.
It should be emphasized that these constituent elements should be applied in an integrated fashion. This is further outlined in the next section. Moreover, the various elements should be properly phased as will be further explained in the final section of this chapter.

4.7.2
Scope of Technology Transfer

The objective of technology transfer is to strengthen the capabilities of institutions and individuals to solve problems independently. As stated above the Pressure State Response diagram is used to analyse the problems and to define appropriate solutions. Any technology transfer program should use this approach as a starting point, therefore.

A simplified generic model for technology transfer, based upon the PSR diagram is shown in Fig. 4.7a. The left part of the figure shows the problem analysis phase, which corresponds to the top of the PSR diagram. *Project* signifies a description of the CZM objectives, *problem* stands for the description of the management issues in terms of pressures and impacts whilst finally *process* refers to the processes which determine the effects of these impacts on the environment.

The right part shows the problem solving phase, which corresponds to the lower part of the PSR diagram. *Knowledge* stands for the understanding of the governing processes and the ability to describe them in a tangible format. *Solution methods* are



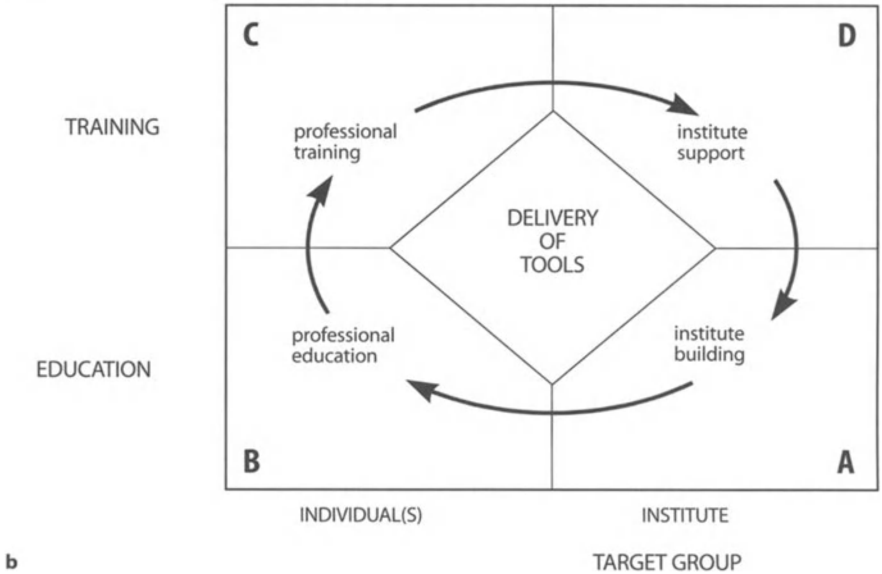


Fig. 4.7. Technology transfer in CZM; **a** Elements of technology transfer; **b** Phasing of technology transfer

the tools and techniques to solve these equations whilst *application* describes the phase where these techniques are used to solve the real-world problems as a basis for the evaluation of proper response strategies.

The column in the centre shows the related elements of Technology Transfer. In order to enhance the scientific level, *transfer of knowledge* is required. In order to improve the problem solving capabilities, *supply of tools and technology* is essential whereas use of knowledge and technology in real-world situations requires *training.*

Basically the diagram indicates that Technology Transfer implies education, supply of tools and technology followed by on the job training.

4.7.3
Phasing of Technology Transfer

Technology transfer can only be effective and efficient if the above activities are well planned. This requires a phased and cyclic approach as shown schematically in Fig. 4.7b.

The vertical axis represents the basic activities: education and training. The horizontal axis specifies the target groups: individuals and institutes. The centre shows the delivery of tools and technologies often the backbone of technology transfer projects.

The diagram implies that technology transfer is more than education and training of individuals, knowledge and experience should also be anchored in institutions to ensure continuity. The following phases are therefore recommended:

- *Phase 1 – Institute building:* the set-up of an organisational structure and the professional training of the institute staff in the basics of CZM management. Through the Centre for Coastal Zone Management the Dutch government offers the possibility to assist countries in establishing proper CZM institutions.
- *Phase 2 – Professional education:* the development of qualified staff to perform the CZM tasks, using graduate and post graduate CZM programs. Universities and institutions for higher education all over the world offer a wide range of curricula. In the Netherlands universities and institutes for higher education have joined forces, resulting in a short introductory course on CZM, which is now part of the curriculum of all partners concerned. The course contents are published in a reader, "The Coast in Conflict", Ministry of Transport (1995).
- *Phase 3 – Professional training:* the development of skills to address real-world problems under the guidance and control of experienced mentors, in the home country or abroad. Dutch consultants and the large technological institutes in the Netherlands have developed a vast experience over the years in a large number of training projects in the Netherlands and abroad financed by the Dutch Ministry of International Cooperation or International Financing Agencies such as UNDP.
- *Phase 4 – Institute support:* the continuous support of institutes through joint research projects, secondment of staff and expert input in ongoing projects.

As shown by the dashed line in Fig. 4.7, often the cycle will be repeated as issues and objectives of the institutes change over time and new institutional arrangements have to be considered.

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Chapter 5

Chances for Nature – A Matter of Substitution

E.C.M. Ruijgrok · P. Vellinga

5.1 Introduction

"Coastal zone management involves the comprehensive assessment, setting of objectives, planning and management of coastal systems and resources, taking into account traditional, cultural and historical perspectives and conflicting interests and uses; it is a continuous and evolutionary process for achieving sustainable development" (IPCC 1993). According to this definition, it may be clear that integration is motivated by the concept of sustainability.

Though sustainability is both an ecological and an economic concept, it will be explained here by using the capital theory. So far the natural capital of the coast has been substituted by physical (defence) capital, even though this may not lead to sustainable economic development. This can be explained by different views on substitution possibilities and the fact that nature is a common.

If one looks at the Dutch history of coastal zone management one can discern a development from a civil engineering approach of flood protection towards an approach of environmental neutrality. For a long time coastal zone management was merely focused on protecting society against the dangers of nature, by substituting natural capital with man made defence capital. At the beginning of the '70s, increasing awareness of environmental impacts of coastal protection works lead to the adoption of the double criterion of flood protection with environmental neutrality. At that stage the aim was to minimize environmental impacts of coastal defence measures. This approach was applied up until the early '90s (Vellinga and Klein 1993). Only recently the view has been adopted that coastal defence and nature development can go hand in hand; examples of this approach are the building with nature approach applied on land reclamations (Waterman 1990) followed by the policy of dynamic maintenance (Bucx and Jonkers 1995) and the recent plans inspired by "Growing with the Sea" (Helmer et al. 1996) that promote both economic and ecological development.

Although the appreciation of natural defence capital seems to be increasing in the Netherlands, nature remains a common which economic value is hardly accounted for in economic transactions since it is unknown. Because natural capital does not have a market price, it is easily exploited or substituted more than would be economically sustainable.

5.2 Nature as a Common

Nature may be regarded as a common because of its characteristics. Natural capital has the following distinguishing characteristics (Verbruggen 1995):

- It is diffuse. It is not homogeneous in quality and it performs different functions at different places. E.g. the water in a river may differ in quality at different locations, because it is used for different purposes at different places.
- There are indivisibilities, which means that the welfare generated by one unit cannot be calculated. The welfare generated by 1 m^2 of a lake of a size of 100 m^2, is not equal to 1% of the total value of the lake. In fact a lake of one square cannot function properly and may not generate anything at all. There are minimum scale requirements.
- There may be thresholds, leading to a sudden huge change in the welfare generating capacity, when the stock is reduced by one extra unit.
- There can be complementarities between various environmental goods (e.g. food chains), but also between natural capital and other forms of capital (e.g. source and sink relations).

These characteristics determine the physical substitution possibilities. They also make natural capital hard to both quantify and qualify. If one wants to make sure that our present substitution behaviour is optimal (that is maximum welfare generation, without reducing the welfare potential), one should identify substitution possibilities. Substitution possibilities depend on physical restrictions whereas actual substitution behaviour depends on economic values. Restrained by physical conditions, the economic values of the different capital stocks, should determine their relative use. This is shown in Fig. 5.1.

The curve in Fig. 5.1 is called isoquant, because it shows the possible combinations of natural and physical inputs, that result in a certain amount of output. The isoquant can be regarded as the physical substitution possibilities curve. At point *A* and *B* the same amount of output is generated, only at point *A* relatively much produced and little natural capital is used compared to point *B*. The optimal combination of physical and natural capital is determined by their relative prices. If the price of natural capital is high compared to the price of produced capital, relatively little natural capital will be used. This is the case in point *A*. In point *B* the price of natural capital is relatively low, as reflected by the steep price line *P*. Here much natural capital is used.

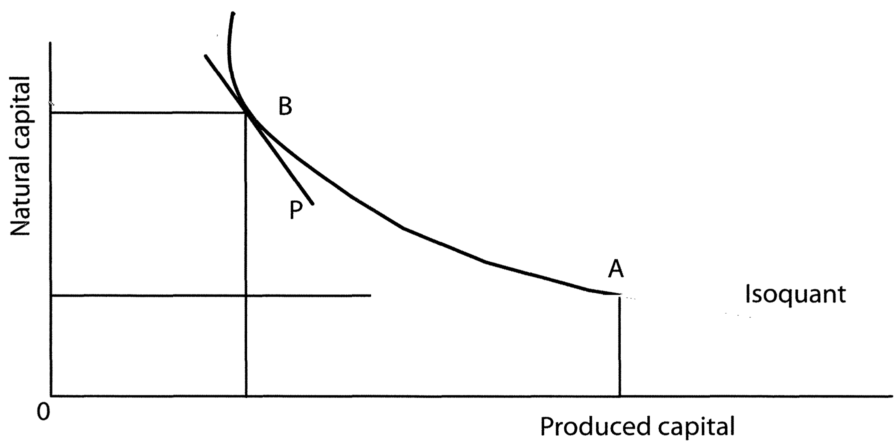

Fig. 5.1. Substitution between natural and produced capital

Because prices determine how much is used of certain inputs, it is understandable that a zero price for nature, leads to an enormous use of this from of capital, resulting in environmental degradation. Consequently, it seems necessary to determine the economic value of natural capital to prevent unsustainable use.

A question that is often raised in reaction to the continuous substitution of natural capital with produced capital, is whether the welfare generating capacity of our total capital stock is reduced by continuous substitution. Some concerns are that it only seems as though the welfare generating capacity is untouched, because people are not confronted with the effects of substitution in the short run. Only when the damage has been done, one may realize that some welfare potential is lost.

Often degradation can be seen clearly (e.g. deforestation), but in economic terms no losses are encountered, because individual user do not have to pay for using natural capital. Environmental goods or services are unpriced and therefore referred to as public goods or commons.

Another related problem is that substitutions are based on present preferences. One could say that people of today probably prefer goods and services that are produced by relatively much physical and little natural capital, leading to continuous substitution. However, if our preferences change to more environmentally intensive products such as the enjoyment of nature and wilderness, it may not be easy to substitute our capital back towards a relatively large natural capital stock. There may be irreversibilities in substitution of nature.

5.3 Substitution of Natural Capital

For an ecologist a sustainable development means sustainable use of natural resources. Resources are used without degrading their quality and reducing their quantity. This also means that the carrying capacity of an ecosystem may not be surpassed. In this view the carrying of human activities is fully ascribed to nature and not to other non-natural resources.

For economist sustainable development has a different meaning. Sustainable development pertains to maintaining the welfare generating capacity of a nation's capital stock. An additional requirement for sustainable development is that the welfare per capita of future generations may not decrease. This means that economic growth is necessary in case of a growing population. The magnitude of the capital stock should thus keep pace with this growth or the stock should become more productive (Verbruggen 1995).

5.3.1 Capital Stock Theory

A nation's capital stock can be divided into four categories (Segraldin and Steer 1992):

1. Natural capital;
2. Produced capital;
3. Human capital; and
4. Social capital.

Natural capital consists of all natural resources and processes humans make use of. Produced capital is man made, e.g. machinery stock. Human capital is labour, both in quantitative (number of workers) and qualitative (skills) terms. Social capital concerns society's institutional arrangements.

In theory one can distinguish between three types of sustainability on basis of the allowed substitutions between and within the four capital stocks: strong sustainability, moderate sustainability and weak sustainability.

Here strong sustainability means that the welfare generating capacity of a national total capital stock may not decrease and that the welfare potential of each of the individual capital stocks may not be diminished. In other words: natural capital may not be replaced by produced capital and one specific type of natural capital (e.g. forests) may not be substituted by another specific type (e.g. wetlands). Both substitution between and within capital stocks are forbidden.

Moderate sustainability will be realized if the welfare generating capacity of both the total capital stock and of each of the individual capital stocks are not reduced. Natural capital may not be substituted by produced capital, because the two capital stocks are considered to be complementary. The welfare generating capacity of a specific part of an individual capital stock may however be reduced here, as long as it is *compensated* for by an increase in welfare generating capacity of another part of this stock. This means that decrease of a part of the natural capital stock (e.g. forests) may be compensated by an increase of another part of this stock (e.g. wetlands), but not by an increase in the produced capital stock (e.g. machinery). In other words: substitution between capital stocks is not allowed, but substitution within capital stocks is.

Weak sustainability means that the welfare generating capacity of all four capital stocks together may not decrease, but it leaves room for substitution. If one capital stock is reduced this may be compensated by growth of another capital stock, as long as the total welfare generating capacity is not reduced. Now it becomes possible to substitute e.g. natural capital with produced capital. It is also allowed to have growth or shrink within one capital stock; a reduction in unskilled labour may be compensated by an increase in skilled labour. Both substitutions between and within capital stocks are allowed.

5.4 Views on Nature

These three types of sustainability can be related to philosophical views on nature. In literature on nature philosophy, various views on how society deals with its natural environment have been identified (van Amstel 1988; Schwarz and Thompson 1990; Soontiëns 1993; Achterberg 1994; van der Wurf 1997). Here the views of conservation, coevolution and functionality will be used to explain approaches towards substitution of natural capital. The envisaged substitution possibilities of these views on nature are illustrated in Fig. 5.2.

5.4.1 Conservation View

The conservation view is mainly concerned with the objective of conserving and restoring the existing natural capital through interventions and isolation. Nature is considered valuable regardless of human use. Active human intervention is considered necessary since nature cannot defend itself against the threats from society. Nature is isolated from the economy since substitution within the natural capital stock and substitution between nature and other capital stocks are rejected. As such this view corresponds with the concept of strong sustainability. All forms of substitution are rejected, since the consequences from substitution are not known. From a conservation perspective, a "no regret strategy" is chosen by rejecting substitutions. To prevent the occurrence of irreversibilities, economic opportunities are passed by. Chances for nature are maximized while accepting risks for the economy. The substitution ratio within the natural capital stock is zero as illustrated by the L-shaped isoquant in Fig. 5.1.

The basic rationale of the conservation approach is that substitution has caused degradation of the natural environment. The influence of the conservation approach in public policy can be seen in the segregation of economic policies and policies for nature.

5.4.2 Functionality

According to the functional view nature derives its value from the functions it performs for society. Utilisation of nature in order to generate income, is the main objective of this view. This does not necessarily mean that nature cannot have an intrinsic value according to this view, but it will only have one if humans find it important for some reason; if they are willing to pay for its mere existence (investing in the mere existence of nature, is regarded as a form of saving according to the functional view). Well functioning markets are supposed to account for the welfare generating capacity of nature, ensuring that producers will not destroy their source of income. Since income maximisation is a priority, chances for economic development are maximized, accepting high risks in reducing natural values; there are endless substitution possibilities both within the natural capital stock and between natural and produced capital. The substitution ratio within the natural capital stock is one, as shown by the straight line isoquant in Fig. 5.2. This functional view corresponds with the concept of weak sustainability.

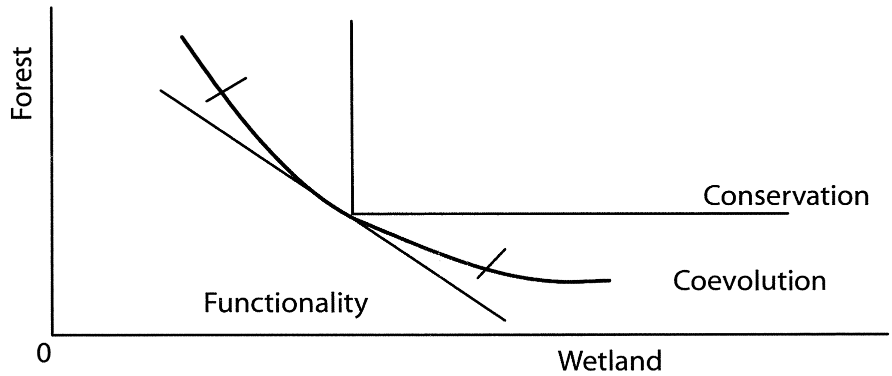

Fig. 5.2. Substitution possibilities and views on nature

The basic rationale of the functional view is that nature produces income just like any other type of production capital. As income generation is the objective of society, one can endlessly substitute according to social preferences. One can however not tell whether the substitutions performed today are sustainable, since sustainability implies that we should also satisfy the preferences of future generations and these remain unknown. Saving some natural capital additional to the stock preferred by our present generation, does not make sense since it deprives the future generation of produced or social capital that they might prefer.

5.4.3 Coevolution

According to the coevolution view nature has both an ecological and a socio-economic value. In this approach a balanced interaction between nature an society is desirable. Social preferences and ecological qualities need to be realized through a balanced multifunctional use of nature; only user functions which do not damage the natural system are allowed, such as naturally friendly forms of recreation and sustainable forms of harvest. Both society and nature are allowed to change and to inflict change upon each other as long as neither of them suffers serious damage, threatening its existence. The objective of this view is maximisation of social welfare derived from nature, without reducing its future welfare potential and without reducing its ecological value. This means that natural capital may in principle not be replaced by other forms of capital. Substitution within the natural capital stock is however allowed as long as the total welfare generating capacity and the ecological quality of nature are not reduced. There are limits to the substitution possibilities within the natural capital stock, because too much substitution may jeopardize e.g. biodiversity and thereby the ecological value the natural capital stock. Nature development and economic development should receive equal chances. Consequently the substitution ratio within the natural capital stock is between zero and one as illustrated by the convex isoquant in Fig. 5.2.

The rationale behind the coevolution view is that substitution possibilities offer efficiency possibilities but they are not a purely economic matter. There are physical restrictions related to the characteristics of natural capital, which may evoke conservation in spite of present preferences towards more substitution. An example of the coevolution view is the compensation principle as laid down in the "Structure Schema of the Green Space". This compensation principle says that if it is decided to implement a project that is of great socio-economic importance but which harms nature, both mitigating and compensating measures should be taken. The criterion is no net loss of natural values in terms both quantity and quality. This criterion can be met by landscape adjustment, mitigating measures and physical compensation. Physical compensation can be achieved through developing a natural site in the vicinity of the project (LNV 1993). As such the compensation principle allows for substitution within the natural capital stock if equal ecological values are realized. *Note:* Because the compensation principle occasionally also allows for financial compensations in case of 'great socio-economic importance', substitution between natural and produced capital is not fully rejected. This means that the compensation principle does not perfectly correspond with the view of coevolution; a slight Functional influence can be discerned.

Table 5.1. Criteria for basic views on nature

Criteria	Conservation 1	Functionality 2	Coevolution 3
1. Trade off ecology-economy	Priority on ecology	Priority on economy	Balanced interaction economy-ecology
2. Substitution between capital stocks	Not allowed	Allowed	Not allowed
3. Substitution within natural stock	Not allowed	Allowed	Allowed if equal values
4. Required value of nature	Ecological values	Financial values	Economic values and ecological values

Table 5.1 summarizes how substitution behaviour depends on one's basic view on nature. It also shows what type of valuations are to be determined for nature according to the basic views.

5.5 Valuation Implications

The three types of strong, weak and moderate sustainability are solely based on substitution possibilities. The three views of conservation, functionality and coevolution correspond with these substitution possibilities, but they add the dimension of valuation. Views on nature do not only determine the substitutions that are considered acceptable, but they also indicate how the allowed substitutions should be realized. They determine on which criteria the trade off between specific forms of capital should be based.

Theoretically one can determine the value of nature from two perspectives: an ecocentric perspective and an anthropocentric perspective. The ecological value of nature is an ecocentric measurement which indicates how well an ecosystem is functioning. It reflects an ecosystems qualitative and quantitative characteristics which are usually measured in terms of biodiversity and rarity of species, since these are regarded as indicators for the well or malfunctioning of ecosystems. Both the economic value and the financial value of nature are anthropocentric measurements which indicate the amount of respectively welfare or income nature provides for society.

An economic price, reflects social preferences for a good. A financial price, is the price that one must pay in the market. A market price does not always reflect social preferences, due to various sources of distortions such as taxes and external effects. For example the market price of gasoline may be Dfl. 2.00 l^{-1}, but its economic price may be much higher, because of the costs of environmental pollution caused by combustion are not included in the market price.

Ecological and economic (or financial) values are two different measurements on the same object. As such they provide two different types of information which can be used to support decisions on trade offs between natural and other capital stocks. Ecological and economic values can be regarded as complementary forms of information to guide decision making processes towards sustainable development.

Since the conservation view does not allow any substitutions, one would expect that valuation of nature is not needed. In practice however supporters of the conservation view would like to make sure that the natural capital stock has not been reduced. In order to determine this, they will try to determine ecological values at various points in time.

The view of functionality allows for both substitution within and between capital stock. The objective of this view is to realize substitutions that increase the income generating capacity of the total capital stock. To achieve this objective financial values can be used, because these represent actually earned income.

The view of coevolution only allows for substitution within capital stocks. In order to determine how much compensation is needed within the natural capital stock, one can use ecological values that indicate whether the new nature is equally valuable in terms of its quantity and quality as the lost nature. This does however not provide information about the welfare generating capacity of nature for society. Since social welfare with maintenance of ecological qualities, is the objective of this view, social-economic values are needed too. In order to determine whether the welfare potential of nature has not been reduced, socio-economic values of nature should be determined. It may be remarked here that the coevolution view allows for giving up natural site at a specific location for the sake of economic activities. This site then needs to be compensated for elsewhere. The compensation site is not necessarily of equal size as the lost site, but it is of the same socio-economic value and also of the same ecological value. This way the welfare generating potential and the ecological potential of the natural capital stock are secured for future generations.

5.6 Conclusions and Discussion

From the above one may conclude that how one wishes to integrate chances for nature in coastal zone management depends on one's basic view on nature. Views on nature determine substitution possibilities and the way in which nature is valued. According to the coevolution view which acknowledges both use possibilities of nature and the possibility of overutilisation, both economic and ecological valuations of may be useful information to support public decision making.

If the coevolution view is to become more widely accepted in public decision making, the need for the development of easy to apply trade off frameworks and the role of socio-economic valuation are expected to increase. Ecological valuation is needed to determine 'nature for nature' compensations. Socio-economic valuation of natural capital seems a necessity for determining sustainable development.

The economic valuation of natural goods and services is necessary in order to determine how much society can use of each type of capital, without destroying welfare generating capacity of the capital stocks. This requires that prices of goods and services reflect true social preferences and that these are internalized in economic transactions. A second requirement is that the inputs are used to achieve a maximum amount of outputs. In other words: if the prices are right and if the production is cost efficient, an optimal situation is reached concerning the use of capital resources. This is called allocative efficiency, because resources are allocated in an efficient way (Varian 1990).

Unfortunately allocative efficiency does not automatically lead to sustainable development; it is however a prerequisite. Both allocative efficiency and sustainable use of resources require the use of correct prices. Using the right prices may direct society towards allocative efficiency and possibly also towards sustainable development. Sustainable development however, pertains to both allocative efficiency and to intergenerational income distribution, since sustainable development is defined as maintaining the welfare generating capacity of our capital stock without decreasing the welfare per capita of future generations. *Note:* Theoretically using correct prices does not ensure allocative efficiency, since there are dynamic effects. As soon as decisions are made using presently correct prices which are based on present capital endowments, reallocation of resource endowments takes place along with price changes. Consequently the allocative optimum shifts to a new (unknown) position. These dynamics make it impossible to determine whether society has actually reached the optimum; it is however possible ensure a movement in the direction of the optimum (Ganley and Cubbin 1992).

Valuation of unpriced natural capital is however not an easy task. Several valuation methods have been developed to determine the value of natural goods and services, and from this the value of the natural capital stock can be derived. Often used valuation methods are Contingent Valuation, Travel Costs, Hedonic Pricing and Averting Behaviour (Freeman 1986; Hoevenagel 1994). These methods can only measure specific components of the total economic value of the natural capital stock. Nature performs several functions that are valuable to society, because they provide welfare. In order to determine the total socio-economic value of nature it is necessary to value all welfare generating functions of nature. In the functions of nature approach a distinction is made between regulation, production and information functions (de Groot 1994). Since nature performs many functions which can be valued by different valuation methods, it is very difficult to determine the total economic value of nature in practice.

If nature is valued in practice, this is usually done in ecological terms since the ecosystems qualities are easier to measure than human preferences. Besides this, policy makers operate on two levels:

- At operational level, where the core question is how obtain a maximum natural qualities, given a fixed budget.
- At strategic level, where the core question is whether or not to allocate a budget to the protection or development of nature.

Mostly valuation studies take place at operational level and therefore ecological valuation studies prevail over socio-economic studies. At strategic level decisions are often made without valuation, based on political and other considerations. This is not surprising since we are probably only on the verge of shifting from a conservation view which calls for ecological valuation, towards a coevolution view which adds socio-economic valuation studies (Ruijgrok et al. 1998).

Whether the presented advantages of coevolution will be realized in the coming decade will very much depend on the operationalisation of the trade off concept. Carrying out coevolution in practice, requires institutional embedding of both the concept and its instruments. Presently both are lacking in the decision making processes.

Thus, one may conclude that in theory the shift towards the coevolution view might entail a revived interest in the valuation of nature to prevent an unbalanced trade off and thus unsustainable use of nature. Socio-economic valuation in addition to ecological valuation could serve as instrument to make the coevolution concept operational and to create fair chances for nature. Still the availability of an instrument is not sufficient to make the coevolution concept practically applicable. The establishment of proper trade off frameworks comprising valuations, needs to be legalized. As long as there are no legal obligations to apply trade off instruments, there will always be economic motives for not taking nature into account. Those who gain from damaging nature, do not suffer the total amount of loss; the 'damage incidence' in on society as a whole. Those who do pay for losses e.g. by compensation projects, will not receive the full benefits, since others will be free riding at their expense. Not even highly advanced trade off concepts or instruments will have any effect without proper institutional and legal arrangements to ensure coercion. Without legalisation and institution building, the authors expect a rebound to the conservation view, since there are instruments, institutions and legal arrangements to apply these in practice. Simply protecting certain natural sites, isolated from economic activities, may then be the only way to save some valuable common property.

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Chapter 6

The Role of Ecology in Coastal Zone Mangement: Perspectives from South-East Australia

A.J. Underwood · M.G. Chapman

6.1 Introduction

There should be growing concern in southern Australia about the nature of management of coastal habitats because of the increasing gulf between the clear scientific needs of managers and the sorts of contributions relevant environmental scientists are allowed to make. The problems for Australia's coastal zones are expanding. We are one of the most urbanized societies on earth (Yapp 1986), so problems for coastal planning around our major cities – which are all on estuaries at the coastal margins – are large. Increased leisure and the "greying" of our population has meant greatly increased demand for coastal life-styles. Approximately 90% of all applications for new residential buildings are on the coast.

Yet management of coastal environments, at least in the most populous state, New South Wales, is under control of six or seven State Government agencies and increasingly fragmented by forcing responsibilities onto local councils. In fact, the latest planning instrument – the NSW Coastal Policy (NSW Government 1997) requires increasing decision-making by local councils, of which more than 20 have responsibility for coastal urban areas in the Sydney metropolitan region. Fragmentation of responses is inevitable and councils have limited resources (and little capacity to increase resources) for sound, ecologically sensible, environmental planning and protection. Our system of hierarchies of government is not well-designed for solving large-scale problems. For a simple example, a local council with responsibilities for part of the urban coast-line in Sydney has no control over activities of inshore and estuarine fishermen (a state governmental fisheries agency is responsible) nor control of planning in catchments that partially determine quality of water around that part of the coast (that being the responsibility of upstream, non-coastal councils and Catchment Management Committees). Nor can a local coastal council be responsible for long-term community education on coastal issues (where that is needed), when the majority of the users of their coastal resources and recreational areas are residents of other municipalities, shires and councils.

This problem of fragmentation is a familiar one; for example, in some metropolitan parts of the United States, environmental problems were managed by >100 bodies (Kneese and Bower 1979). It has, however, been added to by three other issues – some a direct result of changes in official and public attitudes following the Rio Convention (World Commission on Environment and Development 1987). In turn, these issues are, first, that one of the agencies involved, New South Wales Fisheries, is responsible for (and accountable to sectors of the community via political processes for) the effective and efficient management of fisheries resources. This is, of course, the antithesis of a conservationist role. Conservation by hunter-gatherers has only occasionally been a successful process, dependent on draconian regulations. Centuries ago, William the Conqueror of England began the conservation of many species of vertebrates in woodlands and rivers. The mediaeval English "law of the Forest" was entirely directed to the purpose of protecting wild animals – so that they would be available for the gentry to hunt (Stenton 1967). Woodlands were closed to the common people and severe penalties (usually death) were legislated for poachers. Such measures are not generally acceptable in modern societies and would certainly not meet electoral approval in modern Australia. It would be foolhardy to pretend that conservation of any marine biological system is achieved by taking wild stocks of fish and invertebrates for food and bait. Instead, management of fisheries and habitats for fisheries in New South Wales hangs desperately on idealized notions of ecologically sustainable harvesting to save it from complete illogicality. Conservation of stocks of some species for their maximal use by hunter-gatherers is not really what most people consider to be conservation.

The second new problem is that the Rio Convention has encouraged, quite properly, a change in Australia from dependence on representational democracy to a form of participatory democracy. This has the effect of allowing community activists to have an increasingly important role in environmental decision-making. Obviously, there is nothing wrong with this and "bottom-up" or "ground-swell" approaches to environmental issues have potential to be more effective and better sustained forms of managed protection of coastal fauna and habitats.

Yet, this move to participation has not been coupled with a move to recognizing that knowledge is more important than folk-wisdom or that local intense actions do not necessarily build a sustainable, long-term improvement in environmental well-being. As a result, many issues raised by community groups are about what is perceived to be important, rather than what is important (for example, oil-spills are considered disastrous, but invisible chronic pollution rarely gets noticed). Attention is increasingly focussed on expenditure of money by community groups to "monitor" environmental variables, even though there is no clear purpose in the acquisition of the information, no regard to the complexity of sampling designs appropriate to collect the information, no matching of the scale of measurement to the scale of the issue the measurement might be reflecting and no clear connection between the measurements being made and the stated, longer-term objectives of conservation of coastal biological systems. Alternatively, community groups are funded in restoration projects, to rehabilitate damaged habitat. Such projects often suffer from lack of defined goals, lack of understood processes for achieving the desired ecological results and lack of any measures of success (indeed any measures of accountability). How then can such activities continue to be sustained in any country without limitless resources? How can it be demonstrated to be an effective, let alone the most effective, way to achieve the chosen aims of the community?

This paper is from the perspective of ecological science. This is neither the only, nor necessarily the most important component of environmental managerial issues for our coasts. Yet, all developments leading to environmental impacts, all attempts at management of resources and habitats, all notions of conservation through protection and restoration are dependent for their success on scientific models about how the affected systems work, scientific predictions about what will happen under various scenarios and scientific methods of acquisition, analysis and interpretation of data to determine what changes are actually happening in the damaged or managed system.

Here, several examples of scientific problems are used to illustrate difficulties for managers where ignorance prevents available scientific knowledge from helping. Examples are also given as case-histories of particular problems and how they were/are managed, to illustrate some current practical issues. Finally, some recommendations are made as to better ways ecological science could be included in bottom-up, participating programmes responsive to the needs of local community groups.

6.2 Decision-Making Against an Uncertain Background

6.2.1 Natural Ecological Systems

For far too long, managers and the general community have been misled by the quasi-scientific – and very old-fashioned – view that ecological systems are equilibrial, that there is a "balance of nature". This quasi-religious view of the "perfect" world, shaped by external forces or sustained by well-tuned homeostatic mechanisms keeps appearing. Its most recent manifestation is the Gaia view (Lovelock 1979 1988). Yet, we have known for several hundred years that nature, when examined in any but a cursory manner, is much more complicated than our beliefs and non-empirical views. This more flexible and dynamic view goes back to Bacon (1620), but has perfectly respectable modern support (e.g. for forest systems, Botkin 1990; for freshwater ecology, Likens et al. 1985).

One of the consequences of naturally varying systems is that temporal changes in any one place are not predictable and spatial differences are not possible to guess. Spatial and temporal variation must be measured for components of coastal habitats. Increasingly, marine ecologists have been able to demonstrate three features of shallow-water coastal habitats:

i. Interactions among species are complex and require considerable investigation before it is possible to describe, let alone explain and ultimately predict what responses will be to any anthropogenic change (e.g. Dayton 1971; Paine 1980; Underwood et al. 1983).
ii. Life-histories and general ecology of the majority of coastal species (including fish and other commercially exploited species) include pelagic dispersive stages, which make predictions about future numbers very difficult because they depend on oceanographic processes and patterns of weather which remain largely unpredictable at any scale that currently matters ecologically (e.g. Coe 1956; Loosanoff 1964; Roughgarden et al. 1985, 1988).
iii. As a result of variable life-histories, recruitment of planktonic propagules (larvae, spores, etc.) will be variable from place to place and time to time, in complicated ways (e.g. Connell 1985; Underwood and Fairweather 1989). This, coupled with intense but complex interactions with other species (point (i) above), themselves varying greatly in local abundances, means that changes from time to time are generally not consistent from place to place. Such complexity has coined the term "supply-side ecology" to identify the critical role of recruitment in the structure and dynamics of coastal assemblages (e.g. Underwood and Fairweather 1989; Grosberg and Levitan 1992).

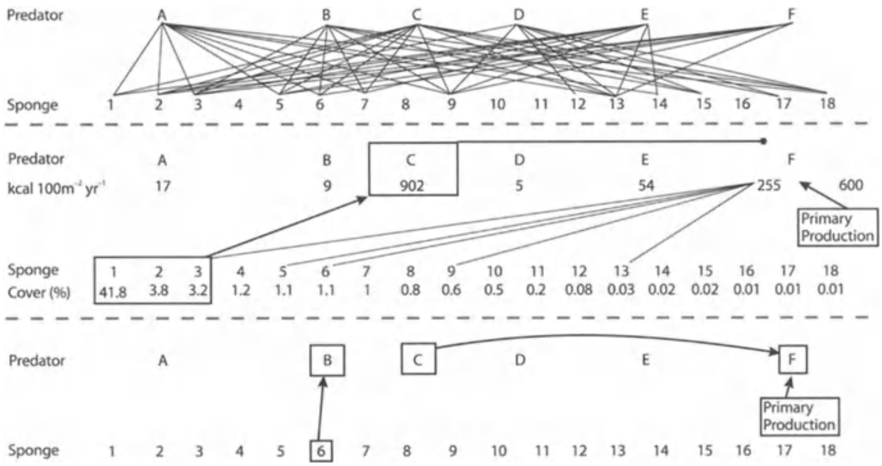

Fig. 6.1. Three views of the complexity of an Antarctic marine assemblage of numerous species. The data are for species of sponges, identified as numbers *1–18* and their major predators, mostly starfish, identified as letters *A–F*. In the upper diagram is a food-web, constructed from observations of which predator has been recorded as eating which species of prey. In the middle is a web based on measures of the energetics of each predator-prey interaction, based on the amount of prey available (its percentage cover) and the energy estimated to go to each type of predator from that prey. Fewer links are now necessary to describe the assemblage. In the bottom diagram, the actual functional linkages between predators and prey are identified from experimental analyses. Very few links are crucially important to maintain the function of the system. The upper two types of representation are over-complex and incorrect views of the nature of the assemblage (Data from Dayton 1984)

The first point has been repeatedly illustrated, yet many environmental assessments and environmental impact statements are still presented to decision-makers as though a simplistic list of species will suffice to make statements about what may happen under certain options of managed environmental change. Even where some more information is gathered (or simply guessed) and food-webs are constructed, no great advance has been made. It is well-known that ecological experimentation is necessary before relationships among species can properly be identified (e.g. Dayton 1984; Paine 1977, 1980). A web of relationships constructed from simple observation is not much value. A web based on energetic relationships (how much of what is consumed by each species) may be more informative. A web based on demonstrated functional relationships is, however, the only way to be sure what is going on (Fig. 6.1).

Why this matters to managers is that community groups often and persistently talk about "indicator" organisms that will be important to monitor because they are well correlated with the functions, numbers, diversity, etc., of entire assemblages. The species chosen are, of course, usually common, attractive, charismatic and not at all likely to be good indicators of anything (see also discussion on problems of choosing which species to consider in Paine 1977; Underwood and Peterson 1988; Keough and Quinn 1991). Clutching at straws by choosing inappropriate species, or deciding without the requisite evidence that some particular species are more important because they play keystone roles (Paine 1966, 1974) have not proven useful in guiding decision-making (Landres et al. 1988; Mills et al. 1993).

6.2.2 Temporal and Spatial Variation

The inevitable variation in space and time (points (ii) and (iii)) has important consequences for the sorts of information that managers can get and the sorts of studies that ecologists and other environmental scientists must do to provide it. To take a relatively simple example, consider the need to detect changes in abundances of fauna on sandy beaches following a managerial decision to prevent access by recreational vehicles in one popular tourist area. It had been a source of concern that vehicles running over beaches were causing loss of polychaete worms, various crabs and burrowing bivalves, because the vehicles compact the sediments and prevent the animals feeding. Numbers of worms (and the other species) do, however, vary greatly from place to place and time to time. This is normal.

The prediction made by the managers is part of an entirely scientifically logical sequence (summarized in Underwood 1990, 1995). It has been observed (or, at least, it is assumed) that the numbers of worms are smaller where recreational vehicles are numerous. It has been proposed that the numbers are smaller because of the vehicles. This model for what is going on led to the decision to remove vehicles, with the prediction or hypothesis that numbers will rise (because the cause of decreased abundances has been removed). Implementation of the new management is, in fact, an experimental test of the hypothesis. The issue remains, however, that someone needs to verify that management has been effective. This requires the hypothesis to be tested by appropriate quantitative sampling.

This would be relatively simple if the numbers of worms were relatively constant from place to place and time to time (i.e. if there were a balance of nature). All that would be needed is some measurement of numbers before management is implemented and another measure after. The anticipated increase would either be evident or not, depending on whether or not the proposed model was correct. Such "before-after" sampling is often done in the belief that there are no natural changes, so that any change in numbers must be due to change of management.

But numbers of worms will always change naturally, so an increase in the managed area is *not* evidence that removal of vehicles has solved the problem. Implementing it elsewhere will not necessarily lead to increases in fauna. So, first, there must be sufficient temporal sampling to be sure that changes from before to after implementation of management are more than would normally be encountered under natural processes of change (e.g. Bernstein and Zalinski 1983; Stewart-Oaten et al. 1986). Second, control areas must also be sampled to demonstrate that the differences in the managed area are not a general change affecting their locations, but that happens to be a larger increase than generally occurs (e.g. Underwood 1992, 1993a). The appropriate hypothesis is therefore the one pointed out by Green (1979) in his pioneering book. If management is effective, there should be a greater change from before to after in the managed area than occurs during the same period in unmanaged areas (illustrated in Fig. 6.2). The appropriate statistical interaction should be detected (Green 1979; Underwood 1993a, 1994a). In this particular case, there is an inevitable asymmetry – there is only one managed location, but there can be appropriate replication of control, unmanaged locations (see Underwood 1992, 1993a, 1994a for all details of design and analysis of such sampling).

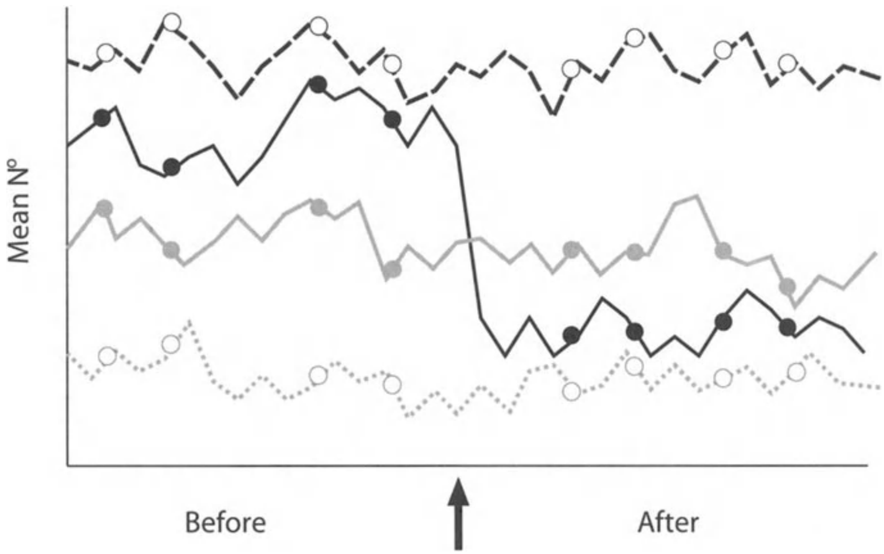

Fig. 6.2. A "Beyond-BACI" analysis of the potential effects of an environmental disturbance affecting the numbers of some organism in the potentially impacted (*filled circles*) and three control areas. BACI designs, i.e. in which there are data before and after the apparent impact and from the potentially impacted and control locations are important for detecting environmental problems. Replication of the controls is necessary for valid conclusions to be made (see Underwood 1992, 1993a, 1994a for details). An impact must cause an interaction, i.e. the change from before to after the impact is different from natural changes over the same time in undisturbed control locations

Managers of attempted improvements in resources or conservation of deleteriously affected species need to aware of the nature of appropriate information and the minimal requirements of measurements. The same realization is true for those responsible for detection and estimation of the magnitude of environmental impacts from planned developments or accidental releases of toxic chemicals. Dealing with ecological uncertainty requires recognition of how to eliminate it.

6.2.3 Life-Histories and Scales of Management

Sometimes, the scale of environmental changes due to pollution, disturbances, planned developments, etc., are not known. It is therefore important to ensure that any subsequent investigation of the consequences be designed to cover the relevant spatial scales. This almost always requires an hierarchical design of sampling that can allow analysis at a series of overlapping spatial scales (see Underwood 1992, 1993a for details).

This does, however, raise the important point that management of any aspect of coastal environments requires very careful consideration of the spatial scales of the biological systems being managed. There may be planned developments of a localized nature, for example, a marina or canal estate may be built on a small patch of the coast. The area chosen, however, may be an important source of offspring supplying new individuals to areas of similar habitats far away. Some marine species disperse over enormous distances (Mileikovski 1971; Scheltema 1971, 1986). Particular care is needed to ensure that representative pieces of natural habitat used for breeding are not damaged if populations elsewhere on the coast are to be sustainable.

The issue of appropriate scale is also of relevance to many programmes of monitoring water quality. Some such programmes in Australia exist because of direct risks to human health from sewage, pollutants, etc. Others, however, are done to evaluate managerial changes proposed to improve "quality of habitats", "health of ecosystems" or to evaluate or increase sustainability of local biodiversity (e.g. DEST 1997). Where the latter is the aim, the projects are often (and probably usually) inept in conception because of misplaced beliefs about scales and linkages in ecological processes. It is, for example necessary to assume that measurements of physical (light, sediments) and chemical (concentration of oxygen, nitrogen, phosphorous) variables are somehow tightly correlated with or are good predictors of sustainability of biological populations or diversity of species in that area. In southeast Australian coastal habitats, no such linkages have been demonstrated and they are not likely, given that abundances and diversity of species are unlikely to be under direct regulation by physical and chemical processes without regard for biological interactions (Underwood and Peterson 1988; Menge 1995).

Above all, there have been (as discussed later for urban wetlands) repeated quantitative demonstrations of the relatively small spatial scales of patchiness of invertebrate populations in coastal habitats. Generally, such scales are not easily inferred from simple measurements (Underwood and Chapman 1996) and knowledge about them is not necessarily transferable from one habitat to another – even for the same species (Underwood 1996a). It is, however, the case that much routine measurement of physical and chemical variables (so-called "water-quality measures") is at temporal and spatial scales entirely inappropriate to be related to known rates of change and scales of difference of the very biological variables to which they are supposed to be related (see Morrisey et al. 1992a,b for discussion of such scales).

Measures of water-quality (outside their use in assessments of risk to human health) are a very poor tool to provide any useful information to managers and decision-makers. The widespread existence in southeast Australia of programmes of measurement probably simply reflects the fact that participation of the community is desirable. Members of community groups can usefully be involved in measurements of water-quality – even if the spatial and temporal scales of sampling are ill-conceived, there is no demonstrable connection to any necessary biological variable and the information itself is useless for any managerial decision. Participatory democracy does not, apparently, have to achieve any environmental improvement!

6.3. Managerial Decisions as Experiments

6.3.1 Sewerage Outfalls on the Rocky Coast of New South Wales

Three sewage treatment plants served a population of 2.2 million people and discharged directly into the sea. The amount of sewage and other domestic, commercial and industrial effluent was about 88% of the total in the Sydney region (Sydney Water Board 1990). Between September 1990 and April 1991, the three outfalls were decommissioned; sewage was, instead, discharged from diffusers over 5–800 m of seabed at 60–80 m depth, 3–4 km offshore. This major plan of changed management was long overdue and largely driven by public concerns about human health and environmental issues for coastal fauna and flora.

As one aspect of such concerns, Fairweather (1990) had reported that assemblages of algae and invertebrates on rocky intertidal shores near some outfalls were quite different from those elsewhere. This observation was explained by increases in nutrients around outfalls (e.g. Borowitzka 1972; Littler and Murray 1975). Generally, assemblages close to outfalls were dominated by early-stage colonising species, primarily green algae and had fewer filter-feeders (barnacles and mussels). Such effects could, however, have been due to the freshwater discharged at the outfalls – which often favours growth of green algae where salinity is reduced. Either way, the managerial hypothesis was that closing the outfalls would result in changed assemblages, to become more like those where there was no disturbance due to sewage.

To test this hypothesis in the Sydney region, Banwell (1996) completed a properly controlled study, with appropriate replication before and after the outfalls closed. She sampled intertidal assemblages on rocky shores at North Head and Malabar, which had outfalls that were to be closed. She also sampled at Potter Point and Bellambi, which had outfalls that were to continue to discharge sewage. At each outfall, she sampled near the outfall and at two reference locations about 1 km away – a distance chosen because Fairweather (1990) had demonstrated no effect of sewage at that distance from an outfall.

The number of algal species is used here to illustrate the outcome of changes of management of sewage. Before the outfalls were closed, there were significantly fewer species of algae at every outfall compared with reference areas unaffected by sewage (Fig. 6.3). After 2 outfalls were closed, numbers of algal species remained depressed at the 2 control outfalls that continued to operate (Fig. 6.3). As predicted in the hypothesis, removal of sewage led to increases in numbers of species of algae at North Head, to match the situation in areas previously unaffected by sewage. So, for North Head, the predicted changes occurred and can be clearly associated with the changed management. There was a general increase in algal diversity during the period of the study. Increased algal diversity following closure of the outfalls was greater than where outfalls were not closed (Fig. 6.3).

There was a smaller increase in numbers of species at Malabar after the outfall closed. In fact, fishermen kept one replicate site clear of algae to increase their safety while standing there. Such damage was sufficient to prevent average numbers of species increasing to match reference areas. Banwell (1996) demonstrated experimentally that algal diversity increased to numbers in reference areas, provided fishermen did not destroy them.

In this case, using normal procedures of experimental design, the changed management was shown to be entirely effective. This was, however, not the case for subtidal rocky regions. Concern had been raised that inshore subtidal outfalls were deleteriously affecting assemblages of invertebrates and algae. Sampling at several depth around the North Head subtidal outfall after it was closed showed no major changes in assemblages (Chapman et al. 1995; Underwood and Chapman 1997). The explanation was that the outfalls were, in fact, having very little effect on these subtidal assemblages dominated by filter-feeders and red algae. Assemblages were not really different from those in similar, reference habitats where there was no sewage. In this case, the data collected from a controlled and replicated experimental design were useful for guiding decisions

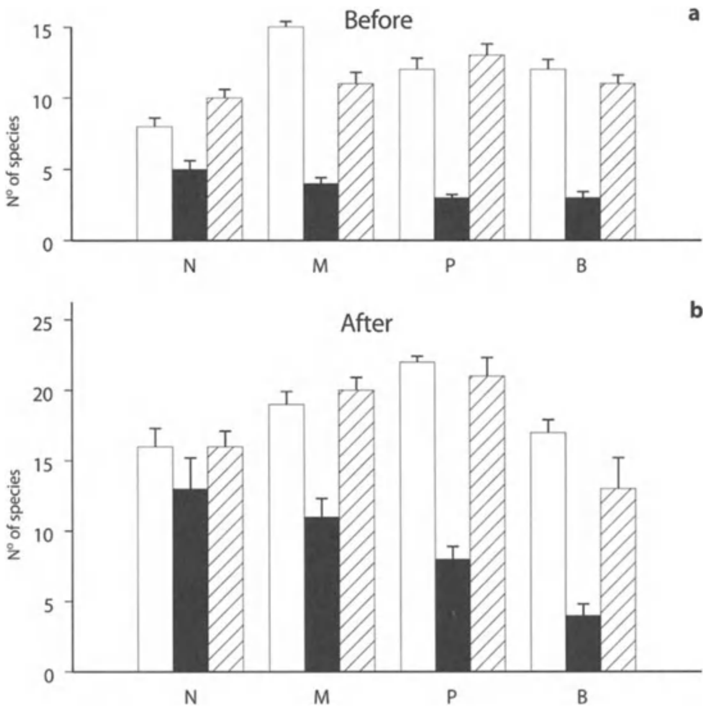

Fig. 6.3. Numbers of species of algae before and after closure of two sewage outfalls on the coast of New South Wales (Data from Banwell 1996). Mean (S.E.) numbers of species are shown for (*black*) 4 outfalls (*N:* North Head; *M:* Malabar; *P:* Potter Point; *B:* Bellambi) and (*white, striped*) nearby control locations without outfalls. There were fewer species near outfalls **a** and numbers increased to be more similar to controls **b** after North Head and Malabar were closed (see text for problems at Malabar). No similar changes were observed at Potter Point and Bellambi where outfalls continued to discharge sewage

about other subtidal outfalls, in that they demonstrated no major environmental impacts of sewage on assemblages in subtidal rocky habitats.

6.3.2 Recreational Boating

Until recently, the environmental effects of recreational boating have been largely ignored. With increasing urbanisation and increased affluence in countries such as Australia, recreational boating has increased markedly during recent decades. Although there are obvious potential impacts associated with the use of boats (e.g. pollution from fuel and litter), much of the environmental concerns with recreational boating arise from the mooring of boats when not in use. Some boats are still moored on buoys. The majority are, however, moored in large densities in marinas, attached to a system of floating pontoons or jetties attached into the substratum. The large concentration of boating into marinas and the often extensive, associated built structures have caused increased concern about the effects of marinas on estuarine habitats.

The commonly cited potential effects of the development and running of marinas include

i. degradation of quality of water from pollutants and changes to natural patterns of circulation (Baird et al. 1981; Turner et al. 1997),
ii. detrimental changes to the fauna and flora in habitats near marinas because of pollutants, changes to water flow and shading (Iannuzzi et al. 1996),
iii. direct damage to sensitive habitats, such as seagrass beds by physical impacts of anchors and chains (Walker et al. 1989), and
iv. direct toxicity to fauna by contaminants such as TBT (Waldock and Thain 1983; Gibbs and Bryan 1994).

Nevertheless, despite such widespread and varied potential impacts, there are no systematic data on the relative importance of the different effects of marinas and other forms of mooring of recreational boats in urbanized areas of Australia, including Port Jackson (Sydney) and the other estuaries. This is the case, despite the fact that there are approximately 40 marinas and more than 10 000 mooring berths (in marinas and on floating buoys) in the four estuaries around Sydney. In addition, managerial decisions about the development and expansion of marinas and other mooring structures, including decisions to replace jetties with floating pontoons, are being made on an ongoing basis and changes to marinas are subject to varied regulations because of potential environmental impacts. The results of such decisions are seldom examined within a scientific framework to evaluate their relative usefulness.

Because of a need to evaluate the relative effects of mooring in marinas or on mooring buoys in order to improve management of marinas and recreational boating facilities, in 1995 a collaborative research programme was developed between the Institute of Marine Ecology (University of Sydney), the Boating Industry Association of Australia and the Marinas Association of New South Wales. The research was aimed to identify effects of marinas and mooring buoys on marine fauna and flora in the vicinity. This study was supplemented by a study of organisms on rocky reefs near and away from marinas (Glasby 1997a). This information can be used by the recreational boating industry to improve management of these facilities, thereby changing management from a reactive response (to perceived or real impacts on a case-by-case basis) to a proactive response (developing general practices to improve their environmental record).

The fauna examined included invertebrates living in the sediments, on nearby rocky reefs, in seagrass beds, in the holdfasts and on the blades of kelps growing on these reefs and on the blades of the seagrasses. Such assemblages of invertebrates are diverse and numerous and their responses to different types of disturbances (e.g. chemical contamination, turbidity, changes to flow of water) are documented. In addition, as adults they are generally sessile or do not disperse very far and any differences in their abundances or diversity are likely to be strongly influenced by local conditions. Any widespread and general effects of marinas or boat moorings should, therefore, be found in a number of different assemblages. Although fish accumulate around structures (Picken and McIntyre 1989), they were not examined in this project because they can respond to influences away from the study sites and therefore any differences identified from place to place cannot easily be attributed to conditions in those places. In addition to the fauna, the areal extent of the seagrasses *Posidonia australis* and *Zostera* *capricorni* were measured in those estuaries in which they were found. Assemblages were examined in a number of estuaries around Sydney, although all assemblages were not examined in each estuary because of their patchy distributions.

The experimental design was to compare replicate sites in each of a number of marinas, areas with mooring-buoys and control locations (similar habitats without permanent mooring facilities) in different estuaries, although the precise detail of the design differed for the different assemblages according to the precise hypotheses being tested.

There were no widespread and general effects of either marinas or other boat moorings on the faunal assemblages or seagrasses, although effects could be identified for some assemblages in some places. For example, the animals in the sediments in one marina in Pittwater (one local estuary) were consistently different from those in the relevant boat-mooring sites and control sites. The sediment itself was much finer near this marina and sediment-size is known to be a strong determinant of the infaunal assemblage (Gray 1974). Whether the previous construction or the running of the marina themselves influenced the sediment-size is not known and was outside the scope of the study. This difference was, however, specific to this marina and not found near other marinas. It cannot therefore be identified as an effect of marinas in general.

Similarly, there were significant differences in the infauna between marinas, boat-mooring areas and their control locations at some times of sampling, but not at others because of variable temporal changes in the fauna. Managerial decisions based on single samples in time, no matter how well replicated in space, are likely to be faulty because they do not take into account natural temporal change.

In other examples, marinas did appear to have had persistent localized effects on the fauna, although different species responded to marinas in different ways. For example, in Pittwater, paraonid polychaetes and Anthurids in sediments were consistently negatively affected by marinas, maldanid polychaetes were positively affected by marinas and none was affected by other boat-mooring facilities. In Port Jackson, abundances of cirratulid polychaetes and general diversity were negatively affected by marinas. Therefore, effects of marinas on the same faunal assemblage varied from marina to marina and from estuary to estuary.

It was quite clear that once a marina or boat-mooring area was established, the areal extent of surrounding seagrasses and the encrusting animals and plants on the blades of seagrasses were not affected by the continued operation of marinas or boat-mooring areas. This contrasts with suggestions from other studies that seagrasses will be adversely affected by runoff containing metals in urban environments (Ward 1989). Similarly, the animals associated with the leafy portion (the blades) of the kelp *Ecklonia radiata* did not show any strong or consistent impact around boat mooring areas or marinas, again contrasting with studies elsewhere (Jones 1973). In contrast, in Port Jackson, the animals living in the holdfasts of the kelp showed consistent and significant impacts of marinas and boat-mooring areas, with fewer Nematodes, Tanaids, Ostracods, Isopods and Gammarideans than in control locations. These comparisons may, however, be confounded by the locations of the marinas, boat-mooring areas and control locations in Port Jackson. The control locations were necessarily closer to the open ocean because of the difficulty of finding locations without mooring facilities near the marinas.

This study convincingly demonstrated that any effects of marinas or other boat-mooring facilities on the associated invertebrate assemblages were varied in space and time, making any environmental assessment based on single times of sampling difficult to interpret. If data from a long enough time-course before and after a marina is built are not available, comparisons can still be made between ongoing facilities and control locations (Glasby 1997b). Careful consideration needs to be given to the location of appropriate controls (Green 1979) and spatial and temporal scales of sampling (Underwood 1992, 1994a). Future management of such facilities will also be improved if each marina is not treated on a case-by-case basis. In busy estuaries, environmental decisions about the development and functioning of marinas are being made continuously. Each of these decisions is an experiment, with a predicted outcome. If these decisions and tests of their predicted outcomes can be amalgamated, managers could develop more powerful (and general) methods of assessing effects of facilities such as marinas. This requires, however, a very different approach on the part of planners and managers to the way in which environmental impact is assessed.

Note that, as is the case with many ongoing activities, such as recreational boating, it is often assumed that any impacts are due to current activities. This needs more careful consideration by managers. For example, if developments, such as marinas, are carefully built in particular parts of estuaries (perhaps because of shelter from waves or wind), then these areas may contain different assemblages of animals and plants, prior to any development. It will then be very difficult to distinguish between prior differences in the assemblages and ongoing differences cased by the activities of the marina itself, unless data are obtained prior to the development.

Finally, there is an increasing tendency to change from pylons and fixed jetties to walkways with free-floating pontoons for attachment of the boats. This is, in part, due to decreased costs of maintenance and in part due to the perception that free-floating structures will allow greater flow of water and therefore be more "environmentally friendly". The surfaces of floating structures may support dense assemblages of animals (Fletcher 1980), many of which may not generally be found in nearby natural structures. Similar structures, such as racks for cultivation of mussels, have very deleterious effects on the sediments below the racks, because of the large quantities of waste produced (Kaspar et al. 1985). The consequences of the decision to change from jetties to floating pontoons are not known and do not necessarily appear to be under consideration. The necessary experiments to test for the environmental effects of this decision are straightforward, but relatively expensive (testing environmental effects on assemblages in sediments is generally expensive because of the time needed to sort samples). They are, however, necessary. Mangers need to recognize the potential consequences of their decisions and to plan experimental tests of these consequences before decisions become widespread and generally accepted as "good for the environment".

6.3.3
Restoration of Wetlands

As another example, consider the managerial decision to restore (rehabilitate) wetlands or other degraded and damaged habitats. The reasons for such a decision are usually specific to each project and often driven by societal (rather than ecological) needs. For example, damaged habitats may be restored to provide recreational or aesthetic amenities. Even when the stated need is restoration of habitat for wildlife (Zedler 1996), it is not always clear that the process of restoration will achieve this. Restoration is frequently an end in itself, with little evaluation of the success or failure of its desired outcomes (reviewed by Eliot 1985; Race 1985).

Restoring wetlands can have many forms, including increasing on changing drainage channels, altering the tidal regime (Zedler 1996), building banks or levees, or recreating new wetlands *de novo* (Griffiths 1995). These are all very large experimental manipulations. Nevertheless, they are seldom treated as such and the outcomes of restoration are seldom interpreted within an experimental framework. The need or desire for restoration usually comes from a series of observations that the habitat under consideration is degraded or damaged in some way – usually with respect to the diversity or abundances of animals and/or plants. For example, the managerial decision to change tidal flushing in patches of urban wetland around Homebush Bay (Port Jackson, New South Wales, Australia) was based on the perception that these habitats were depauperate in marine benthic macrofauna in contrast to similar habitats with better tidal flushing (Berents 1993). Inadequate flushing by tidal waters from the nearby bay was therefore proposed as the reason for the depauperate nature of the fauna.

Similarly, tidal flow was restored to Batiquidos Lagoon (Calif., USA) to compensate for loss of habitat for fish in Los Angeles harbour (Zedler 1996). The observations were that

i. there had been much loss of habitat and
ii. Batiquidos Lagoon was of little value because it was non-tidal.

The managerial decision to change totally the tidal regime to the area was based on the model that tidal flushing is necessary to provide suitable habitat for fish. Such models lead to the hypothesis (prediction) that enhanced tidal flushing will

i. increase density and/or abundances of benthic macrofauna and
ii. increase areas of habitat for fish and, ultimately, increase density/abundances of fish.

Hence, the decision is made to alter tidal flushing.

Unfortunately, with respect to most restoration projects, this is where the scientific process stops (reviewed by Kentula et al. 1992). In many instances, the necessary tests of the prediction are not made (no monitoring is done of the predicted changes; Race and Fonseca 1996). The managerial actions are simply assumed to have had the desired effects. In some cases at least, this is because monitoring (on other equivalent measurements) after restoration is not legally required by the conditions of the permit (or other permissions) (Race and Fonseca 1996). In many cases, it is because, although monitoring is required, the design of such monitoring has not been thought out in the framework of experimental design. (Kentula et al. 1992; Chapman and Underwood 1997a).

Although the precise definitions of restoration often vary from project to project, they are often based on what society wants, rather than what is ecologically feasible. It is extremely common to suggest successful recovery to an historic or previous condition (Bradshaw 1987; Brinson and Rheinhardt 1996; Cairnes 1996). This is meaningless because

i. there is no realistic way to determine which previous condition is the appropriate one (Botkin 1990) and
ii. there is increasing evidence that nature is not equilibrial or balanced (see earlier); temporal change and spatial variation are natural.

Therefore, any previous condition is not necessarily appropriate at the time a particular proposal is made to begin restoration.

Second, even if we could reach a decision about the previous conditions that restoration is attempting to achieve, it is unlikely that there are adequate data to describe these quantitatively (except perhaps for certain large plants and/or a few species of vertebrates). Most species are not only characterized by average changes in abundances from place to place and time to time. Abundances also vary at an hierarchy of small and large spatial and temporal scales and patterns of variance across these scales may be extremely important in

i. quantifying natural patterns of abundance and
ii. identifying responses of assemblages to disturbances or restoration (Underwood 1992, 1994a; Warkwick and Clarke 1995).

These findings are relatively recent and it is extremely unlikely that the relevant data about spatial and temporal variability are available for historic or past conditions for most habitats being restored.

Recognition of the above problems has led to some restoration projects having more realistic goals, e.g. to make restored areas resemble in structure and function other natural, undamaged habitats (e.g. Galatovitsch and van der Valk 1996; Simenstad and

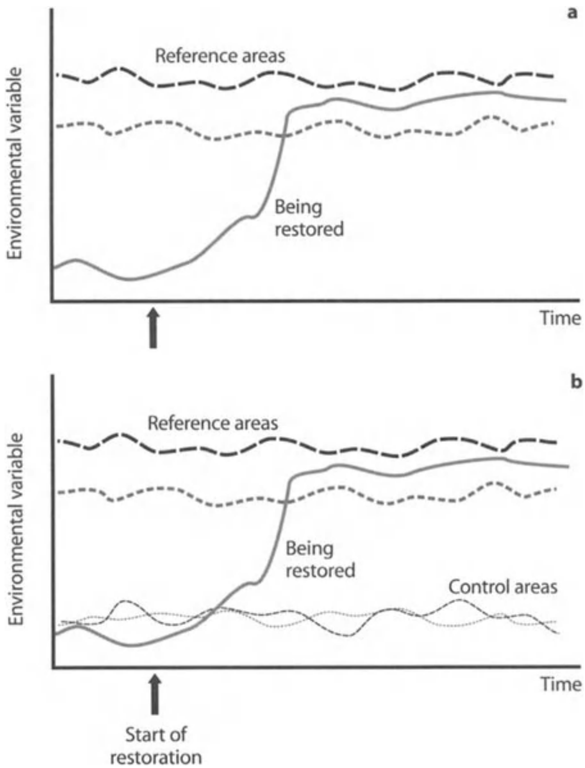

Fig. 6.4. Restoration of a damaged habitat to show natural change in a relevant environmental variable in an area being managed to restore natural structure and function. **a** Restoration is proposed to result in similar values to those in undamaged reference areas. In **b**, the process of restoration is measured by com-parisons with damaged control areas that are not being restored (see Underwood and Chapman 1997)

Thom 1996). Such areas are called reference areas. Successful restoration predicts that the variables used to measure structure or function will initially differ between the damaged habitats and the reference areas, will change after the start of restoration, will converge on average conditions in the reference areas and will thereafter show similar time-courses (Fig. 6.4a). Therefore, to evaluate the success of restoration, the environmental variables of interest (diversity, productivity, etc.) must be compared between the restored habitat and a number of so-called reference areas (Chapman and Underwood 1997a).

Although such an experimental design is appropriate for measuring environmental impacts and other disturbances (e.g. Underwood 1992), it is, however, not adequate for measuring the success of restoration. Although a change in the environmental variable coincident with the start of restoration of the habitat is essential to successful restoration, it is not in itself sufficient to demonstrate that the managed restoration is the cause. Habitats change naturally without intervention. To conclude without doubt that the changes were a response to restoration, it is necessary to compare the outcome with similarly damaged areas which are not managed (i.e. control locations). It is therefore predicted that changes in those control pieces of habitat will not mirror those in the restored habitats (Fig. 6.4b)

This methodology has led to concerns about the quality of data used to assess success of restoration. Typically, inadequate or shoddy sampling (or measurement) will give very imprecise estimates, with large standard errors and confidence intervals, associated with mean values. The prediction that restored habitats change to become similar to reference habitats will be supported if standard errors around the mean values in the different habitats are large, even when the mean values are very different and restoration has not been achieved (McDonald and Erickson 1994; Fig. 6.5a).

Under the same conditions, precise sampling (with associated small standard errors) would lead to the conclusion that restoration has not occurred (Fig. 6.5b). Therefore, imprecise data which are least likely to be able to measure restoration are also more likely to cause one to conclude that restoration has been successful! This has led to the concept that one must, *a priori*, state the desired measurement that would signify successful restoration. For example, one might decide that restoration would be considered successful if the confidence limits in the restored habitat fall within ±10% of the confidence intervals around average conditions the reference locations (Fig. 6.5c). Small errors and confidence limits in the restored location (and, hence, more precise sampling) will be more likely to indicate successful restoration. Unfortunately, such quantitative predictions about the end-points and goals of management are not yet commonly made in restoration projects.

Finally, one needs to consider problems associated with structure and function of habitats. Many managerial strategies involve changes to the structure of the restored habitat (planting trees, removing exotic species, changing flow of water). Restoring structure is relatively easy, as is – within the limitations described above – measuring changes to structure. Functional aspects of damaged habitats are, however, more important to restore if restoration is to be sustainable. Function includes productivity, capacity for self-generation, maintenance of biodiversity, networks of interactions, food-webs, etc. Even when appropriate structure and function are each stated to be goals of restoration, structure is often the only means by which restoration is assessed (reviewed by Kentula et al. 1992). It has been assumed that if an area looks right, it will function adequately. A few recent studies have shown that constructed and natural wetlands are

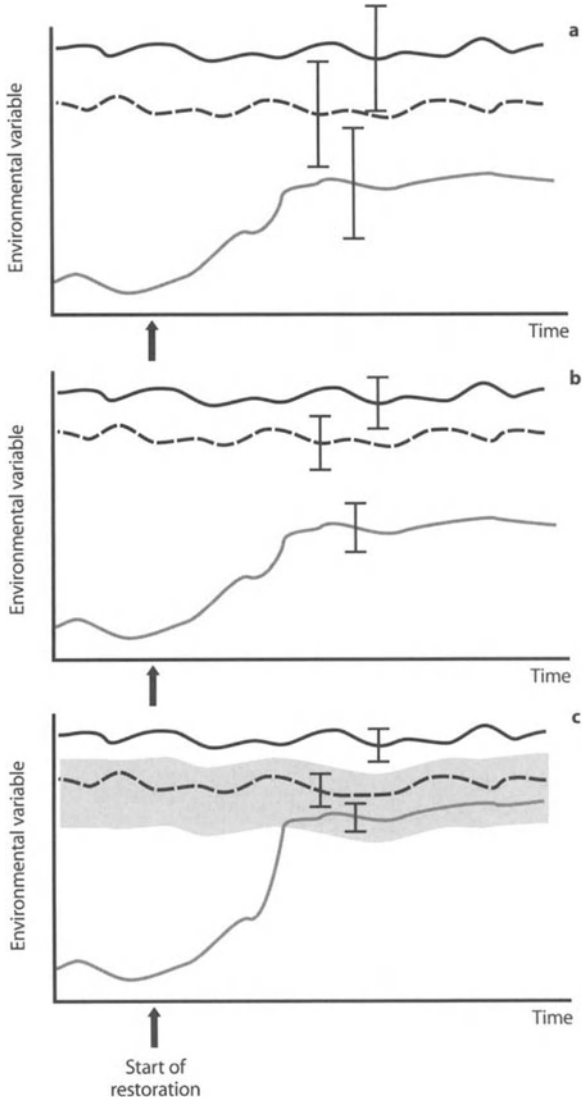

Fig. 6.5. Bio-equivalence in restoration of degraded habitats (Adapted from procedures in McDonald and Erickson 1994). In **a**, wide confidence limits (due to inadequate sizes of samples) cause the conclusion that the area being restored is not statistically different from the natural, reference areas and restoration is complete – even though the mean value is much smaller than those in the reference areas. In **b**, in contrast, the more precise sampling would reveal the failure of restoration. Sloppy sampling in **a** would lead to restoration being thought complete. In **c**, the shaded area indicates a pre-determined range below the mean of the reference areas that has been defined to indicate that restoration is adequate. Precise sampling is necessary to ensure that confidence intervals around the mean value in the restored area are above the minimal value defined to represent adequate restoration

neither structurally or functionally equivalent (Race and Fonseca 1996; Scatolini and Zedler 1996). In addition, the time courses within which one might expect structural recovery and functional recovery are not known, although it is thought that the latter might take decades (Simenstad and Thom 1996). Few, if any, assessment of the success of restoration have involved detailed environmental sampling over that period of time.

In conclusion, therefore, although restoration of habitat is a managerial decision with expected ecological outcomes, it seldom conforms to any coherent scientific process. In part, this is due to the fact that definitions of restoration vary from project to project and are frequently ill-defined and scientifically untenable. In addition, goals of restoration are frequently driven by society, politicians or planners with little or no knowledge of current ecological theory. Predictions from the proposed management are usually not clearly stated and, all too often, there is inadequate thought of the appropriate spatial and temporal experimental design needed to test these predictions. With the increasing need to restore damaged habitats as more and more natural areas are lost, it is essential that society, managers and scientists collaborate to put relevant, up-to-date science into projects involving restoration of habitat.

6.3.4
Marine Reserves and Intertidal Foraging for Bait and Food

Foraging for food and bait on intertidal shores is not new – it has been going on for thousands of years (Spjeldnaes and Hemmingsmoen 1963; Sullivan 1987). What is new is the intensity of foraging in areas of dense human settlement (Kingsford et al. 1991), which has caused widespread and persistent changes to intertidal assemblages (Lasiak 1991; Moreno et al. 1984). Scientific (Kingsford et al. 1991) and public concern about the long-term impact of foraging has led to a number of managerial decisions, e.g. introduction of closed seasons (Siegfried et al. 1985), bag or size-limits on the species most heavily targeted (Underwood 1993b) and closure of some areas to collection (Castilla and Bustamante 1989). These managerial decisions are all scientific experiments, but they are seldom assessed as such. For example, they usually start with observations about human behaviour and perceived changes in densities, size-structures, etc. of intertidal organisms. These changes are explained by the model that they are due to foraging by people, with the hypothesis that reductions in foraging would change the densities or size-structure of the intertidal populations in certain predictable ways (Castilla and Duran 1985). Hence, the experiment – changes to the regulations to limit foraging.

In many situations, this is then the end of it. There is no scientific evaluation of the experiment (managerial practice) to assess its value. For example, if taking particular species is limited to those above a certain size (e.g. Henry 1984), one can predict few animals of large size in heavily impacted areas, more animals of large size in unimpacted or lightly impacted areas and similar numbers of animals of smaller size in each type of area. One can also make very specific predictions about changes in size-structures of populations after the imposition of the size limits. Despite the relatively straightforward nature of such large-scale experiments, there have been few studies of the effects of such regulations that have incorporated clear hypotheses and appropriate sampling with control locations (Lasiak 1993), especially in Australia (but see Keough et al. 1993).

Regulations regarding bag and size limits have been in force in New South Wales, Australia, for many years (Henry 1984). These regulations are not, however, particularly useful in conservation of intertidal animals. Bag limits generally have no scientific basis – they must depend on how many people forage, how many animals each person takes on average and the extent and rate of removal that a particular species can tolerate before it can no longer persist. Although there is some information about rates of removal (Kingsford et al. 1991), there is no ecological data on the latter for most, if not all, species that are targeted. In addition, such regulations are frequently ignored (Chapman and Underwood 1997b), in part because it is not possible for regulatory agencies to clearly identify the effects of alternative managerial practices on intertidal populations and, in part, because there is no clear ethic of conservation of intertidal animals (which are treated as an exploitable resource by the same agency that is commissioned to protect them). Similar criticisms can be applied to the imposition of size limits, with the added concern that allowing removal of larger animals may indeed remove those members of the population that are most fecund and may therefore contribute disproportionately to future generations.

Because of difficulties with such regulations therefore, in 1994 the New South Wales government responded to public and scientific concern about intertidal foraging by declaring a number of Intertidal Protected Areas on the coast around Sydney, New South Wales. Shores around Sydney are particularly impacted by foraging because of a large urban population, although these activities are widespread around the southern coast of Australia (Kingsford et al. 1991). Intertidal Protected Areas (IPAs) were selected according to a number of criteria (among others, scientific value, relative inaccessibility, the degree of concern by residents and local government) and they were interspersed among unprotected areas, thus allowing most users of the coast access to some shores for their continued plundering. There was to be no collection of intertidal organisms in IPAs, although anglers could still fish on condition that they used purchased bait. The original plan of management included declaration of IPAs, appropriate signs informing the public of the regulations, imposition of the regulations by Fisheries inspectors and local government rangers, a programme of public education and subsequent "monitoring" of the effectiveness of the regulations. Unfortunately, only the first two of these were dealt with satisfactorily – IPAs were declared and some signs were (eventually) provided, although it was up to local government to decide where to place these signs and how many to erect. Adequate resources were not allocated to either the policing of the regulations or the programme of public education, the latter of which was largely left up to local community groups to organize.

The original plan also included promises of funds for a scientific assessment of this method of protecting intertidal organisms before deciding whether to extend IPAs further along the coast. This experiment (closure of areas to foraging) had very specific hypotheses and should therefore have been relatively straight-forward. One would predict, after declaration of IPAs, an increase in abundances of targeted species (crabs, large whelks, sea urchins) in IPAs relative to abundances prior to the declaration and relative to abundances in unprotected areas (where foraging continued) (Underwood 1993b). Similarly, because foragers frequently target larger animals, one would predict an increase in the average size (or an increase in the abundance of the larger size class) of targeted species in IPAs relative to such measures prior to the declaration and relative to such measures in unprotected areas (Underwood 1993b). Finally, because it is known that certain large species may have large effects on the rest of the assemblage (e.g. by creating bare space; Stimson 1973), one can predict that the assemblage in IPAs may change over a period of time after declaration in a different manner to such temporal changes on unprotected shores.

Therefore, this managerial decision gave rise to clear predictions which could be and should have been tested by an appropriate sampling programme, as was required in the original plan of management. This was not done by the regulatory agency in question, who have nonetheless a policy to extend IPAs further afield. The Institute of Marine Ecology (University of Sydney) applied for and received competitive funding from the Federal government to test, over a period of three years, the above predictions in three IPAs around Sydney. Changes in abundances and size-structures of targeted species and changes in midshore and lowshore assemblages were compared between each IPA and two nearby unprotected control locations. Each set of two controls and their IPA were treated separately because of very different patterns of use among different parts of the coast around Sydney. In addition, a collaborative programme of surveys with a municipal council evaluated the success of the local programme of public education (which was probably the most extensive for any IPA). This was done by making specific predictions about changes of behaviour and attitude of foragers and anglers in one IPA and two unprotected areas during three years after declaration of the IPAs (Fig. 6.6).

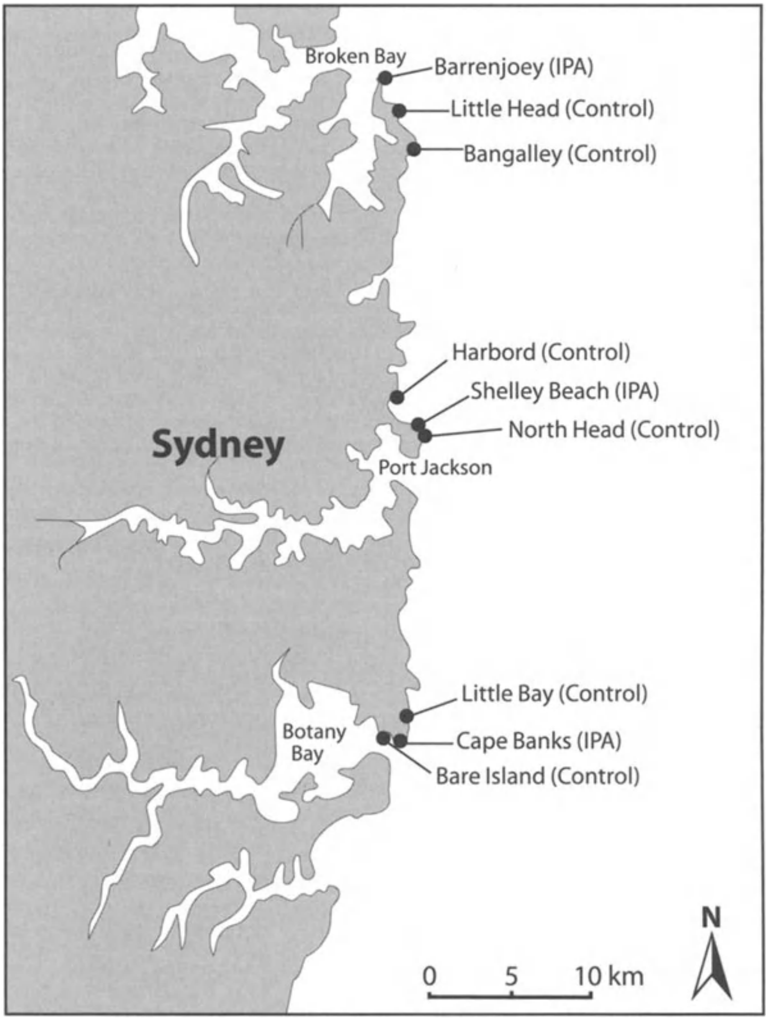

Fig. 6.6. Map of part of the coast-line of New South Wales around Sydney, indicating positions of three intertidal protected areas (IPAs) and, for each one, two unprotected control shores

The results of the ecological sampling were quite straight-forward (Chapman and Underwood 1997b). There were no changes in abundances or size-structures of targeted species or lowshore or midshore assemblages in any of the three IPAs compared to their control locations that would indicate the success of the regulations (Chapman and Underwood 1997b). In fact, some changes in particular species suggested evidence that collection of animals continued in IPAs. The surveys of human behaviour and attitudes in the single IPA and two control locations examined showed no changes of attitude to intertidal conservation, knowledge of IPAs or the amount of organisms removed from shores in the three years after the IPAs were declared. This, despite the fact that this coastal area had a widespread and funded programme of public education, run by the local community and strongly supported by local government (Chapman 1996).

Many reasons could account for the results obtained in this study (summarized in Chapman and Underwood 1997b), but the most plausible explanation was that the lack of policing of IPAs had not led to any change in behaviour by foragers and IPAs were never actually protected. This is supported by numerous unquantified observations of continued plunder on protected shores with no intervention by the regulatory agency. This is, no doubt, due to a lack of resources, e.g. personnel to regularly inspect the shores, rather than lack of will. Resources were not increased with the declaration of the IPAs. In countries where similar regulations are strictly enforced, intertidal assemblages are protected (Duran et al. 1987; Lasiak 1993). The results also suggest that without appropriate resources for policing reserves, declaration of IPAs will not be an appropriate managerial strategy to protect and conserve intertidal organisms (see also Underwood 1993b). Nevertheless, it has been decided to increase the numbers of IPAs in New South Wales as one of the primary means of conserving intertidal species. Such management is going to continue to be pointless if the results of previous failed attempts are simply ignored.

6.4 Marginalization of Scientific Contributions in Australia

Many aspects of current planning and policy for management of coastal environmental issues serve to marginalize the roles and contributions scientists can and should make. Reasons for and responses to this are considered later. Here, some examples are given to demonstrate the problems that result when appropriate scientific contributions are ignored or actively prevented from consideration in solutions to environmental problems.

6.4.1 Biological Diversity and its Conservation

Government agencies in Australia have made decisions to map coastal regions and their diversity using broad sweeps of coast-line as the units (e.g. Thackway and Creswell 1995). State agencies have done the same with attempts to determine how marine reserves should work. Considerable effort goes into documenting distributions of species using large-scale methods, e.g. Geographic Information Systems (GIS) (e.g. Thackway and Creswell 1995).

This is almost inevitably doomed, given the large amount of existing, published ecological work that demonstrates the small-scale nature of processes causing variation and change in coastal assemblages in southeast Australia (e.g. soft-sediments, Morrisey et al. 1992a,b; mangrove forests, Chapman and Underwood 1997a; rocky shores, Underwood 1994b, 1996a; Underwood and Chapman 1996; Underwood et al. 1983; kelp-beds, Kennelly and Underwood 1992).

Obviously, managers and policy-makers cannot have processes and instruments that match exactly the bewildering array of small-scale ecological complexity. Nevertheless, they have a responsibility for their actions and decisions. They should therefore take some interest in determining the consequences for long-term environmental welfare of managing by regions, catchments, council boundaries. Instead, they are simply dismissive of any process that could investigate the relationships and likely outcomes of mismatches between scales of ecological patterns and processes and scales of managerial decisions. The current Federal Minister for the Environment's decision-making creates desperate and urgent needs for research to help him be efficient and cost-effective (which are goals of many modern governments).

A further issue is that there are widespread attempts by government agencies and community groups to be involved in "monitoring" and "assessment" of coastal biodiversity. This involves decisions to spend considerable sums of money (DEST 1997). Unfortunately, no current methods are available to document biodiversity of complex assemblages in complex habitats where there is considerable spatial and temporal variation. Efforts to provide such methods (Legendre and Anderson 1998; Underwood and Chapman 1998) require urgent validation at the scales needed for managers. They also require urgent simplification to ensure their reliability for community groups. At the same time, Australia has suffered the world-wide downturn in funding for taxonomy and systematics (Ladiges 1992). Consequently, on both accounts, the inevitable outcome of large-scale spending on pseudo-documentation of patterns of biodiversity by amateur groups must be waste, lost opportunities and very limited environmental understanding and protection. In the absence of professional science, external review of projects by experts, demonstration of quality control and consistent reliability and integrity of any data, there are no possible positive alternatives.

A second issue concerns the whole notion of "monitoring". Environmental science moved a long way to rid itself of the shackles of routine, hypothesis-free data gathering. Monitoring environmental variables, be they physical (e.g. turbidity or sediment-load in estuarine water), chemical (dissolved oxygen) or biological (concentration of phytoplankton or local richness of species) is largely a pointless exercise. Very occasionally, such as with loss of raptorial birds because of bio-accumulation of DDT, routine observations and monitoring lead to the discovery of a problem (Hickey and Anderson 1968). This is, however, rare relative to the costs (Underwood 1989).

Monitoring to detect change actually requires explicit statements about the nature of change, the processes causing it, the anticipated magnitudes and directions of change and their time-courses. Then and *only* then can an appropriate framework of sampling and measurement be designed. It must have the relevant spatial scales, frequency and duration of timing (Underwood 1991) and intensity of measurement to detect the proposed changes (Green 1979).

Stopping the waste of unplanned, hypothesis-free monitoring and directing effort into properly planned campaigns of sampling to get information needed to inform decision-makers is crucial (Green 1979; Connor and Simberloff 1986; Cairns et al. 1993; Caughley 1994). It also requires adequate *a priori* statements of the precise nature of the problems, their time-courses and how much change matters, so that adequate resources are made available to get precise enough information to be useful (Hilborn and Walters 1981; Peterman 1990; Fairweather 1991; Gray and Bewers 1996; Underwood 1997).

Unfortunately, it also requires managers and decision-makers to be precise about what they are doing and what they expect to happen and potentially involves them in risks of being shown to have made the wrong decisions (Longood and Simmel 1972; Ward and Kassebaum 1972; Peterson 1993). It also involves proper planning of environmental sampling and this needs trained, qualified and experienced scientists. If the object of the exercise is improved environmental management, neither is a disadvantage. If, in contrast, the aim is to preserve the status of decision-makers and to increase electoral favours by funding community groups and environmental activists, both the risks of being wrong and the need to involve professionals would be seen as disadvantages.

6.4.2 Reduction of Scientific Uncertainty for Managerial Decisions

As in all other science, public funding of fundamental and strategic coastal environmental science has declined, in southeast Australia. Nevertheless, per capita of population, particularly given the large geographical area involved, there has been considerable return in terms of publications, findings, innovations, etc., from the scientific community. It is a great pity that so much of the available information is not used – even though it is readily available.

The reasons for this are beyond the scope of the present discussion, but include the failure of scientists to take any initiative in environmental issues or to spend adequate time explaining what is the purpose of the work they do. It also involves the "turf wars" of State and Federal agencies spending more effort protecting their own boundaries than seeking the best collaborative solutions to problems by involving outside (and sometimes demonstrably better informed) scientists (a point made well in the analyses by Longood and Simmel 1972; Ward and Kassebaum 1972). A further issue is the various and non-transparent political agendas of community and environmental groups. These are often composed of "domestic elites" (Jamison 1996) – who have filled the vacuum of responsibility for long-term environmental issues. In doing so, however, they have created a new radicalism that is self-centred and self-absorbed. Political necessity has created an activism that has often lost touch with the need for real information (Princen et al. 1994). Instead, increasingly and without question or the possibility of criticism, "local" or "folk" or "indigenous" knowledge has supplanted real knowledge. There are huge and well-known dangers in this shift of the nature of environmental knowledge – e.g. discussions of local knowledge in Agrawal (1995), Jackson (1995) and Jewitt (1995). So-called "cultural ecology" is slowly catching up with scientific ecology to include the scientifically well-known realization that the very landscapes and seascapes in which we live are created by human influences. There has been a widespread non-scientific view that, somehow, environmental processes are external to human actions, but environmental problems are caused by such actions (Conklin 1954; Netting 1993). Fortunately, this may now be fading.

Unfortunately, not fading are other currently fashionable views not supported by scientific evidence. These include the sociological fiction that local or indigenous knowledge is superior to documentable, criticisable knowledge (Agrawal 1995). They also include the ecologically documented demonstrations that there is no balance of nature (Botkin 1990), that indicator species or even indicative chemical or physical variables must exist to represent other components of biological systems (Landres et al. 1988) and that conservation of complex assemblages in coastal habitats will be aided by focussing on single or a few species deemed to be particularly important or "keystone" in their roles (Mills et al. 1993). One further barrier to our capacity to progress in sustained conservation is the widespread belief that commitment of resources to "endangered species" will somehow help. This notion comes from terrestrial ecology – where it has already been demonstrated to be a poor way of preventing future increases in the numbers of species declining until they too, become endangered (Caughley 1994; Caughley and Gunn 1996). Even if it were a good model of terrestrial conservation, it would have little relevance to coastal fauna and flora, where the issues are about habitats and assemblages and where individual species rarely go extinct (Carlton et al. 1991).

It is a great pity that an increasing focus on coastal management and conservation (Ray 1976; Ivanovici 1987) has not been coupled with increased use of what really is known about these systems, what is not useful from terrestrial systems and what is useful. The latter includes detailed analyses of how to ensure representativeness and irreplaceability of components of landscapes (reviewed by Pressey 1992; Pressey et al. 1993), instead of inventing new models for systems of reserves that not just attempt to re-invent the wheel, but seek to make it square.

6.5
Conclusions: Towards a New Scientific Social Contract

In Australia, we are in a state of transition in environmental management. Society is gradually changing its focus from "brown" (pollution, degradation of habitats) to "green" (conservation, sustainability) issues (Hardoy et al. 1992). The future will undoubtedly see greater moves towards building new habitats and repairing and maintaining damaged habitats, so that we create sustainable managed environments, supporting maximal diversity.

Such changes seem to have gone hand in hand with increasing distance from the sorts of science available and needed. There will, however, never be a satisfactory substitute for real knowledge and expertize, even though this is an era when apparently anyone can claim (and be accepted uncritically by the media) to be an ecologist, a marine biologist or what-have-you. For the future of environmental decision-making to be better than the past, there need to be major changes in the way environmental scientists contribute (e.g. Sagoff 1985). Some commentators want radical change in the nature of knowledge-making institutions (Yearley 1996) and assert that environmentalists must make demands for restructuring these institutions a major component of their political objectives. Such strident activism cannot possibly help until the various and competing environmental movements demonstrate capacity to comprehend the nature of and need for substantial and documented knowledge – even if it contradicts well-meant points of view.

Restructuring of the roles of environmental science is happening inside the institutions. Reviews of the potential roles of ecological research (Lubchenco et al. 1991; Underwood 1996b) reflect the interest in such change. These are, themselves, subject to proper critical appraisal (Ludwig et al. 1993). So the point for Australian coastal environmental management must be restructuring towards what desirable end-point?

In current democratic structures, a better coalition of policy-makers, managers and scientists to bring about increased, long-term sustainability of Australian coastal environments must have several elements:

1. Better awareness by scientists of responsibilities to the wider community's wishes and needs, so that the need for the fundamental and strategic science can be articulated inside frameworks likely to receive support. This would remove some of the self-induced isolation of many environmental scientists.
2. Greater recognition by those who make decisions, as end-users of scientific (among many other sources of) information, of the difference between reliable information and the sorts of data that are collected without proper objectives, plans, methods and external reviews.
3. Policies that include finding out about issues that must be solved rather than battering on in the naïve hope that current decision-making, in the absence of firm information must be appropriate. Evaluation of managerial actions as properly controlled experiments (rather than the current uncontrolled experiments) will not only allow increased sale and relevance of ecological investigation, It will also mean that intrusive management begins to conform to legislated requirements (e.g. the New South Wales Coastal Policy; NSW Government 1997) about precautionary principles. Uncertainty and ignorance can lead to inappropriate management and unworkable regulations. Precaution in the face of incomplete information *requires* investigation and *taking notice* of the outcomes. Otherwise ignorance and uncertainty must persist. Precautionary principles require that, when in doubt, the potentially least damaging decisions are made. The only way to know what was least damaging is to investigate, which requires structured tests of the managerial decisions (Underwood 1997).
4. Recognition that programmes to empower local communities are encouraged by the Rio convention (World Commission on Environment and Development 1987). It is, however, abnegation of responsibility not to inform and educate community groups of the often-encountered needs to support some fundamental or strategic or methodological research to ensure that local action can achieve the stated aims and objectives. Many current projects of monitoring and restoration cannot. Even when aims are clear, methods are not. No-one is being given greater, "bottom-up" involvement in the eventual management of environmental problems if their activities are pointless.
5. Actions to ensure that, where scientific information is necessary for some environmental policy-making, planning or action, the information is sought. Often it will not be available, but looking for it may well alert parts of the research community to the needs and may therefore generate proposals to do the work to get that information. Unfortunately, few people in agencies, educational planning, etc., consult either the scientific literature or those who know how to consult it. For example, recent developments of curricula for schools on topics of biodiversity cited as authorities for ecological content only two, internal, non-refereed documents produced by

the New South Wales Environment Protection Authority (NSW Department of Education 1997), rather than any of the readily available mainstream scientific literature on the topic.

6. Where adequate information exists so that a desired programme of environmental management can be predicted to be successful, the scientific components should be reviewed by appropriate experts. This requires more honesty and openness by decision-makers to recognize that they are rarely, if ever, in possession of all the relevant expertize, that a highly desirable project is not necessarily based on the appropriate scientific foundations and that external critical appraisal of proposals and outcomes of projects is the norm in science. Such review would increase the long-term worth of all scales of environmental management.

Above all, planning and management in the face of uncertainty (Lee 1993) and variability is complex, coastal environments require more commitment by managers, scientists and local community groups to the ideal that environmental well-being is more important than shorter-term goals and political struggles.

This is not a new message. It is a well-worn one. For the coastal regions of south-eastern Australia, it is a critical and urgent one. Experience in other parts of the world suggests that there are different models, different mixes of policy and different ways of reaching outcomes. For example, uncertainty in the United States is open, but can become a weapon in the arsenal of legal challenges to decision-making. In contrast, in Europe, scientific uncertainty tends to lead to less open, but potentially more effective discussions among dissenting experts (Klapp 1992). Neither seems to be the way forward in Australia. Uncertainty about scientific issues exists as in all other parts of the world. Added to it, however, is greater apparent uncertainty because many current environmental programmes determinedly ignore available scientific knowledge – making it seem that less is known. In consequence, decision-makers act in greater potential ignorance than is necessary, individual projects do not receive sensible advice to help them increase their success, catchment managers have completely inappropriate or unskilled technical advisers and the long-term ideals of environmental improvement are not achieved with maximal effectiveness.

It may not be too late to improve the situation, but hope and optimism are not well-documented as a basis for firm, scientific predictions. What can be predicted confidently is that, without increased incorporation of appropriate information, expertize and education, our coastal environments will continue to wither, despite increasingly expensive management.

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Chapter 7

The Implications of Oceanographic Chaos for Coastal Management

E. Wolanski · B. King · S. Spagnol

Graphics. The graphics on the CD can be accessed using a web browser such as Netscape Navigator or Microsoft's Internet Explorer. To start open the file 'index.htm' on the CD-ROM. All animations on the CD are stored in AVI format using Cinepak compression. If your browser has trouble viewing these animations visit the homepage (http://home.netscape.com or http://www.microsoft.com) to download the appropriate plugin. Also read the help.htm file on the CD.

7.1 Introduction

Water currents are usually the first thing measured in environmental impact assessment studies in the ocean. To predict the impact of a pollutant discharge the speed and direction of the currents are used in a model to calculate the trajectory of contaminants. To characterize a non-conservative material carried by the water currents, the usual practice is to incorporate in the model sink and source terms. In the model turbulence is usually parameterized, often using an eddy diffusion approach, or explicitly calculated using a turbulence closure assumption. This modelling technique is successful in reproducing simple ecological and biogeochemical processes in the open ocean (e.g. Nihoul 1993 and references therein).

This technique is also routinely applied in the coastal engineering community to determine environmental impacts from human activities such as structures, dredging and dumping of contaminants (e.g. oil, sewage and dredge spoil). Usually the predicted contaminant plumes are smooth. These plumes are then superimposed on an atlas of marine resources to determine likely environmental impacts.

In practice, post-construction verification of models is the exception rather than the rule. Thus, if the structure works within expectations in an engineering way, i.e. the wave field is within predicted range, then the environmental impact from engineering structures is also assumed to have been predicted correctly.

Wave models, the principal tool of coastal engineers, have nothing to do with models related to environmental issues. Ecosystem or pollution models are seldom verified. Sewage plumes are an example. Discharges from sewage outfalls are predicted to be continuous, smoothly varying pollutant plumes. In practice however, these plumes are extremely patchy (Wu et al. 1994; Pritchard et al. 1996). This patchiness applies to other contaminants also. For instance, oil slicks commonly break up into patches that the models do not reproduce (Dean et al. 1990). This patchiness has important implications for a coastal manager because an oil spill at sea along a rugged coast can oil one beach while the adjoining one remains untouched (Hayes et al. 1990).

At the ecosystem level patches are known to exist at all scales in all environments, and patches have been recognized as important natural processes (Engbert and Drepper 1994; Hamner 1988; Hassel et al. 1991; Pickett and White 1985; Steele 1978). Surprisingly, this knowledge has largely been ignored in environmental engineering models for coastal management.

Our study sites are topographically complex coastal environments. They include estuaries (Fig. 1), islands and coral reefs (Fig. 2) and mangroves (Fig. 3). We demonstrate that patches are the common rule and not the exception. We argue that engineers, scientists and marine resources managers need to take this process into account. Specifically they must learn to deal with variability and unpredictability and not with static or quasi-steady, rigid models. When dealing with particularly sensitive areas, more caution is needed to deal with the unpredictability of the system.

7.2 Water Currents

Eddies behind islands and headlands are commonly observed in coastal waters (Fig. 4; see also Wolanski 1994). They generate patchiness and variability along the coast, but this process has remained largely unstudied. Oceanographers have largely ignored them, as recently as 1983 Robinson's book on eddies in marine science does not even mention them.

Water currents are usually one of the primary parameters measured in the field, this is best done from oceanographic moorings with current meters suspended under a subsurface buoy on a taut wire or, in shallow waters, within a frame (Anim. 1). In topographically complex systems, such as around a headland or an island, eddies are a common feature (Fig. 4). Many current meters are needed to characterize the flow field. For instance 26 current meters were necessary (Wolanski 1994) to measure the eddy behind Rattray Island, a 1 500 m wide island in 20–30 m depth of water (Anim. 2). All 26 current meters were needed because currents in the eddy region varied rapidly, both temporally and spatially (Anim. 3). If only a few current meters had been used, as is common practice in most environmental impact assessment studies, an unrealistically simple (and incorrect) picture of the flow field would have emerged. The flow field at Rattray Island develops an eddy, a patch of water which varies in size throughout the tidal cycle; with currents inside the eddy lagging that of the undisturbed tidal current outside the eddy (Anim. 3). Other measuring techniques are possible, e.g. the use of an acoustic Doppler current profiler mounted on a ship criss-crossing the area (Geyer and Signell 1990; Signell and Geyer 1991). This improves spatial resolution but diminishes temporal resolution.

It was only after the Rattray Island data set became available that it was possible to test if 3-D models were able to reproduce complex coastal flows and to compare the performance of the models against the observations from the 26 current meters (Galloway et al. 1996). The only other comparison between 3-D models in the literature was the MOMP numerical experiment for which no field data were available (Roed et al. 1995). Four models compared by Galloway et al. (1996) were NOAA's Mecca Model, the Princeton Ocean Model (POM), the Hamburg Oceanography Model (HAMSOM), and the AIMS-GHER model. Initially none of the models performed satisfactorily because they all under-estimated by 30 to 90% the size and strength of the observed eddy (Galloway et al. 1996). For reliable predictions it was necessary to introduce other processes previously not incorporated in these models, such as the high turbulence in the free shear layer shed at the flow separation points (Wolanski et al. 1996). The final simulation, shown in Anim. 4, reproduces within 80% the size and intensity of the observed eddy.

The Rattray Island study demonstrates that the flow behind a single island leads to patchiness at horizontal scales varying in time. There is no unique length scale of the island wake because it is continuously changing. Over a few tidal cycles the processes are even more complex. Indeed, models predict that small eddies merge into large eddies and that these large eddies can recirculate back and forth around the island and merge in a process apparently akin to that of strange attractors (see Anim 5 that results from the model of Furukawa and Wolanski 1998). This leads to a chaotic distribution of vorticity.

Topographically generated patchiness in the flow field does not require that the obstacle emerges from the water, it also forms in a system of shoals and channels such as the Dutch Wadden Sea (Riddenrikhof 1995). In its simple form this circulation consists of periodic tidal currents superimposed on a lattice of residual eddies the size of the chaotic region. This simple representation, valid for the Dutch Wadden Sea, breaks down when widespread chaotic advection occurs, which happens when the bathymetry varies significantly within a tidal excursion length (typically a few km). This occurs commonly throughout the Great Barrier Reef as well as in many rugged coastlines with headlands and islands. For such rugged systems the flows are fully chaotic. This is shown in Anim. 6, generated from the model of King and Wolanski (1996b) for the tide- and wind-driven flows through the Great Barrier Reef. The flow field resembles an ever-changing mosaic of eddies, jets and stagnation zones. Model verification is only possible in open waters far from obstacles, where the flows vary smoothly. In the presence of topographic complexity it is not realistic to ensemble-average to obtain mean currents or mean flushing rates for large areas; every area has its own dynamics.

Chaotic circulation leads to patchiness in the distribution of passive tracers. Shown in Anim. 7 is the result of two plume releases, one in the open water and the other one in the reef matrix. It can be seen that the open water plume remains coherent and that its width increases in time as mixing progresses in all directions. This behaviour is to be expected from mixing models based on a fairly uniform flow field (Fischer et al. 1979). However the reef matrix plume rapidly becomes chaotic.

To cope with this patchiness, the classical engineering technique would be to use ensemble-averaging. This would be counterproductive for the users of such models, e.g. biologists, because chaotic water circulation drives the chaotic distribution of the biology. Indeed, Hamner and Hauri (1977) noted that water in an headland eddy over a coral reef contained a different population of zooplankton than did the free stream water flowing over a sandy bottom. In a process sketched in Anim. 5, the eddy was ejected back into the free stream when the tides reversed and became a patch of reef water rich in zooplankton surrounded by plankton-poor shelf waters. The patch retained its reef zooplankton for as long as it was tracked it (a few hours). When many reefs are present, such as on the Great Barrier Reef and near a rugged coastline, the coastal sea becomes a mosaic of patches. This chaos is apparent in biological properties (e.g., chlorophyll) measured from ships and satellite (Wolanski 1994).

Ensemble-averaging this chaos to produce simple statistics such as a mean value and a standard deviation for various parameters (e.g. nutrients and chlorophyll) is not useful because each patch has its own ecosystem dynamics (Hassel et al. 1991; McCook 1994).

Ensemble-averaging is also questionable even in much simpler systems, such as a branched estuary. A case in point is the Fly river estuary in Papua New Guinea (Fig. 1). The estuary is about 60 km long, is shallow (typically only a few metres deep at low tide) and has three major channels. The dominant forcing is the tide, the freshwater inflow and the wind (Wolanski et al. 1997b). Current data of 2–8 weeks duration at ten sites were available to verify the model. The model explained at least 90% of the variance at the mooring sites (King and Wolanski 1996a), so it can be used to explore the dynamics of the system. The flow field is very complex and its understanding requires computer visualisation (Anim. 8). This animation illustrates clearly the tides propagating from the sea to be dissipated over the shallow bottom. It shows the tides propagating at different speeds and with a different flood-ebb tide asymmetry in each channel. In each channel there are strong lateral and along-channel variations, with zones of extremely strong flushing next to zones of much weaker currents leading to stagnation zones. The currents are strongly steered by the topography of channels meandering through shoals. At the apex of the delta where the three channels meet, each channel injects momentum and vorticity at different times in the tidal cycle and at different locations. The resulting currents in this area are chaotic with horizontal quasi-turbulent motions at the scale of the channel width.

7.3 Suspended Sediment and Plankton

Visual observations in the muddy coastal zone (Fig. 5) show the presence of patches of turbid waters in blue waters. These patches can be a few metres to a few hundreds of metres in diameter, with no clear pattern of distribution. To quantify the dynamics of the fine sediments, there are a number of field techniques that rely on deploying automated sediment samplers in an oceanographic mooring or on ship-born measurements.

Because of the high costs of automated samplers, an oceanographer can seldom deploy more than a few samplers at sea, usually obtaining temporal but not spatial data. Automated samplers are usually very bulky and necessitate large ships for most deployment and recovery (Anim. 9). Even 40 km offshore from the mouth of Fly river in Papua New Guinea, in shelf water deep enough that resuspension of bottom sediment does not occur, suspended sediment distribution is extremely patchy. This can be seen from the factor of 10 difference between daily catches of sediment (Fig. 6).

Suspended sediment concentration can also be measured using optical sensors such as nephelometers and transmissometers, though marine fouling can limit their use. Used in turbid topographically complex estuaries, these instruments also record enormous temporal and spatial variability (Wolanski et al. 1998). As a result of this variability even 24 nephelometers as they used may have been insufficient to measure the net flux of sediment at the mouth of the Fly river.

In very muddy coastal environments a convenient ship-borne sampler is a high-frequency echo-sounder. The data show enormous patchiness, with fluid mud entrained in suspension in patches at scales of centimetres to metres in an apparent chaotic manner (Fig. 7).

Another shipboard technique is direct observation of suspended sediment and the plankton in suspension, using an underwater video camera equipped with a macrolens (Fig. 8). This technique is the preferred option because it minimizes disturbances to the suspended matter (Eisma et al. 1990). However it has limitations because of four reasons. First, it necessitates a lot of power to illuminate the field of view, and this requires an electric cable to the main research vessel or a small boat (Fig. 9). Secondly, in rough weather waves introduce rapid and violent instrument motions that blur the images. Third, it is impractical in very turbid systems (usually the cut-off point is about 100–200 mg l^{-1}) when the concentration is so high that excessive floc overlap occurs on the images. Finally, strong currents cause floc breakage around the camera housing's optical port. In these environments an alternative sampling technique for suspended sediment is to sample the water using a wide Niskin bottle with no rubber cord inside the tube. This minimizes floc break-up. The suspended matter settles onto a microscope slide with a well (Anim. 10). Using an externally operated piston, the well slide is then capped with another slide without disturbing the sample, which can then be examined with an inverted microscope.

All these techniques reveal an enormous amount of patchiness at all scales. Duplicate casts can yield widely different estimates of sediment concentration.

In clear waters, without mud, nonmotile and asexual zooplankton commonly occur in patches up to 20 cm wide and most oceanic plankton in patches up to 5 m wide (Davis et al. 1992). Patchiness in this case is generated by the plankton aggregating by swimming. In muddy waters the instruments reveal that the marine snow is sticky and traps small flocs of suspended sediment to generate microaggregates typically 500–2 000 μm in diameter (see examples in Figs. 10–12). These microaggregates have settling speeds 10–100 times faster than those of the original small mud flocs. This settlement process constitutes a biological filter at the mouth of turbid tropical estuaries that trap the sediment in patches in the coastal zone (Ayukai and Wolanski 1997).

There is a dynamic feedback in these patches between the physics and the biology. Previously the common belief was that the main effect of mud was to decrease light and hence primary production. It was also thought that that bacterial activity was extensive on mud (Alongi 1998). Mud obviously affects both light and bacterial activity, but our observations reveal that plankton are also strongly affected. Frequently we found plankton grazing on the surface of the flocs (Anim. 11). At other times we found plankton actually being killed by the flocs. For instance, plankton can become glued by a string to a floc and cannot escape even after swimming madly in circles around the floc, like a dog on a leash (Anim. 12). Plankton can also become trapped in a floc by its hooks and be unable to escape (Anim. 13). Plankton can also become buried in a stringy mud floc and trapped like a fly in a spider web (Anim. 14). Because of this apparent direct interaction between plankton and mud, one suspects that patchiness in mud distribution would introduce patchiness in the plankton distribution, which in turn would introduce patchiness into the entire food chain. This requires further investigation.

7.4 Turbidity and Seagrass

Mangrove-fringed Hinchinbrook Channel in tropical Australia (Fig. 13) is shallow, with a series of sand banks, a muddy coast and a number of natural channels several metres deep (Anim. 15). Strong tidal currents prevail. At spring tides the waters inundate the fringing mangroves near high tide. The currents vary smoothly spatially and temporally (Anim. 16), calculated from the model of Wolanski et al. (1990). The complex topography and the location of distinct sand patches and mud patches result in suspended sediment distribution that is also highly patchy temporally and spatially (Anim. 17). Further patchiness is introduced by the wind because some areas are sheltered by sand banks while other areas are exposed to wind and waves (Anim. 18). In turn this patchiness is reflected in a patchy distribution of sedimentation zones in the fringing mangroves. Presumably this patchy suspended sediment concentration is reflected in patchiness of the plankton abundant in this channel. Seagrass forms rich meadows along the shallow mangrove-fringed coast and somehow they survive repeated events of high turbidity and sedimentation (Wolanski et al. 1997c). If high concentrations of suspended sediment concentration (1000–5000 ppm) were prolonged, the meadows would not survive (Onuf 1994; Schoellhamer 1996). The response of seagrass to chaotic events of high sedimentation and turbidity is unknown.

7.5 Coral, Fish and Prawn Larvae

On the Great Barrier Reef most hard corals spawn once a year in a synchronized event called mass spawning. Mass spawning can release millions of eggs that float around a single reef, such as Bowden Reef on the Great Barrier Reef (Fig. 14). Yet as this cloud of eggs is advected and mixed by the currents, the egg plume is extremely patchy (Anim. 19), with no apparent correlation spatially (from site to site) or temporally (at a given site from daily samples). The distribution is chaotic, with the standard deviation from the triplicate samples having the same magnitude as the mean at a given site. In such cases the mean values are probably meaningless. Patchiness develops quickly after the release of eggs into the water (Fig. 15). These patches usually take the form of slicks, a few metres in width and several hundreds of metres to a few kilometres in length (Wolanski and Hamner 1988). Clearly the distribution the concentration of eggs is chaotic.

The distribution of coral fish larvae is also patchy. At Bowden Reef, for example, fish larvae occur in patches for a few days. Patches of weakly motile larvae are located generally downstream of the reef (Anim. 20) and patches of highly mobile fish upstream of the reef (Anim. 21) (Wolanski et al. 1997a). There is thus no smooth distribution.

The distribution of prawn larvae in shallow, mangrove-fringed waters is also patchy and highly variable from species to species. This is shown in Anim. 22 for the case of Klang Strait on the west coast of Malaysia. No spatial or temporal correlation exists.

Scientists cope with such spatial and temporal patchiness by calculating the mean over triplicate samples and the ensemble-average of the data (e.g. Oliver et al. 1992, for coral eggs and Chong et al. 1996, for prawn larvae). With this technique the only parameter retained to characterize patchiness is the standard deviation. However, in these chaotic flows the standard deviation has a magnitude comparable to the mean (e.g. Anim. 19). This makes the mean and standard deviations meaningless. These parameters indicate only that there are either plenty of larvae or there are none; no useful statistics remain.

It is only recently that modellers have tried to understand this patchiness at a scale of tens to hundreds of metres (Wolanski and Sarsenski 1997). The verification of these models is extremely difficult because the biological data are collected at different times at different sites in a tidal cycle; hence a synoptic picture of the distribution in the field is unavailable. For the case of coral eggs spawned at Bowden Reef, the model predicts the formation of a plume entraining eggs away from the reef (Oliver et al. 1992). As can be seen in Anim. 23, the predicted plume is extremely patchy, if not chaotic. Model verification was carried out by comparing, at a given instant of time, observed and predicted concentrations. In some cases, such as in Fig. 16, where biological data were available simultaneously at different points (the exception rather than the rule because it requires several small boats operating simultaneously), the comparison is pleasing. However, when all the data over several days and at about twenty sites are used, no significant correlation is found between observed mean concentrations (calculated from triplicate samples) and the instantaneous predicted concentrations (Oliver et al. 1992). It is not clear if this model failure is due to the model underestimating the patchiness due to sub-grid scale aggregating processes (Wolanski and Hamner 1988) or to the patchiness being so large that triplicate samples are not enough to reliably estimate the mean values.

For prawn larvae, modellers did not attempt to reproduce patchiness. They focused instead on the process of recruitment into the mangroves. The adult prawns spawn at sea and the larvae find a refuge in mangroves where they mature. The modellers used the observed prawn larvae concentrations at sea to seed advection-diffusion models and predicted the fate of the larvae over the subsequent two weeks (Anim. 24). The distribution is chaotic. The only available information to verify the models was the relative distribution of prawns in the mangroves, and comparison with predictions was favourable.

For coral fish larvae, the field data suggest that the bulk of the recruits immigrate from reefs further upstream (Wolanski et al. 1997a). Advection-diffusion models of the fate of a cloud of larvae carried passively by the prevailing currents and coming into contact with a reef are unable to reproduce the patchiness (Anim. 25). Indeed, the model predicts that most of the larvae are simply deflected around the reef and do not aggregate. This prediction is contrary to the observations shown in Anims. 20 and 21. However, if larval swimming behaviour is included in the model, the model predicts the formation of patches in agreement with the observations (Anim. 26). Because the larval fish patches are not static but move around the reef, the distribution is chaotic.

The longevity and size of these patches depend on larval swimming speed. The predicted location of recruitment zones agrees with observations if the larvae swim at about 0.05 m s^{-1} (aggregation is downstream) to 0.15 m s^{-1} (aggregation is upstream). These swimming speeds are realistic, based on visual observations (Leis et al. 1996). The predictions are also sensitive to the distance to the reef that fish larvae are "aware" of the reef and swim toward it. Direct observations suggest this distance is at least 1 km (Leis et al. 1996). In the model a distance of 2–3 km gave the best match of the predictions to the observations.

Chaos is also observed in the horizontal distribution of sprat larvae even in a much simpler topography, e.g. the German Bight (Bartsch and Knust 1994). Their attempt to model this was unsuccessful, maybe because the larvae were assumed not to swim horizontally.

7.6 Water Quality

Typically water quality may involve nutrients and faecal coliforms from sewage discharges and heavy metals from mining and industries. In tropical waters nutrients are rapidly consumed and predictions of the directly impacted zone can be limited to the first few days of residence after discharge. Over longer periods the impact is on benthic communities. Distinguishing natural from pollution-related environmental changes in the benthos is very difficult (Boesch et al. 1990), yet this is a key to coastal management because of the confounding effects of natural and pollution variability (Ferraro et al. 1991).

Nevertheless, the first impact to be studied is the spatial extent of the water-borne pollutant plume. Simple analytical plume models (e.g. Fischer et al. 1979) are elegant but unrealistic along a rugged coastline. A typical example is Malakal harbour, Palau (Fig. 17). It has a deep water harbour surrounded by shallow waters and a coral reef to the east. The currents were studied by Hamner et al. (1997). They are primarily tidal and are complex because channelled by the topography (Anim. 27). As a result the impacted zone from a sewage discharge varies enormously with small changes (100 m only) in the discharge point. For instance (Anim. 28), if the discharge is located just offshore of a small headland, as is actually the situation in the harbour, the plume spreads over much of the outer harbour and the southern shipping channel while the inner harbour remains relatively uncontaminated. The sewage plume is patchy and intermittent over the coral reef and since it is 2 days old by the time it reaches the reef its impact on the coral reef is thus likely to be small (Hamner et al. 1997). If the discharge occurred just inside the headland (Anim. 29), the inner harbour and the northern shipping channel would be contaminated. In both cases the plume breaks up in patches in the outer harbour. Occasional water quality sampling at a few scattered points in the harbour without synchronising the sampling with the expected location of the plume as a function of the tide, as is the usual practice, is clearly meaningless.

In turbid estuaries mud is a major sink for pollutants such as heavy metals. Predictions of the fate of these pollutants necessitate understanding not only the dynamics of water and fine sediment but also the chemistry of the heavy metals in the estuary (Salomons and Forstner 1984). In particular, different forms of particulate metals may exist and the metals may be exchanged between the particulate and the diffused states and between different forms of particulate states (Fig. 18). These reaction rates are *a priori* unknown but may be derived from laboratory experiments. The results are generally very difficult to interpret because several parameters are important, including salinity, suspended sediment concentration, pH, POC and DOC. Nevertheless, for practical applications it may be necessary to simplify these relations to incorporate only the dominant parameters. For instance, a decay model could be used to parameterize the transformation of releasable metal into exchangeable metal, and a K_d model could be used for the reaction between particulate and dissolved metals. The estuarine mobile mud can be assumed to be ultimately saturated with metal at steady state. With all these simplifying assumptions the resulting distribution of predicted dissolved (Anim. 30) and particulate (Anim. 31) metals can be predicted. Further modelling shows that the zones of maximum concentrations vary continuously with varying tidal amplitudes and with the wind. The size of the impacted zones, the maximum concentration, and the duration of these high concentration events are predicted to be highly variable temporally and spatially. A mean and a standard deviation at target points are insufficient to characterize the impact because essentially the situation is chaotic.

7.7 River Plumes

River plumes are often very patchy, especially when the coast is rugged and the freshwater discharge unsteady. An example is the Burdekin river, Queensland, Australia. The plume is extremely patchy (Fig. 19). Oceanographers are able to successfully model this plume (King et al. 1998). The results, shown in Anim. 32, show the plume forming as the river discharge increases. It turns left at the mouth, a result of the Coriolis force, and flows northward along a rugged coast around numerous headlands and islands. The model suggests that the patches are due to the unsteadiness of the wind and to the freshwater discharge, and to the complex currents at the headlands. The patchiness in the salinity field was also enhanced by discharges from neighbouring rivers and by tidal interactions with headlands along the coast. The model underestimates by a factor of about 2 the observed patchiness at the reef (Wolanski 1994), patchiness in this case being the amplitude of the salinity variability at times scales of 2–5 days.

The main influences on the size of the river plume, and thus on which reefs are impacted, are the discharge volume of the river and the local wind forcing. These vary annually, so one would expect different reefs to be impacted differently each year. Given that the fate of the plume is highly variable and patchy, a risk assessment analysis from a hindcast of the floods for the last couple of decades is needed to quantify the impact of river floods on the Great Barrier Reef. This is achieved by simulating many years of floods and by quantifying the recurrence and duration of freshwater impact on given reefs.

This modelling capability provides a tool to assess physical impacts to reefs from riverine material (e.g. fine sediment and nutrients) produced as a result of various land management policies in the catchment area. Although the physical impact is chaotic, it can be quantified statistically although the model underestimates the patchiness. The resulting ecological impact probably cannot be predicted yet. Research on the biological response of reefs to such transient forcing clearly is warranted because riverine material affects the biology of coastal waters and its quality and quantity are both greatly affected by human land use.

7.8 Discussions

Topographically complex environments include rugged coastlines comprising headlands and islands, coral reefs and mangrove-fringed coastal waters. While our examples refer to tropical environments, the conclusions probably apply also to temperate systems with a rugged coast with headlands, shoals and salt marshes. Such environments are common in the world, yet they have been little studied compared to topographically simple systems such as the North Sea, where there are continental shelves with comparatively straight coastlines. Physical, biological and chemical data from those areas with complex topography reveal extremely complex, if not chaotic, distributions. Standard measurements in biology and chemistry, e.g. triplicate samples at a number of sites, are meaningless, as we have shown for the case of coral eggs and fine sediment concentration.

How then to use the scientific information from field data and computer models to help coastal management? This question remains unresolved. However engineering experience in dealing with oil spill predictions provides a clue to a likely new approach. In such man-made crises modellers use a wide range of current predictions for different scenarios of winds and tides to calculate the probability of an impact and the severity of an impact should one occur. An example of risk assessment modelling using chaotic inputs to the model is shown in Fig. 20. This shows the predicted region "at risk" from an oil spill in Surat Thani harbour in the Gulf of Thailand, when strong and dominant winds from the southwest are blowing. Under these conditions, it is suggested that about 150 km of coastline are at some risk of impact. The most probable fate of an oil spill under these conditions is shown in black which will see the oil slick at sea for many days allowing time for weathering and dilution of the oil. These data are then superimposed on a map of coastal resources, such as ports, seagrass, mangroves, beaches and rocky shores, to predict probabilities of environmental impacts at various locations along the coast. Managers can use this information to develop a statistically-driven strategy to cope with an oil spill. The situation is relatively simple because the original environment essentially has zero background oil.

A similar strategy could be applied to faecal coliforms from sewage discharges because they are naturally absent from the environment.

It is much more difficult to predict environmental impacts in a complex topography from other human activities such as dredging, structure engineering, spoil dumping and nutrient discharges. One reason for this is that, contrary to purely anthropogenic wastes such as oil, a topographically complex environment naturally exhibits high variability in parameters that man can influence, such as currents, suspended sediment, nutrients and metals. At our study sites chaos or random environmental fluctuations dominate the system and this variability is under-estimated by numerical models. The status of modelling environmental impacts in a complex topography is insufficient to reliably predict the response of a naturally chaotic environment to additional disturbances from man.

The risk assessment approach is promising. So far it has mainly been applied to quantify physical effects from waste discharges from man. Present marine eutrophication models (e.g. Gray 1996) and deterministic management models that are derived from them (e.g. Done et al. 1997), neglect the oceanographic and biological chaos and may generate misleading answers. Indeed, ecological processes are known (e.g. McCook 1994) to be influenced by a very large number of factors, both physical (e.g. oceanography and climate) and biological (e.g. recruitment and interaction between species or species assemblages). Many of these processes vary chaotically, so that ecological outcomes may be largely unique to a particular set of circumstances (e.g. Underwood and Denley 1984; Foster 1990; McCook and Chapman 1997). This in turn means that prediction of a biological impact is intrinsically uncertain, aside from any difficulties with detection rationales.

This does not mean that modelling is not useful. It is helpful because it can predict the concentration of substances (e.g. mud, metals, nutrients and larvae) under various scenarios, though it under-predicts the patchiness. These predictions, particularly if they extend to biological processes, may not be helpful to management if they do not successfully incorporate also natural patterns of variability. Because the biological response is often the key criterion in environment impact studies, modelling is usually seen as having failed management. Solving this problem is not trivial because attempts to incorporate chaos and patchiness in ecosystem models are still very much at the research stage (e.g. Hassel et al. 1991; Engbert and Drepper 1994; McCook 1994).

More often than not, the natural variability appears chaotic to environmental engineers, they usually characterize it by computing means and standard deviations. Simplifying the system by these simple statistics destroys any chance to characterize topographically complex coastlines and lead to unreliable predictions for important applications. Practical such cases include responses of seagrass and corals to short-term events of high turbidity, both natural and anthropogenic. Other cases include algae in coastal waters responding to pulses of nutrients, both natural and anthropogenic. Other practical applications include changes in recruitment patterns for fish and crustaceans in the presence of engineering structures and dredged channels. There has been no attempt yet to quantify how a marine ecosystem already subjected to chaotic forcings will respond to an increase or a variation in this forcing from anthropogenic effects, present state-of-the-art practice (e.g. Gray 1996) largely ignores the natural chaos. For environmental impact modelling to reach the desks of coastal resources managers as practical tools in the decision-making process, these pitfalls need to be addressed as a matter of priority.

7.9 Conclusions

Chaos is largely ignored in environmental impact studies in the coastal environment, this may lead to meaningless predictions especially if the predictions extend to biological processes. Also, chaos needs to be better taken into account when collecting field data. In particular in most environmental impact assessment studies for coastal developments, only the mean and standard deviation of a number of parameters are measured occasionally at a few points. Our studies demonstrate that in a topographically complex coastal environment much more data are required in view of the chaos in the flow, chemical and biological distributions.

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Part II

Regional Practice and Experiences

Chapter 8

Quality Status, Appropriate Monitoring and Legislation of the North Sea in Relation to its Assimilative Capacity

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8.1 Introduction

The North Sea is one of the most heavily polluted marginal seas on earth (Degens 1988), and used to be one of the most biologically productive. The problems have been slowly recognized and the eight North Sea states are committed to "... the principle of safeguarding the marine ecosystem of the North Sea" (Ministerial Declaration 1987), and regular Ministerial Declarations set out agreed measures to achieve these ends. The Quality Status Reports provide the scientific basis for the Ministerial Declarations, and with associated research programmes (see Quality Status Reports for the North Sea 1987, 1990, 1993), demonstrate that the North Sea is also one of the most intensely studied and monitored in the world. The example must therefore provide an instructive case study for those enclosed seas where the need to achieve a sustainable environment may be in conflict with the economic growth of bordering states.

Our aim is to consider the North Sea from the perspective of its assimilative capacity for wastes and effluents. Assimilative capacity is a cross disciplinary concept that describes a resource of considerable economic value which, if it is exceeded, represents a limitation on the sustainable use of the marine environment. An integral part of the argument for accepting assimilative capacity as a resource is that contamination is not a threat to sustaining North Sea ecosystems unless it has a biological impact. Thus we advocate the use of biological techniques to monitor environmental quality, and will demonstrate that a predominately chemical approach is no longer appropriate.

Currently, monitoring effort and resources are directed to establish compliance with environmental legislation and regulations, which are expressed mainly in chemical terms. For example, the effective application of Environmental Quality Standards (EQS) depends on chemical monitoring of individual contaminants. However, the assumptions that are made in the setting of EQSs raises questions as to their relevance. We therefore consider North Sea pollution and its control in a cross-disciplinary manner, centred on the observation that it is the assimilative capacity of the North Sea that we utilize as an environmental service. It is the extent to which that capacity is exceeded that represents the threat to the sustainability of ecosystems. Until recently there has been little reason to consider the assimilative capacity of the North Sea as an entity, since there has not been much evidence that its overall capacity to dilute, to disperse and detoxify chemical contamination might be exceeded by contaminant inputs, and the accumulation of those that persist. Here we consider evidence, using a biological approach to monitoring, that has developed over the last decade and more, which provides more relevant data, quantifying pollution in terms of its biological impact on water quality.

The approach uses measures of the biological impact of contaminant loading, rather than attempting to assess the health of the system by monitoring each chemical or class of chemical contaminant. We advocate monitoring in terms that relate directly to the criteria used to gauge environmental health. We will consider the capacity of the North Sea as a whole to assimilate wastes and effluents, and in the light of recent data (post 1990) which demonstrate that it is being exceeded. Since the work of the regulatory authorities is to monitor the conformation of contaminant concentrations to pollution legislation, we ask whether the present statutory controls and approach to monitoring are appropriate for their purpose.

8.2 The North Sea

8.2.1 Inputs and Outputs of Contaminants

The North Sea is a centre of intense human activity for eight west European countries, for it is their only access to the sea for shipping, oil and mineral wealth, and fishing. The North Sea provides an environmental service by accepting the industrial, agricultural and societal wastes and effluents from the 164 million people that live on its shores and in the catchment of the rivers that flow into it. Such inputs are likely to challenge the capacity of the environment to sustain the indigenous biota by their volume, if not their toxicity.

The catchment area of the rivers flowing into the North Sea is 850 000 km^2, compared with its surface area of 575 000 km^2. It has a volume of 93 830 km^3 and receives a variable run-off from these rivers of 296–354 $km^3 a^{-1}$. The catchments of the major rivers are densely populated and heavily industrialized, providing the main anthropogenic inputs (contaminants and nutrients) to the North Sea. The river basins of the Thames, Humber, Elbe, Weser, Rhine, Scheldt and Seine are the most densely populated (statistics are drawn from ICES (1983) and Quality Status Report for the North Sea 1993). The North Sea (Fig. 8.1a) is bounded on three sides by land with its principle exchange with the Atlantic to the North and a minor route for exchange via the Dover Straits to the south. It is a shallow sea (30–200 m), less so in the south, such that the volume of water that can dilute estuarine inputs is greater for those rivers that flow into the northern North Sea (rivers Forth and Tyne) than in the south (rivers Thames and Rhine).

While the North Sea can be considered as a semi-enclosed system flushed by relatively clean waters from the North Atlantic, its northern open boundary is also a route by which contaminants may be imported and exported. Input via this route is well illustrated by radioisotopes originating from Sellafield and Dounrey (Kautsky 1988). The Norwegian coastal current provides the major outflow of all water from the North Sea and the Baltic, originating in the Skagerrak and hugging the coast of Norway as it moves north.

The stronger tidal flows (Fig. 8.1a) are coastal, with weak and variable currents in the central North Sea. The dominant residual flows are from north to south along the UK East Coast with a reciprocal flow northward along the European coast towards the Skagerrak, supplemented by an input via the Dover Straits. Current speeds fall as the northward flowing currents slow at the entrance to the Skagerrak and Kattegat, before returning to the North Atlantic.

Fig. 8.1 a. Map of the North Sea indicating residual currents. The width of arrows indicates the magnitude of volume transport (From Quality Status Report for the North Sea (1993), after Turrell et al. 1992)

On average the water in the North Sea is exchanged with the North Atlantic every 1–2 years, but the renewal time varies between 0.5 and 3 years for different areas. For example, a renewal time of less than 6 months is expected for Norwegian coastal wa-

Fig. 8.1 b. Map indicating biological monitoring sites in the North Sea. Stations numbered *1–38* refer to sites used for sampling mussels for scope for growth measurements (see Fig. 8.7); those lettered *A* to *I* refer to stations used during the ICES/IOC Bremerhaven Workshop (see Fig. 8.5 and 8.6, where they are laballed 1 to 9)

ter north of Stavanger, while a period of more than 3 years is required for waters in the German Bight and the western part of the central North Sea (Maier-Reimer 1977). Hydrodynamic models demonstrate that the age of water in the North Sea increases anti-clockwise round the coastlines of Scotland, England, France, Holland, Germany and Denmark (van Pagee and Postma 1986).

The southern North Sea is more vulnerable to pollution, not only because of the longer residence times, but because the water is shallower, providing a lesser volume in which contaminants can be diluted. In addition greater loads of contaminating inputs occur in the more urbanized and industrialized south particularly from the inputs of rivers Rhine and Thames. These are ameliorated to some extent by the small inputs of Atlantic water via the Dover Straits, which provide a diluting input through the Channel to the north along the coasts of Belgium and the Netherlands, plus additional contaminants originating from along the Channel coast.

The major inputs of contaminating effluents and wastes is principally by way of the major rivers. In addition there are more direct inputs from boating and shipping

(5 000 shipping movements at any one time), from oil exploitation activities and platforms (approx. 150 presently in the North Sea). In recent years there has been an improved awareness of the importance of diffuse atmospheric inputs (Quality Status Report for the North Sea 1993). The accuracy of riverine load estimates is much greater (+20–30%) compared to those for atmospheric inputs (+50–100%). Nevertheless, estimates of the proportions of different classes of contaminants indicate that those entering the North Sea by atmospheric wet or dry deposition represent a significant proportion of the total inputs (Nitrate 34–51% (QSR 1993); cadmium 11–108%, mercury 20–42%, copper 13–36%, lead 31–58%, zinc 17–43%, chromium 2–11%, nickel 43–63% (Kersten et al. 1988); PCBs 96% (Huiskes and Rozema 1988); PAHs 50–1 300% (van Aalst 1988)). There seems to be agreement that elevated lead levels in North Sea sediments are due to atmospheric inputs (Kersten et al. 1988), probably from motor vehicles, and that the relationship with PAHs (Preston et al. 1992) implicates a similar route. However at the time of the Quality Status Report (1993) there were no input data for PAHs. Inputs to the sea surface from the atmosphere tend to be held in the sea surface microlayer, where concentrations of contaminants (e.g. metals) are elevated by one or two orders of magnitude, and may be toxic (Hardy and Cleary 1992) to life exposed to the microlayer.

Contaminants entering the marine environment most often disperse, dilute and become degraded, such that their toxicity is decreased. Some may be accumulated preferentially by organisms in their food or because they filter large volumes of water (e.g. bivalve molluscs). Bio-accumulation of contaminants may cause toxic effects due to bio-magnification of concentrations in higher trophic levels. However, it is also useful in monitoring, since concentrations are not only higher, but tissue levels can be expected to relate to toxicity and assist in establishing causality (Stebbing et al. 1980; Chapman 1997). Many other contaminants become partitioned to particles, when it is the movement of suspended particulate matter that becomes responsible for contaminant flux. South of a line from Hull to the Skagerrak the North Sea is significantly more turbid (1–10 mg l^{-1}) than to the north (0.1–1 mg l^{-1}) (Eisma and Irion 1988). Fine-grained suspended matter in the North Sea is the most important phase for heavy metals and synthetic organic contaminants. It consists of a clay fraction (illite, mectite, kaolinite) with large surface areas for adsorption relative to volume, and complex ion exchange properties. The fine fraction is also rich in Particulate Organic Matter (POM) derived from plankton, such as faecal pellets of copepods and the degradation products of planktonic production in the water column. The high adsorption capacity of clay minerals and the complexation of organic compounds by POM, scavenges the water column of contaminants. Thus the concentrations of heavy metals and organic contaminants on particles (µg g^{-1} dry weight) is much higher than their concentrations in solution (µg l^{-1}), and the fine fraction accumulates contaminants preferentially. The interpretation of contaminant flux, and the capacity of the North Sea to assimilate wastes, depends critically on the behaviour and movement of fine-grained, organic-rich suspended particulate matter (Kempe et al. 1988).

The partitioning of contaminants between particulate matter and solution is defined by a partition coefficient (K_d), i.e. the ratio of concentrations at steady state in particulate and dissolved phases. Since K_ds vary with salinity and the concentrations of contaminants and particles, their use in estuaries and near-shore waters is complex and their utility constrained where they could be most useful. K_ds have been widely used to interpret metal equilibria and behaviour in the marine environment, particularly those of radionuclides (IAEA 1985). For organic chemistry hydrophobic partitioning depends on the organic carbon content of suspended particulate matter; this partitioning can be calculated from the octonol-water partition coefficient (K_{OW}) (Harris et al. 1993). However, recent findings suggest that some polyaromatic hydrocarbons (PAHs) detected on suspended marine and estuarine particles may not be subject to particle-water equilibration and that for those important contaminants (see Sections 8.5.1 and 8.6.4 the partition coefficient is not adequately developed as a means of describing and predicting contaminant behaviour in the environment (Zhou, pers. comm.), let alone their use for management purposes.

This organic-rich fraction is highly mobile, settling to the bottom in calm conditions and low current speeds, providing a superficial covering of a few mm thickness in depositional areas. However this layer is quickly remobilized and carried up into the water column by storms and the turbulence they create, only to settle again through the water column where currents weaken. It is during repeated deposition and resuspension that particulate organic matter scavenges the water column of many contaminants. Deposited organic material provides the basis for production by benthic ecosystems. Many species live by removing fine grained particles a few microns in diameter from suspension (e.g. filter feeding bivalves) or from within the sediment itself (e.g. polychaetes and ophiuroids). Since it is this fine fraction to which many contaminants are adsorbed or bound, even where it represents <1% of the total sediment, these organisms will be exposed to much higher concentrations than those in the sediment as a whole (Kempe et al. 1988). Hence it is likely that organisms will take up and may concentrate the associated contaminants.

The residence time of contaminants adsorbed to sediments in the North Sea is much longer than for those in solution. The average residence time for adsorbed contaminants is likely to be decades (Lohse 1988), if inputs were to cease, it might take centuries for levels to return to those in pre-industrial times (Kempe et al. 1988). Although there are temporary depositional areas on the Dogger Bank, and sedimentation occurs in the Wadden Sea and German Bight, it is predominately in the Norwegian Trench (depth 225–700 m) that suspended sediments are deposited. Some 77–84% of the total net accumulation of fine-grained material in the North Sea occurs here, together with most of the persistent chemical contaminants which are bound to it (Skei 1981). Thus Lohse (1988) speculated that, from sources in the southern North Sea to their sink in the Norwegian Trench, organochlorine contaminants will, over a period of years, be digested and excreted several times before final deposition.

8.2.2
Perceptions of the Health of the North Sea

The North Sea is rich in the variety of its natural habitats and the diversity and productivity of life that inhabit them. Regular "Quality Status of the North Sea" reports review the monitoring effort by those countries that bound the North Sea, providing an overall assessment of its health. The 1987 Quality Status Report concluded "In general deleterious effects, at present, can only be seen in certain regions, in the coastal margins, or near identifiable pollution sources. There is as yet no evidence of pollution away from these areas".

Six years later the 1993 Quality Status Report concluded: "Large areas can be shown to be subject to concentrations of contaminants that are clearly above the North Atlantic background level. Generally, the impact of these enhanced concentrations, which are directly attributable to inputs from around the North Sea, is only clearly identifiable where the concentrations are highest, that is, close to sources e.g., in estuaries or deposition areas such as the Norwegian Trench and parts of the Dogger Bank, or in the Wadden Sea and the sea areas where the pattern of water movements restricts water exchange, e.g., along the Dutch and Danish coasts".

The Report goes on to say that "some detectable effects can be attributed to particular contaminants, as, for example, the effect of high concentrations of PCBs on the reproductive success of seals and the effect of TBT on the shell shape of oysters or the induction of imposex in dogwhelks".

A comparison of the conclusions of successive Quality Status Reports suggest that either the North Sea is becoming more polluted, or our awareness of its polluted state is improving. Ministerial Declarations following North Sea Conferences identify new contaminants for monitoring and new targets for reducing inputs (e.g. endocrine mimics, PAHs, nutrients; Ministerial Declaration 1996).

Given the suggestion of a decline in water quality in the North Sea over the period 1987 to 1993 (QSR 1987, 1993), it must be concluded that the measures introduced by Ministers of the riparian North Sea states have been ineffective in their aim "... to protect and enhance the quality of the North Sea environment" (Ministerial Declaration 1987). Some researchers are unrestrained in their views on the state of the North Sea. Salomons et al. (1988) write of "ecosystem deterioration". Degens (1988) similarly writes that the North Sea is deteriorating at an 'alarming rate'. MacGarvin (1990) extravagantly concludes that any capacity the North Sea might have had to assimilate waste was exceeded decades ago.

We believe any approach to controlling the quality of the North Sea environment by means of chemically-based legislation and monitoring is inappropriate. Among many problems is the changing nature of chemical contamination, which now includes large numbers of synthetic organic contaminants. These compounds may be biologically active at very low levels and available to the biota in various matrices in which they may be preferentially adsorbed and concentrated.

The technical task of analysing large numbers of synthetic compounds in sea water at low concentrations, in several matrices, in all receiving waters, at regular intervals has greatly outstripped the resources available for the task. The problem has been compounded by the number of new chemicals that enter the environment each year and the rate at which legislation can be drawn up to provide a mandate for regulators to monitor them. There is now a tendency to enact legislation more quickly through "Ministerial Orders in Council", but the requirements lag well behind the needs. It is clear that a different approach is now essential, which this chapter attempts to justify.

8.3 Assimilative Capacity

The concept of assimilative capacity has its origins in quantitative environmental toxicology and chemistry. It should also be considered as a valuable and exploitable economic resource. In this section we consider the concept from both disciplinary perspectives.

8.3.1 Definitions

The original definition of assimilative capacity was applied to freshwater pollution and meant the ability of an ecosystem to cope with certain levels of waste discharges, without suffering any significant deleterious biological effects (Cairns 1977). This was broadened later to mean "the amount of material that could be contained within a body of seawater without producing an unacceptable biological impact" (Goldberg 1981). It was then redefined by the GESAMP (Group of Experts on the Scientific Aspects of Marine Environmental Protection) and given a wider meaning as "a property of the environment, defined as its ability to accommodate a particular activity, or rate of activity, without unacceptable impact" (Pravdic 1985). (GESAMP renamed "assimilative capacity" as "environmental capacity", but this change has not been taken up by environmental economists and social scientists, so the original term will be retained here.) The history and semantics of the concept are considered in more detail by Stebbing (1992).

We emphasize two points: First, Cairn's definition referred to an ability to "cope" with discharges, while Goldberg's refers to the amount of material that could be "contained", but Pravdic's wording provides more insight describing assimilative capacity as accommodating a "rate of activity". This is an important distinction, as we will show in Section 8.3.2. Second, throughout the evolution of the concept, the aim has been to permit the use of the assimilative capacity of receiving waters to accept wastes without causing harmful biological effects.

The GESAMP considered the concept in some depth and agreed that it was based on three premises, which give greater meaning to their definition:

1. A certain level of some contaminants may not produce any undesirable effect on the marine environment and its various uses.
2. Each environment has a finite capacity to accommodate some wastes without unacceptable consequences.
3. Such capacity can be quantified, apportioned to a certain activity, and utilized.

GESAMP changed the emphasis of the definition to "levels of contaminants", rather than their "biological effects", and much hangs on the use of the word 'undesirable'. We consider this to have been a retrograde shift of emphasis, since it is as though the presence of chemical contaminants in the marine environment, rather than their deleterious effect, that is of more importance.

The related concept of "pollution" has been defined by GESAMP and their definition generalized by Holdgate (1979) is as follows:

> "The introduction by man into the environment of substances or energy liable to cause hazards to human health, harm to living resources and ecological systems, damage to structures or amenity, or interfere with legitimate uses of the environment." (Authors emphasis)

The concepts of "pollution" and "assimilative capacity" are clearly related terms, although the way in which they have been defined does not link them explicitly (Pravdic 1985). The underlying intent of both "assimilative capacity" and "pollution" is the prevention of deleterious effects on biological systems. Pollution or "harm to living resources and ecological systems" can only be avoided where rates of input are "without unacceptable impact", so it is clear that pollution occurs where assimilative capacity is exceeded. We suggest that the twin concepts of assimilative capacity and pollution need to be more explicitly linked.

Some have considered the concept of assimilative capacity inherently permissive, which it is in relation to the precautionary principle, which is inherently preventative. There has been considerable debate regarding the virtues of the precautionary principle as a way of controlling pollution, rather than the use of assimilative capacity. However, the concepts are not mutually exclusive (Stebbing 1992). It is possible, and environmentally desirable, to be precautionary in the use of assimilative capacity. Both concepts have become incorporated in the UK government's policy in managing pollution. While the assimilative capacity concept is permissive up to a biologically defined threshold, it is important to accept that the concept itself is essentially neutral and the constraints built into the use of assimilative capacity may be as stringent as is necessary to maintain environmental quality in the light of scientific uncertainties.

8.3.2 Quantification

A rigorous approach to quantifying assimilative capacity requires a quantitative knowledge of all significant and relevant processes of geochemical cycling of a pollutant. Some have employed the concept of assimilative capacity in a practical context, using EQS's as a proxy for a biological threshold when assimilative capacity is exceeded (Portmann and Lloyd 1986). Others have used critical pathway analysis approach to identify the most sensitive target species, whose susceptibility is assumed to protect others in the receiving waters (Krom 1986), since knowledge of the processes involved (see Table 8.1) is insufficient for more informed estimates. In an example involving copper pollution of the Krka river estuary (Adriatic Sea) Pravdic and Juracic (1988) identify the key steps in developing a mass balance model to estimate assimilative capacity for copper, recognising that ideally it would need to incorporate the hydrography (flushing times), chemistry (reactivity), sedimentology (deposition/remobilisation) and biological activity.

Here we propose a general model for assimilative capacity

$$\frac{dC_{i,x,n}}{dt} = I_{i,x,n} - D_{i,x,n} \; . \qquad (8.1)$$

Equation 8.1 says that the change in the concentration C of contaminant i at place x and compartment n is the difference between those processes I leading to increases in concentration at that place and/or compartment, and other processes D leading to reductions in concentration. Both I and particularly D may themselves be functions of the contaminant concentration, i.e. $I\{c\}$, $D\{c\}$. x may represent a discrete point, a defined area or volume as appropriate. The significant environmental compartment n may be water, sediment, individual fish, shellfishery, or biological community, etc. I and D represent the sum of those individual processes (units concentration per unit time) contributing to increased or decreased contaminant concentrations. So I includes input and transport processes, bio-accumu-

Table 8.1. Summary of some of the processes that may increase (*I*) or decrease (*D*) assimilative capacity by influencing the concentration, availability or biological impact of contaminants in the sea

Mechanism	Increase in concentration, availability and impact (I)	Decrease concentration, availability and impact (D)
Hydrographic		
Distribution in water	Reconcentration (frontal system)	Dilution (tidal mixing)
Distribution of particles	Benthic deposition, settlement (further concentration by gyres and at turbidity maxima)	Remobilisation (fast currents, waves and storms)
Partitioning on particles	Desorption (salinity, pH dependent)	Adsorption (salinity, pH dependent)
Interfacial effects	Accumulation at interfaces (sea bottom, surface, thermocline, pycnocline)	Dispersion from interfaces; Burial
Boundary effects	Importation and accumulation on shores (e.g. litter, oil)	Exportation
Chemical		
Complexation and chelation	Ligand unbinding	Ligand binding (e.g. metals on humic acids)
Transformation	Potentiation	Degradation (e.g. UV photo-oxidation of organic contaminants)
Biological		
Adaptation	Sensitisation	Homeostatic control, acquired tolerance
Joint toxicity	Synergistism	Antagonistism
Bioavailability	Remobilisation	Sequestration (e.g. in shells)
Benthos	Biodeposition	Bioresuspension
Pelagos	Bioresuspension	Biodeposition
Tissue concentration	Bioaccumulation, biotransformation (e.g. methylation of mercury)	Excretion
Ecosystems	Biomagnification	

lation, bio-magnification, adsorption onto, synergy with. *D* is the opposite: processes contributing to contaminant export, dilution, dispersion, transformation from, de-adsorption, degradation, detoxification, etc. An appropriate mass-balance equation for a contaminant *i* can be constructed where the size of the compartments (n, x) and flux of contaminant are known. Where the rate *I* exceeds the rate *D*, then concentrations will increase. Some of the principle hydrographic, chemical and biological processes capable of contributing towards assimilative capacity are summarized in Table 8.1.

The unutilized assimilative capacity may be approximated by the difference between *D* and *I* $(D > I)$ for all natural (i.e. non-anthropogenic) inputs of contaminant *i*. If or when concentrations exceed a threshold (i.e. $C > C_{crit}$) at which deleterious biological effects are observed for significant compartments *n* in the area of interest, then pollution has occurred and assimilative capacity will have been exceeded. For sustainable long-term management, it is the regulators role to maintain the rate of input to this point (or area, or whatever) below that for which (over an appropriate timescale)

$$\frac{dC_{i,x,n}}{dt} \leq 0 \quad \text{and} \quad C_{i,x,n} \leq \text{EcoQS}_i = fC_{\text{crit}_{i,x,n}} \cdot \qquad (8.2)$$

It is this rate of input that is a measure of the assimilative capacity of the environment of interest. Historically D is simply treated as the capacity of the environment to dilute, disperse (e.g. metals) and degrade (especially organic sewage). C_{crit} is taken to be the toxic threshold determined for a small range of species n, usually from short-term, acute laboratory toxicity tests (i.e. the Ecological Quality Standards or EcoQS for contaminant i), including precautionary extrapolation factor (Zabell, pers. comm.) f (normally in the range 0.01–0.1). We know that C_{crit} also depends on the quality of the environment (i.e. on x). It appears to be a working assumption, largely untested, that for the marine environment D will always exceed I.

We wish to make the following points:

i. Natural processes lead to concentrations of contaminants in certain areas (estuaries, fronts, areas of reduced water movement such as the Norwegian Trench and Dogger Bank) and compartments (sediment, water in estuaries, surface microlayer, biota) that are greater than the relevant EcoQS, and actually have a polluting effect (PCBs, etc.) (Table 8.1).
ii. Assimilative capacity of the system for a particular contaminant is determined by the balance of those particular processes (e.g. bio-accumulation and chemical transformation, etc.; dilution and degradation, etc.) that lead to concentrations at a particular point (or area or volume), that exceed a threshold of effect on a living component. It is not clear whether the assimilative capacity for particular contaminants can be considered independent, or whether certain contaminants with similar properties may act additively (e.g. hydrocarbons may sum dependent on their octonol-water partition coefficients (K_{OW}) (see Donkin et al. 1989).

Those processes that contribute to assimilation capacity, in relation to any species (n), or contaminant (i) or site (x), will tend to increase (I) or decrease (D) assimilation capacity. Such processes are summarized in Table 8.1, indicating the hydrographic, chemical and biological processes that contribute towards greater, or utilize, assimilative capacity. The way in which they do so is self-evident in many cases, but some of the less well known should be described.

Even where contaminants enter the marine environment from diffuse rather than from point sources, e.g. by aerial deposition, they rarely become distributed homogeneously in sea water, but are typically reconcentrated by various processes, often at interfaces. Those that result in benthic accumulation have been discussed, but significant accumulation may also occur at the sea surface (Hardy 1982). Metals (Hardy et al. 1985) and organometals (Clearly and Stebbing 1987) may accumulate to concentrations one or two orders of magnitude higher than those at the immediate subsurface. Accumulation in the sea surface microlayer is of importance as a site of exposure of the permanent and transient members of the neuston, which include developing eggs and larvae of fish and benthic invertebrates. Marine mammals (seals, cetaceans), and sea birds are inevitably exposed to contaminants in the microlayer, as are the littoral fauna and flora with each tidal excursion. While it is not known to what extent the indigenous biota are affected, microlayer samples taken offshore in the German Bight were found to be toxic when tested with bioassay techniques, and TBT concentrations were found to exceed the UK EQS (Hardy and Cleary 1992).

Different mechanisms are involved in the accumulation of contaminants at the frontal systems that are the boundaries between water masses. Work by Tanabe et al. (1991) has shown that persistent organochlorines (PCBs, DDT, HCH isomers) occur at elevated concentrations in frontal regions, due to their affinity for lipids and particles concentrated by fronts. This has been demonstrated for water samples taken at the sea surface, but it is also true for the benthic sediments beneath frontal regions, due to the deposition of particles to which organochlorines become adsorbed. The possible accumulation of contaminants at fronts in the North Sea does not appear to have been investigated.

There is evidence that the thermocline and pycnocline may provide the kind of density discontinuity that results in the accumulation of contaminants. Further reconcentration of sea surface contamination can occur due to Langmuir circulation in open water, or axial estuarine convergences on the flood tide causing slicks (R. G. Uncles, pers. comm.). Suspended sediments and their associated contaminants may be concentrated in estuaries at turbidity maxima due to tidal pumping (Uncles et al. 1988), or by gyres drawing suspended particles to their centres due to centripetal forces and depositing them (Stebbing et al. 1984). Accumulation at all such interfaces is of particular importance as these are often sites of intense biological activity. This is because the same processes that accumulate biogenic material, (organic matter and nutrients) on which organisms feed, also concentrate chemical contaminants. The localized coincidence of contaminants and biota is likely to result in exposure and cause toxic effects.

8.3.3
For Individual Contaminants

Early thinking on the "dispersion capacity" of the environment (Holdgate 1979) was formulated in terms of the relationship between concentrations of an individual contaminant and the capacity to disperse it (Fig. 8.2). The key statutory instrument by which water quality is managed is the environmental quality standard (EQS). EQSs are required under both EC (Dangerous Substances Directive, 76/464/EEC) and UK (Environmental Protection Act 1990) legislation. An EQS is defined as the concentration of a substance which should not be exceeded in the receiving water in order to protect the use of the water; they provide the standards by which the regulatory authorities operate to monitor the aquatic environment and assess the possible biological effects of contaminants.

Critically, EQSs provide the one statistic that links contaminant concentration in the environment to its potential biological impact, so it is important to consider briefly how these aim to protect biological water quality by controlling chemical inputs (Zabell, pers. comm.). First, the acute and chronic toxicity data are reviewed. After considering available data on a contaminant (chemical/physical properties, behaviour pathways and fate, analytical methods, environmental concentrations),

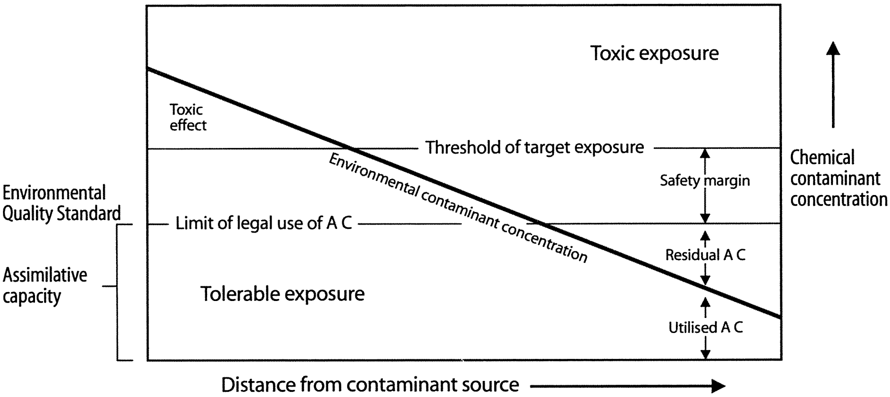


Fig. 8.2. Relationship between contaminant concentration, assimilative capacity and the environmental quality standard for individual contaminants (Derived from Holdgate 1979)

the lowest reliable and relevant concentration is selected from laboratory toxicological data. An extrapolation factor is then applied. Typically the factor is 100 for acute and 10 for chronic/sublethal toxicological thresholds. The factor may be varied depending on the persistence of a chemical contaminant in the environment, its tendency to bioaccumulate, or due to the acute/chronic threshold ratio. The preliminary EQS is then evaluated in relation to field studies before being recommended, reviewed by the regulatory authorities and finally adopted as a standard against which environmental concentrations of each contaminant are monitored. This approach to legislation and monitoring is now not adequate for various reasons.

i. The large number of contaminants in the North Sea that are potentially harmful are now numbered in tens of thousands. Even though EQSs sometimes relate to a group of chemically related compounds, through QSARs for example (Donkin et al. 1989), it is clearly impracticable that there should be an EQS for every contaminant that could potentially have a toxic effect.
ii. The paucity of toxicological threshold data, both chronic and sublethal, limits the appropriateness of EQSs for their purpose. Available toxicological data exist for <5% of chemical contaminants and <1% of species, so extrapolation between compound and species is a necessity.
iii. EQSs based on the toxicity of individual contaminants do not adequately account for their interactions, which may be antagonistic, additive or synergistic.
iv. EQSs depend upon acute or chronic laboratory toxicity experiments under controlled conditions. While protocols aim to achieve reproducibility (e.g. constant temperature, light, feeding regime etc.), environmental relevance is thereby lost. Many environmental factors, such as pH, turbidity and salinity, the test organisms' resistance, and the complexation capacity of the water, affect contaminant toxicity, yet are often not taken into account.
v. Numbers of contaminants in the environment may occur at concentrations less than their various EQSs, yet collectively have a deleterious biological effect.

vi. EQSs can be based on 'annual average' concentrations or 'maximum allowable concentrations'. They may thus allow transient concentrations that are toxic, while the annual average concentration remains less than that permitted by an EQS.
vii. The extrapolation factor used varies between nations, and there seems to be agreed protocol for their specification. In the UK it is arbitrarily determined (Wharfe and Tinsley 1995), and adjusted in the light of experience, rather than having a basis in scientific understanding. It is intended to account for uncertainties and lack of knowledge in extrapolating between species, from acute short term exposure to chronic long term exposure, from one environment ecosystem to another. Extrapolation factors may vary between ranges of 1–5, where confidence is greatest that effects in the field may be avoided, to 200–1 000 for persistent new chemicals, where the toxicological database is sparse. Some use larger extrapolation factors account for possible synergistic effects between contaminants.

Derived in this way, EQSs for listed contaminants provide the means by which statutory limits of environmental contamination are determined and controlled, providing the standards to which the regulatory authorities operate in order to prevent pollution. However, chemical EQSs have led to a waste of monitoring effort, measuring inconsequential contaminants (i) in the wrong place (x) and in the wrong compartment (n) (see Section 8.3.2).

8.3.4
A Resource of Economic Value

The marine environment has a capacity to assimilate wastes and effluents by their dilution, dispersion and degradation, such that they are reduced to harmless concentrations, are transformed into less toxic species, or utilized and recycled by the ecosystem. This capacity is an environmental service of considerable economic value. Globally such services are approximately valued at $1.28 tr p.a., which is 7.1% of the global Gross National Product p.a. (using data from Costanza et al. 1997).

When the basic ecotoxicological and economic variables are considered together (Fig. 8.3), it is clear that a number of factors bear on the management of the rates of contaminant inputs to the system. A low level of loading by nutrient-rich organic wastes (Fig. 8.3a) promotes primary and enhanced heterotrophic production. Increasing nutrient inputs can cause eutrophication. Primary production has increased in the German Bight by 3–4 times since 1962 (Radach et al. 1990). In stratified waters eutrophication and the consequential phytoplankton blooms can lead to hypoxia. The system becomes overloaded at the point at which hypoxia and metabolic by-products have an adverse effect on productivity, although community and other ecosystem changes may occur earlier. Where such events are severe, mortalities of benthic and pelagic organisms occur. The stages of marine eutrophication and its harmful consequences are considered by Gray (1996) and will not be considered further to give greater consideration to toxic contaminants and their control.

With non-degradable toxic contaminants such as metals (Fig. 8.3b), resistance to low concentrations may incur a physiological cost, but typically there is a threshold concentration at which toxic effects occur in an individual organism (Willows 1994), or may occur in a population or community (Warwick and Clarke 1992).

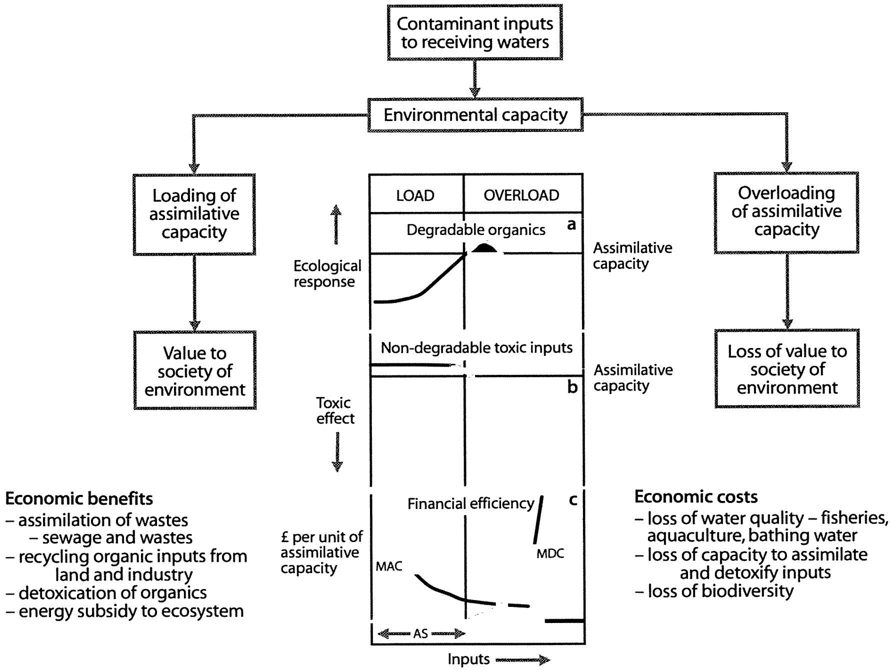


Fig. 8.3. Relationships between the effect of organic inputs **a** and toxic contaminants **b** to the economic efficiency **c** of using assimilative capacity. *MAC* Marginal Abatement Costs; *MDC* Marginal Damage Costs; *AS* Assimilative Capacity

Such relationships represent an over-simplification, yet provide an adequate basis to consider the economic efficiency of utilising assimilative capacity (Fig. 8.3c). With increasing levels of input, Marginal Abatement Costs (MAC) are likely to fall due to efficiencies of scale, while in progressing from load to overload, Marginal Damage Costs (MDC) may increase as toxicological thresholds are exceeded and the ecosystem is damaged. Thus as the assimilative capacity is exceeded, the capacity to assimilate further wastes will be reduced by toxic effects on biota that contribute to the sequestration, degradation and detoxification of chemical contaminants (Table 8.1). The reduction of assimilative capacity may be accentuated by positive feedback. Expressed in this way, the optimal economic use of assimilative capacity occurs where MAC = MDC (Turner et al. 1994). However, such an optimum is not sustainable, since even at that level biological contributors to assimilative capacity will be damaged and their contribution reduced thereby (Pearce 1976).

To protect the ecosystem and its biological contribution to assimilative capacity, a safety margin is desirable (Fig. 8.3), perhaps as great as an order of magnitude less that the lowest toxic threshold, but for clarity is not shown (see Section 8.3.3). Some contaminants may be so toxic that it is assumed there is no capacity to assimilate them. Expressed in this way the assimilative capacity concept can be formulated in a way that allows for precautionary margins to safeguard living resources.

In relating toxicological to an economic analysis of environmental contamination, it is clear that an economic optimum level of contamination (where MAC and MDC intersect) would permit higher levels of inputs than would be desirable on ecological grounds alone. It is evident that, near threshold concentrations, disproportionately large effects may result from small changes in concentration. Since many environmental factors influence the precise threshold, a safety margin is essential. That the utilisation of assimilative capacity then becomes less economically efficient indicates the cost of precaution and the reduction of risk.

8.4 Chemical Versus Biological Monitoring of Assimilative Capacity

Environmental legislation is both enabled and constrained by the monitoring techniques necessary to implement it. Progress in adopting more effective legislation is constrained by advances in research and monitoring techniques. Often the adoption of such techniques by a regulator may also depend on simplicity of application and cost-effectiveness, as well as efficacy.

Chemical analysis presently provides the most important means by which regulators monitor the effectiveness of environmental legislation. The EQS itself is expected to provide the link between chemical contamination and its biological rele-vance, since it is based on laboratory toxicity data, as already discussed (see Section 8.3.3). However, it is significant, when considering the role of particles and sediments as binding sites for many contaminants, that there are no EQS for them in the particulate phase.

We ask whether it is better to monitor "targets" or "factors" (Holdgate 1979), the chemical causes of pollution or their biological effects, or some integration of the two approaches. To present the arguments clearly, we consider first the advantages and disadvantages of an approach that depends on analytical chemistry (Section 8.4.1), before considering one that relies on biological techniques (Section 8.4.2). However, it is evident that monitoring of chemical contaminants that does not relate to their biological consequences or effects is of little benefit in determining the use of assimilative capacity. For those that do, it is only necessary to control contaminants that have biologically harmful consequences. It is essential to establish causality rigorously, to provide an adequate body of evidence to impose regulation and control with the minimum of delay and without excessive cost. Thus after considering the arguments for chemical and biological approaches alone, we go on to advocate an integrated approach (Section 8.4.3), as we will demonstrate that while chemical analyses do not adequately indicate toxic impacts, biological techniques do not adequately identify their chemical causes.

8.4.1 Chemical Monitoring

A chemical approach to the control of pollution was appropriate for an era when contamination of the water system was principally by point source inputs of effluents with relatively few chemical constituents of concern entering rivers; essentially one dimensional systems with unidirectional flow. Contamination of the water course is now more complex because of the numbers of chemicals released into the environment, the many and diffuse routes that they may take, and that our concerns have now extended from rivers to marine systems, where they tend to accumulate. Any system based on controlling chemical contaminants individually is now outmoded and inappropriate for its purpose.

The following points summarize important ways in which we believe a chemically-orientated pollution control system is proving inadequate:

Environmental Quality Standards. While the protocol by which EQSs are determined is rigorous enough, too many assumptions have to be made in their application for them to serve their purpose adequately. EQSs are sometimes based on insufficient data, or are not revised to take account of new data. Others have not been set because the hazard posed was not recognized until the chemical was in widespread use and a common contaminant (e.g. endocrine disrupters). The utility of EQSs depends crucially on the relevance of laboratory-based short term toxicology data to the environment, which for many reasons has always been doubtful, except as a means of determining the relative toxicity of a group of compounds.

Relationship of chemical data to toxicological thresholds. The utility of any EQS to its purpose hinges on the extent to which toxicological thresholds, determined from short-term laboratory experiments, have relevance to the biological impact of the chemical in the environment (see Section 8.3.3) for which in situ data are much more relevant). Laboratory experiments typically do not take into account many of the factors known to be important in the environment in determining the health or susceptibility of the organism (sex, season, breeding condition, etc.), or the bioavailability of the chemical in the experimental medium (turbidity, DOC concentration or complexing capacity, salinity). Sensitivity of biota to toxic effects depends on the environment experienced by the biota, which is at variance to that used in standard toxicity tests. The relevance of an EQS to pollution depends on how well it indicates the likelihood of a biological impact in the environment. The use of short-term lethal thresholds to predict long-term sublethal effects assumes a constancy in the acute/sublethal toxicity ratio. This is unjustified, since the ratio is low for narcotic toxicants and high for others that have a specific mode of action (e.g. TBT).

Weight of numbers. The sheer number of chemical contaminants entering the environment, particularly synthetic organic chemicals, has become too much for a regulatory system based on the control of individual contaminants. The effluent of the river Rhine is now estimated to contain as many as 40 000 individual contaminants. The problem of control is aggravated by the fact that some classes of chemicals are biologically active at concentrations of nanograms per litre, and many are persistent with half-lives of years in the marine environment. The growing burden for those regulatory authorities with responsibilities for monitoring listed chemicals under EC and UK legislation has become overwhelming. Many significant contaminants go unmonitored, and the frequency and spatial definition of monitoring is inadequate for its purpose, and delays between sampling and analysis devalues the data. As it is, the chemically-based legislation motivates monitoring; links to the biological significance of the data are often overlooked.

Redundancy in chemical legislation. Some classes of contaminants for which there is pollution legislation and a requirement to monitor are now known to pose much less of a threat to environmental quality than was assumed. Mechanisms to remove contaminants from monitoring programmes whose environmental threat is now known to be minimal or inconsequential are ineffective. For example, most metals are no longer considered to pose the threat to water quality in the North Sea, yet they are a class of contaminants that have long featured in pollution legislation. The ICES/IOC Bremerhaven Workshop deployed over 50 biological effects techniques on what is perhaps the most marked pollution gradient in the North Sea (Stebbing et al. 1992), but no deleterious effects related to metals were demonstrated. Similarly, the chemical causes of the pollution gradient identified by Widdows et al. (1995) along the UK East Coast do not include metals. There is therefore a need to critically examine the appropriateness of chemical monitoring programmes for their purpose, since present knowledge suggests there is redundancy. Chemical monitoring of contaminant levels that are biologically insignificant, and do not cause pollution, is a waste of resources. The problem has grown considerably with the number of micro-contaminants now present in the marine environment, but which are unmonitored.

Appropriateness of chemical analyses. Regrettably environmental legislation, and the chemical analyses to enforce it, do not necessarily relate to the same fraction, species or phase of a contaminant that is biologically available and potentially toxic. For example, legislation for copper and cadmium relates to the concentration of the metal in sea water, while the ionic activity of the metal determines its bioavailability and toxicity. Since a large fraction of these metals is bound to organic matter in the case of copper (Sunda and Guillard 1976) and for cadmium to inorganic ligands (Sunda et al. 1978), the ionic fraction which is determined is only a proportion of the total present in the environment. The problem of the biological relevance of chemical analysis can be circumvented by monitoring bio-accumulated tissue burdens, which can be used to predict effects (Chapman 1997) for some chemicals. Not only do the enhanced levels ease the analytical problems, but tissue burdens are integrated over time.

Inadequacy of spatial definition in monitoring. There is a growing awareness that contaminant behaviour in the environment does not lead inevitably to their dilution, dispersion and/or degradation. Thus any sampling strategy should recognize those processes that reconcentrate contaminants and to sample accordingly, particularly when those sites are foci of biological activity. One example of importance is the potential of the turbidity maximum in estuaries to accumulate contaminants (Uncles et al. 1988). Similarly coastal fronts have been shown to accumulate organochlorine pesticides at the sea surface and in benthic sediments (Tanabe et al. 1991). The air-sea interface is a well known site of contaminant accumulation (Hardy 1982), besides being one of the accumulation of sensitive early life stages of pelagic and benthic species. Thus monitoring programmes assume homogeneity in distribution, when heterogeneity is the norm.

8.4.2 Biological Monitoring

Pollution as defined (see Section 8.3.1) relates primarily to "harm to living resources and ecological systems" due to contaminants of various kinds. Since concern relates to the biological impact of pollution, and the criteria for environmental quality are biological, the compelling logic is to use biological indices of pollution. The advantages of such an approach are outlined below.

Detection of new and unsuspected pollutants. To depend on a chemically-orientated approach presumes that it is known which chemical contaminants are likely to be important, but repeatedly the detection of environmentally significant, new contaminants has depended upon research that recognized their biological impact. Numerous examples could be cited, such egg shell thinning in birds due to organochlorine pesticides, but the best marine example is probably that of TBT (tributyl tin), a biocide used in antifouling paints (see Champ and Seligman 1996). It was first detected due to the failure of oyster larvae to metamorphose and the shell-thickening of adult oysters (see Fig. 8.4). It could not have been detected chemically when it first became a significant pollutant, because analytical techniques had not been developed to detect it at extremely low concentrations (ng l^{-1}) at which TBT and its degradation products are biologically active. The inescapable conclusion, from this and other examples, is that biological surveillance monitoring is the most effective way of detecting new and previously unsuspected pollutants.

Integration of the combined effects of chemical contaminants. Many biological indices have been developed and tested over the last ten years which provide an overall measure of the quality of the environment that organisms inhabit, whether it be the benthic sediments, the water column or the sea surface. Suitable indices using sensitive organisms, reflecting the combined effect of different mechanisms of toxic action, provide an overall measure of environmental quality, integrating the combined effect of the many stresses to which organisms are exposed. More specifically, the combined effect of numerous contaminants, their synergistic or antagonistic interactions, and the many

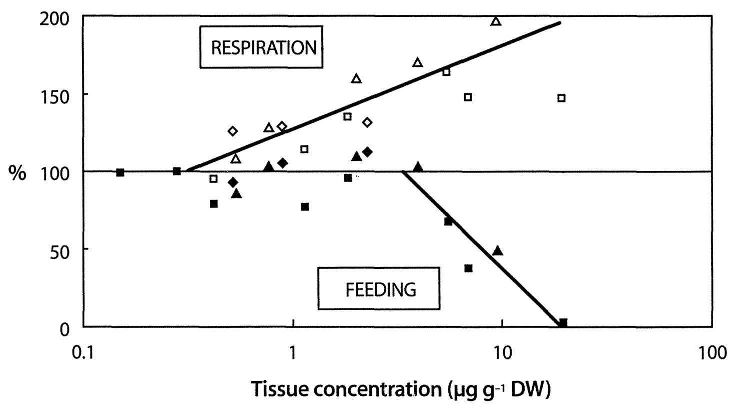


Fig. 8.4. The effect of tissue concentrations of total butyl tins, (μg g^{-1} dry tissue weight) on two components of scope for growth: respiration rate and feeding rate expressed as a proportion of control values. Note the difference in toxic thresholds for the two physiological processes and the difference in the rate at which they are affected by the tissue concentration of butyl tins (see Willows 1994, for more details; data redrawn from Widdows and Page 1993)

physical and chemical environmental effects that modify contaminant bioavailability and impact are integrated by such indices. A suite of four techniques have been advocated by the North Sea Task Force, and were tested with many others on the same pollution gradient in the German Bight (Stebbing et al. 1992).

Environmental quality: chemical factors or biological targets? The benefits of measuring the impact of pollutants on biological targets is obvious, since they relate directly to the most commonly used criteria for environmental quality, where biological activity, richness and diversity are the standard. The argument that the detection of toxic effects implies that damage is done, and that their use cannot be preventative, is not the case where techniques utilize adoptive responses to toxic exposure. To monitor chemical factors, rather than biological targets (Holdgate 1979; Stebbing 1996) implies that the causal relationship between each is sufficiently adequate to predict one from the other. Such comprehensive knowledge of environmental processes (Table 8.1) is unlikely to be attained in the medium term. Besides which, the burden of monitoring has grown to the extent that, logistically, target monitoring is the only way to manage the task cost-effectively. In the past, biological techniques lacked the sensitivity and reproducibility required, but this is no longer the case, in that a suite of techniques is now available that potentially fulfil the necessary criteria.

It has never been suggested that biological techniques should be used alone. Their role is as an initial monitor and surveillance of water quality, that can then be used to direct subsequent analytical effort to establish the chemical cause(s). Used alone, biological monitoring techniques are of limited utility because:

a they typically do not identify the specific cause of the toxic effect detected. Specific indicators like imposex in gastropods for TBT are rare,
b only representative species can be used from a limited number of communities to represent whole ecosystems. Extrapolation between species is not straightforward,
c the availability of species and use of biological techniques may be seasonal, or may not cover the geographic range to be investigated,
d few techniques have been used widely enough for rigorous protocols to be established, and problems of reproducibility of results between laboratories resolved,
e only in recent times have a range of biological techniques achieved the necessary sensitivity with reproducibility and precision.

Over the last decade the advantages and disadvantages of chemical versus biological monitoring have been debated within international bodies, such as ICES and IOC. The adoption of research developments in biologically-based indices have been held back by the commitment to legislation expressed predominantly in chemical terms. Nevertheless the rationale for biological monitoring has a logical appeal that is gradually winning support, as concern over the effectiveness of chemical monitoring and its cost-effectiveness have risen, while the rigour of improved biological techniques has been repeatedly demonstrated (Bayne et al. 1988; Addison and Clarke 1990; Stebbing et al. 1992; Wharfe and Tinsley 1995).

8.4.3
An Integrated Approach to Monitoring

While the arguments for and against biological and chemical monitoring have been considered separately, it is clear that an integrated approach is essential. Chemical analysis of contaminants could no more be expected to give a true impression of their biological impact than biological effects techniques alone could pin point their chemical causes. Advances in environmental toxicology have combined the relevance and cost-effectiveness of using biological techniques, closely allied to chemical analyses that enable the identification of the chemical causes of toxic effects. Issues of causality, the generality of biological techniques and their deployment, in an environment where contaminants become heterogeneously distributed, remain key issues and are considered below.

Establishing causality. In any chemically orientated monitoring, potential causality between chemical contaminant and its toxic effect is implied by environmental concentrations that are in excess of the EQS. Historically the limitations of techniques to establish causality have weighed against the wider use of biological techniques for monitoring. Thus operational techniques depending on weight of evidence, rather than rigorously demonstrated causality, have been advocated (Stebbing 1992). Such techniques depend on correlative evidence and the relationships between environmental concentrations, or tissue concentrations, and toxicological threshold concentrations. In the approach advocated here, the need to establish causality becomes an integral part of the method.

Recent developments have improved the rigour of relationships between contaminants and biological effects. Thus the toxicological interpretation of tissue burdens of contaminants using QSARs (quantitative structure activity relationships) is adequate to identify PAHs and organotins as two important classes of contaminants causing the depressed scope for growth in mussels along the UK East Coast (Widdows et al. 1995). Similarly the use of ion exchange resins allied to sensitive water quality bioassays can be used to demonstrate metal pollution (Stebbing 1979a), or to concentrate contaminants and bioassay the eluate to demonstrate the toxicity of organic contaminants (Bening et al. 1992). Such extraction and fractionation techniques have considerable potential for establishing causal relationships between chemical contaminants and their biological effects.

Several biochemical techniques which measure enzyme activity help to identify their chemical causes. The induction of Mixed Function Oxygenases (MFOs) identifies the limited range of organic compounds (including PAHs and PCBs) which induce their production. Thus the induction of EROD in dab indicates pollution by such organic compounds (Fig. 8.6). Similarly induction of the metal-binding protein metallothionein indicates exposure to metals, typically copper, zinc, cadmium and mercury (Hylland et al. 1992). Acetyl cholinesterase activity (AChE) in freshwater fish is used to indicate the impact of some pesticides (including organophosphorous and carbamate pesticides). The occurrence of increased activity of AChE in dab in the German Bight follows the same distribution as MFO activity, suggesting that chemicals which induce AChE have the same distribution as the chlorinated or polynuclear aromatic hydrocarbons (Addison 1992). The induction of imposex in marine gastropods has been found to be specific enough that the degree of imposex is used as a surrogate for chemical analysis to monitor TBT pollution (Gibbs et al. 1966).

Biological indices of water quality allied to the distribution of chemical contaminants may provide correlative evidence of causality, when applied along a relatively simple pollution gradient but such evidence is rarely adequate for management action. Those biological techniques that indicate the class of contaminants responsible have an important role, especially where they are as specific as imposex in gastropods. The technique with greatest scope for application is the toxicological interpretation of tissue burdens with the aid of QSARs. Thus, biological effects techniques that enable chemical effort to be focussed on establishing causality where there is demonstrable pollution, offer the most cost-effective approach to monitoring water quality.

Of those techniques currently available, imposex in gastropods is unique as a specific index of organotin pollution (see Section 8.6.2), while EROD induction indicates exposure to organic contaminants (see Section 8.5.2). The use of QSARs and tissue contaminant concentration-response relationships allied to scope for growth in mussels (Widdows et al. 1990) provides a toxicological interpretation of observed reductions in physiological (energetic) health terms of contaminant tissue burdens (see Section 8.5.4); an approach that could be extended to other species. Similarly the use of liquid-solid extraction technology for the selective extraction and concentration of different classes of contaminants (Bening et al. 1992) has potential, when linked to water quality bioassay techniques, as an aid to establishing causality, but has not yet been used operationally.

The generality of biological techniques. The lower the level of biological organisation at which a technique measures contaminant effects, the more likely it is to have generality of application and comparability, since organisms resemble one another more closely at lower levels. Thus genetic, biochemical and cellular indices, collectively referred to as biomarkers may be used effectively in organisms as diverse as fish and molluscs. Indices at subcellular or cellular levels may usefully indicate specific classes of contaminants due to adaptive metabolic responses to them, but those at the organismal level are more integrated and relevant to management issues. However, the organismal significance of toxic effects or responses at lower levels has rarely been clear. While techniques may be transferred between taxa, there remain difficulties in relating the results of indices at different levels of biological organisation, although advances have been made (Moore 1992; Willows 1994; Goss-Custard and Willows 1996).

More important is whether indices of toxicity in one or a few organisms can be used to indicate the biological quality of different habitats, the health of ecosystems or the North Sea. Clearly, no single species can adequately represent a community of species occupying a single habitat, since the routes by which toxins become biologically available vary, as do the expressions of different mechanisms of toxic actions likely in different taxa (neurotoxin, respiratory inhibitor, genotoxin, endocrine mimic). Thus, a suite of suitable species representative of different taxa from the plant and animal kingdoms is essential in establishing an EQS. Toxicological data from algae and/or macrophytes, arthropod (e.g. crustacean), non-arthropod (e.g. mollusc), fish are considered necessary (Zabell, pers. comm.). However, additional species representative of different habitats, and ecological niches are desirable, since contaminant behaviour will result in the accumulation of contaminants at different sites (air-sea interface, surficial benthic sediments).

Biologically-orientated objectives and standards for marine environmental quality (i.e. EcoQSs) should be based on a taxonomic range of species (microalgae to fish), representatives of functional ecological groups (autotrophs, heterotrophs, symbionts) from different habitats (pelagic, benthic epifauna and infauna, planktonic), modes of toxic action (genotoxic, respiratory inhibition, endocrine mimic) and life phases (egg, embryo, larva, adult).

The heterogeneity of contaminant distribution. The deployment of techniques to assess contamination in the marine environment does not reflect the known heterogeneity in contaminant distribution (see Table 8.1). It has been shown that contaminants bind to particles, especially those which are fine and organic (POC). They are also highly mobile, and both a substrate and food for many species. At the sea surface buoyant organic-rich particles provide the substrate for a specific community of microzooplankton and specialist neuston species, apart from the transient embryonic and larval stages of benthic invertebrates and pelagic fish. Yet here contaminants accumulate to concentrations orders of magnitude greater than the immediate subsurface. Thus contaminants accumulate on more dense but highly mobile organic particulate substrates, which are sites of biological activity. If such sites are where contaminants accumulate, it is here that monitoring effort should be focussed, particularly since it is where biological activity is often greatest.

Cost-effectiveness of an integrated approach. Present legislation, and consequent monitoring effort, requires chemical analysis for those named contaminants for which legislation exists. This strategy leads to considerable redundancy in monitoring effort. Many contaminants are below the detection threshold of available analytical techniques. Other contaminants are only present at inconsequential concentrations. Although required by legislation, such effort is wasted, leading regulators to direct effort in a way that is required by the legislation, but does not adequately serve its purpose, which is to protect the biological quality of the marine environment.

The approach advocated here is to use biological monitoring as the means of overall monitoring and surveillance, using a suite of tested and robust techniques. Such techniques should be widely deployed over the area for which the regulator is responsible at regular intervals. The distribution of sampling efforts needs to be informed by knowledge of the relevant environmental processes. In particular understanding of contaminant transport and behaviour incorporated in simulation models (Taylor 1987) should be used to focus and minimize monitoring (Radford and West 1986)

No chemical technique should be as widely or frequently deployed, since it is assumed failure to detect any biological impact implies that environmental health is satisfactory and sustainable. The chemical monitoring capability should be reserved for deployment alongside biological techniques to establish causality when depressed water quality is detected (Stebbing and Harris 1988). Such a strategy would not only be more effective in detecting new contaminants, but could more economically provide improved awareness of the utilisation of assimilative capacity and the health of the North Sea ecosystems.

8.5 Environmentally Significant Pollutants

The advantage of using biological indices is that not only do they provide an overall, integrated measure of environmental quality, but where techniques identify the contaminants responsible for toxic effects, those classes of chemicals of greatest significance in coastal waters can be clearly identified. Here we consider some of the more significant contaminants that have been detected in this way.

8.5.1 Polyaromatic Hydrocarbons (PAHs)

Wild and Jones (1995), in their budget for PAHs in the UK environment could not quantify marine inputs. PAHs in the fine fraction (<63 μm) of sediments are significant contaminants in the Humber estuary (0.7–2.7 mg kg^{-1} dry weight) and follow the path of the freshwater plume offshore (Klamer and Fomsgaard 1993). Such findings mirror those for the Elbe-Weser estuarine plume, whose contaminant chemistry (including metals, aromatic and chlorinated hydrocarbons) shows declining concentrations over two order of magnitude over a pollution gradient of 200 km to the north east and the Dogger Bank (see Stebbing et al. 1992, Appendix 1). Although the inputs responsible for such gradients have not been quantified, they do demonstrate significant PAH fluxes to the North Sea which can be considered typical of industrialized and urbanized estuaries, having an effect on sediment concentrations of PAHs well offshore.

Wild and Jones (1995) estimate UK inputs of PAHs to the atmosphere amount to 712 t a^{-1}. They estimate a considerable potential export of PAHs to Europe across the North Sea. Approximate estimations of total PAH inputs to the North Sea by atmospheric deposition have been given at 50–1300 t a^{-1} (reviewed in van Aalst 1988). Preston and Merrett (1991) indicate that the dominant source of hydrocarbons to the North Sea atmosphere is from air which has recently passed over the UK. The aerosol is dominated by hydrocarbons of terrestrial origin. While Brorstroem-Lunden (1996) provide analyses of deposited PAHs from coastal and offshore sites (Swedish west coast) of a similar order of magnitude, Preston and Merrett give evidence of preferential deposition over the sea, which they believe has important consequences for flux calculations, due to the greater proportion of wet deposition over the sea.

It is instructive to consider the distribution of PAHs in relation to lead, whose distribution in the North Sea is partly accounted for by its atmospheric transport and deposition. Markedly elevated lead levels off the UK East Coast have been presented by Kersten et al. (1988) for coastal waters from Flamborough Head to North Norfolk. There is a steep gradient offshore due to scavenging by particles which adsorb strongly and remove fluvial inputs close to the shore (Salomons and Forstner 1984). This has the effect of accentuating the occurrence of elevated concentrations of lead on particulate fines (<20 μm) in the central North Sea to twice that of the surrounding area, implying a different mode of input. Elevated lead concentrations in the sediments from the central North Sea has long been attributed to atmospheric inputs. Since the sediments include a low proportion of contaminant-rich sediment fines (<1%) the shallow waters of the Dogger Bank are considered a temporary deposition site. They are remobilized during the winter gales and likely to be carried further north and finally deposited in the Norwegian Trench (Skei 1981).

Data from Wild and Jones (1995) show that 11% of PAH inputs to the atmosphere are from motor vehicles, and correlations between PAHs and lead in North Sea aerosol samples suggest a source related to road transport (Preston et al. 1992; Chester et al. 1994). They propose the relationship of PAHs with lead, as a tracer of anthropogenic influence, could be used to follow changes due to the adoption of lead-free petrol and the decreasing use of leaded petrol. Airborne contaminant inputs to the northern North Sea are only 50% of those to the southern North Sea (QSR 1993) due to greater urbanisation and industrialisation.

Among the most comprehensive study of estuarine PAHs was that conducted by Readman et al. (1987) for the R. Tamar. They established that PAHs appear to be stable in anoxic sediments, such that PAH concentrations at dated levels in a sediment core reflect inputs to the sediments when they were laid down. He concluded that the exponential increases from 1960–1980 in PAHs and some metals (Cu, Zn, Pb), typical of other UK estuaries, suggests inputs from motor vehicles and road run-off.

Elevated nearshore PAH concentrations also provided the dominant pollutant in the effects observed by Widdows et al. (1995). They conclude that "... at the majority of North Sea coastal (26) sites toxic hydrocarbons are at concentrations capable of inducing significant inhibition of SFG and forming a major component of the overall reduction in SFG". In some instances this accounted for up to 90% of the reduction in SFG.

When considering the effects of North Sea contaminants the QSR (1993) reports that "Information on the occurrence of these compounds in the North Sea is rather scarce and almost no information on inputs is available". Since then preliminary analyses of water samples have been conducted as part of the UK National Monitoring Programme (Law et al. 1997). They show elevated concentrations in industrialized estuaries with levels as high as 10.7 $\mu g\ l^{-1}$, and 15% of samples exceed sublethal toxicity thresholds.

PAHs provide another example (see Section 8.2) where biological techniques are highlighting the importance of a class of compounds which a predominately chemical approach has, until recently, overlooked.

8.5.2 Organotins

The most significant individual contaminant known in recent years to depress coastal water quality is tributyl tin (TBT); the biocide used in antifouling paints. The significance of TBT was first detected by its effect on non-target organisms: shell thickening in oysters and a failure of their larvae to grow to metamorphosis (Alzieu et al. 1982). Subsequently it was found to disrupt the endocrine system in the dog whelk (*Nucella lapillus*), causing infertility by inducing females to become male (imposex) (see review by Gibbs and Bryan 1996). TBT is now known to induce imposex in about 30 species of gastropod, and has been established as a specific index of TBT pollution. TBT constitutes a unique ecotoxicological case study illustrating the complete action cycle, from the problem detected, to causality established, legislation introduced and recovery monitored (Abel 1996; see Champ and Seligman 1996 for a full account).

The impact of TBT is sometimes trivialized as only causing imposex in dog whelks and shell thickening in cultivated Japanese oysters. It is therefore overlooked that TBT was incorporated in antifouling paints as a broad spectrum biocide, to keep vessels free of the full range of sessile communities (algae, barnacles, hydroids etc.). It was also used as an antifoulant on salmon rearing pens. It proved toxic to marine life at such low concentrations that it was probably the first compound for which it was clear that the sea had no assimilative capacity. It is unfortunate therefore that the research programme initiated in the UK was almost exclusively autoecological; the effect of TBT on communities in polluted waters was overlooked, although anecdotal evidence for a wider impact was strong.

Since legislation has effectively controlled the use of TBT on small vessels and the impact of TBT in coastal and estuarine waters has been controlled, attention has turned to the effect of TBT originating from large vessels through studies of imposex in dog whelks around the North Sea. The species was once very widespread and the effects observed during a survey of the entire North Sea coastline in 1992 are likely to prove catastrophic for the species. Offshore, in the German Bight, TBT has been shown to occur in the sea surface microlayer at concentrations in excess of the UK EQS of 2 ng l^{-1} (Hardy and Cleary 1992), while in the southern North Sea high incidences of imposex have been found in benthic whelk (*Buccinum undatum*) populations living in a deepwater offshore shipping lane (Mensink et al. 1996).

The contribution to the depression of scope for growth in mussels due to TBT (Widdows et al. 1990) is significant in increasing the taxonomic breadth of organisms known to be affected in the environment. The results also show the biological impact of TBT in areas (Thames estuary) where dog whelks no longer occur. In the case of TBT, no case needs to be made for the deployment of biological indices with appropriate chemistry, as it has already been established that imposex is a specific biomarker for TBT pollution, to the extent that the degree and frequency of imposex is widely used as a proxy for chemical analyses of TBT.

8.6 Biological Evidence for Pollution Gradients in the North Sea

We now consider examples from the North Sea where the use of biological techniques has demonstrated pollution gradients in terms of the biological impact of contaminants. At the same time these examples demonstrate the extent to which the capacity of the North Sea to assimilate anthropogenic inputs of wastes and effluents is being approached or exceeded.

8.6.1 Gradients Related to Oil Rigs

The North Sea not only accepts inputs of contaminants from the bordering riparian states, it also receives direct inputs from certain offshore activities such as the disposal of sewage sludge, the use of incinerator ships, and as a consequence of the offshore oil and gas industry. While the first two sources of input are now subject to stringent control, oil and gas production and exploration will continue for the foreseeable future. At first it was believed that the major environmental impact of this industry would be a consequence of oil inputs from production platforms. In the event, the largest impacts have resulted from the disposal around the rigs of discharged drill-cuttings (Kingston 1992). Initial drilling activities used water-based drilling muds, but oil-based muds proved more suitable. However, due to evidence of the toxicity of the latter, the oil content of cuttings discharged by platforms in the Norwegian sector was reduced to less than 6% in 1987. In 1993 their disposal was prohibited (Olsgard and Gray 1995). As a consequence there has been a move back to water-based muds. These in turn require larger amounts of weighting agents (up to 10 times more) than oil-based muds, which usually take the form of a barium mineral (barite) which typically contains impurities including a range of other heavy metals (GESAMP 1993). Oil-based drilling muds continue to be used in the UK sector.

Initial evidence from chemical monitoring programmes indicated raised levels of total oil hydrocarbons in sediments sampled in the vicinity of drilling platforms. These can be as much as 10 000 times background levels close to the platforms, but typically decline rapidly at distances greater than 500–1 000 m (Kingston 1992). Oil exploration and exploitation companies are required to conduct both chemical and biological environmental monitoring of their activities. While raised concentrations of contaminants (oil hydrocarbons) from drilling muds can be detected at distances up to 10 km from platforms (Davies and Kingston 1992; GESAMP 1993), evidence for major impacts on benthic animals (reductions in species diversity) were generally limited to 750 to 1 500 m from the platforms. The Norwegian government has a policy of open access to its quality-controlled environmental monitoring data. This has allowed the application of sophisticated multivariate statistical analyses of both the chemical and biological data (Gray et al. 1990; Olsgard and Gray 1995). These analyses have shown that the effects of contamination by drill cuttings of the sea-bed containing a mixture of oil hydrocarbons, barium and other heavy metals, bentonitic clays, together with other bioactive materials, can have a significant impact on the structure of benthic animal communities for areas between 10 and 100 km^2 around individual platforms. Indeed, these effects can extend beyond the original sampling area, including designated reference sites (Olsgard and Gray 1995). Drilling sites may show significant differences in benthic macrofauna 3 years after drilling activity ended, particularly in the deep burrowing and long-lived species. Where such sediments had been covered by several centimetres of clean and well-mixed sediments on top of the contaminated sediments, the meiofauna communities were remarkably uniform (Heip 1992). In acute toxicity studies barite has not been found to be particularly toxic to marine organisms (see Starczak et al. 1992), and Olsgard and Gray (1995) concluded that the major adverse effects on the biota were probably associated with the hydrocarbons contained in discharged drilling muds, although other components probably make a significant contribution. Given the number and spatial distribution of oil and gas platforms throughout the North Sea, it is likely that benthic communities over a substantial area of the seabed have been affected.

8.6.2 Estuarine Inputs

It is well established that the major route for inputs of contaminants to the North Sea is by way of the river estuaries. Perhaps the most significant pollution gradient in coastal waters is that due to the plumes of the rivers Elbe and Weser which flow into the German Bight. This gradient was intensively studied during an ICES/IOC Bremerhaven Workshop in March 1990 along a transect of stations extending 200 km northwest out to the eastern side of the Dogger Bank (Stebbing et al. 1992). During the workshop,

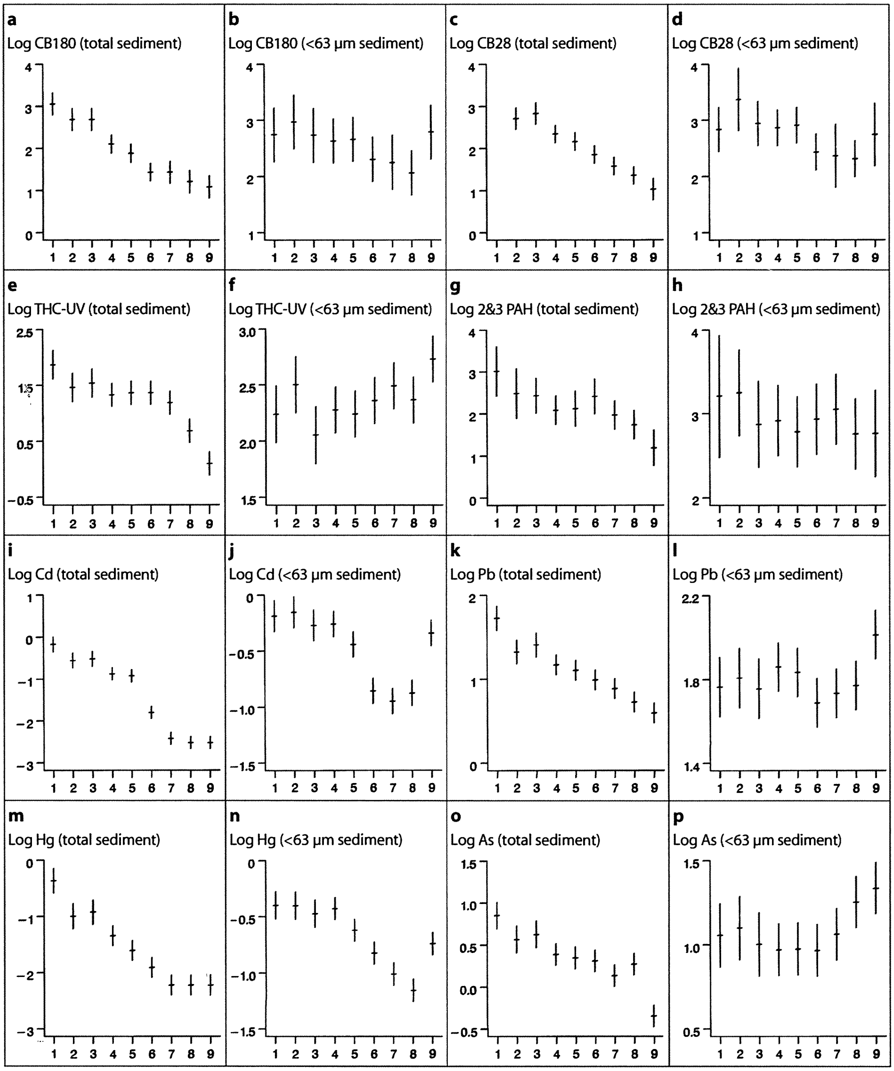


Fig. 8.5. Selected chemical data from the ICES/IOC Bremerhaven Workshop indicating chemical contamination gradients on a transect running northeast across the German Bight from the mouths of Elbe-Weser estuaries (From Stebbing et al. 1992). Units: **a–d, g–h** ng g^{-1} dry wt; **f–g, i–p** µg g^{-1} dry wt. 95% confidence intervals are indicated

numerous biological effects techniques (Fig. 8.5) (including all those adopted by the North Sea Task Force for use in preparing the 1993 QSR), were allied to chemical analyses of water, sediment and tissues (Fig. 8.6).

The biological data relates primarily to the dab (*Limanda limanda*). A wide range of techniques (biochemical, subcellular, organismal responses) indicate that the fish are progressively less stressed with distance offshore (Fig. 8.5). This pattern is reproduced in some of the sediment bioassay data using bivalve larvae. There is a reversal in this trend, at the most offshore station over the Dogger Bank, detected by a number of techniques, whose coincidence suggests that they are significant.

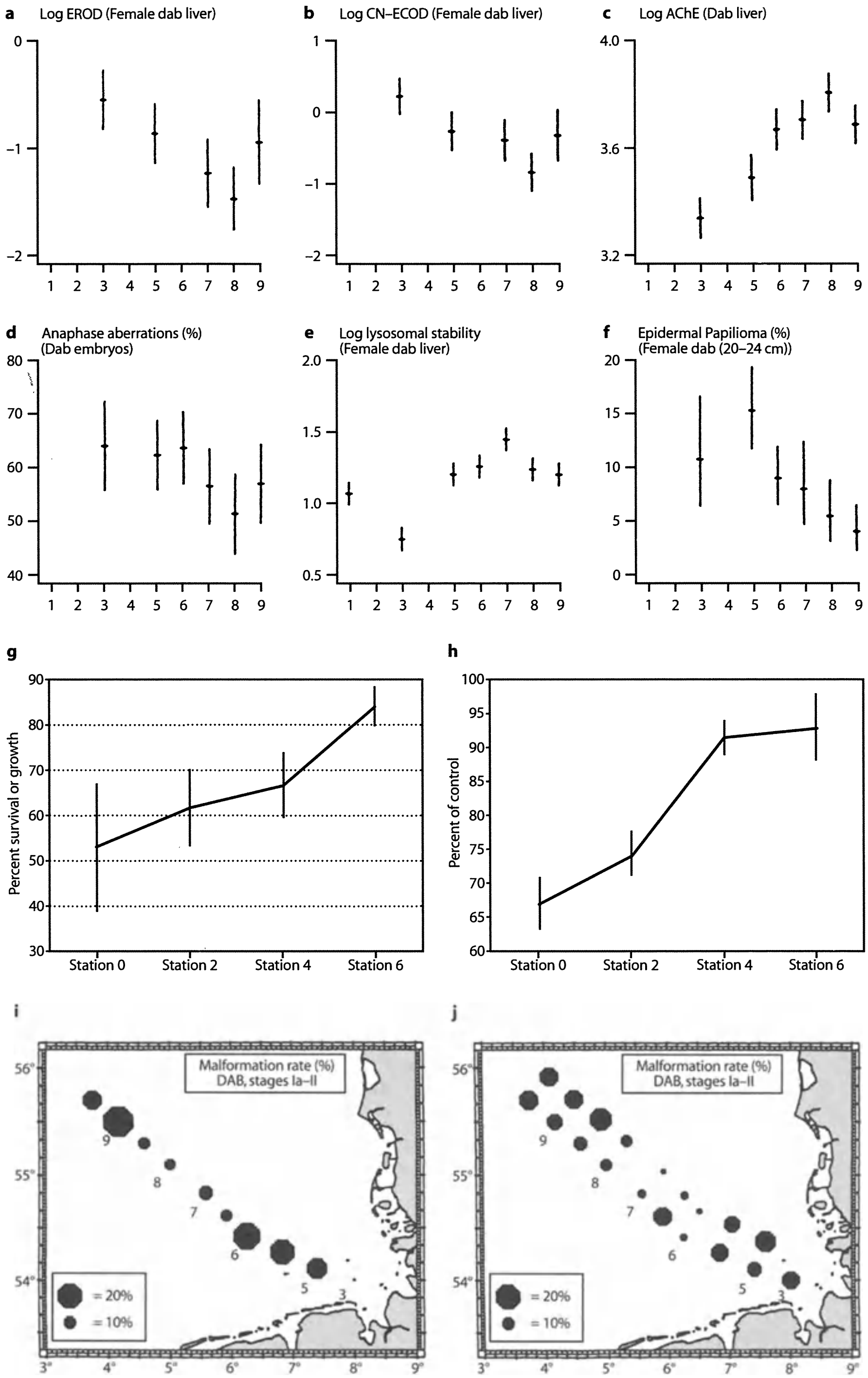
Chemical data showing the concentrations of contaminants in sediments along the transect demonstrate a decrease in concentration with distance offshore. This trend could be seen most clearly in the whole sediment data for PCBs, PAHs, total hydrocarbons and some of the major metals (lead, arsenic, mercury, cadmium). However, when analyses of the fine fraction (<63 µm) are considered, the spatial trends are markedly different, often increasing progressively with distance offshore (total hydrocarbons), increasing only at the most offshore stations (arsenic, lead), or decreasing offshore and then increasing over the Dogger Bank (mercury, cadmium). Such distributions closely match some of the biological data, indicating significant contamination. Inshore the data show marked effects due to pollution of the estuarine plume by the contaminants flowing out of the rivers Elbe and Weser. Effects are reduced progressively with distance offshore as concentrations of contaminants decrease due to dilution. Such data lend support to the interpretation that the association of contaminants with the organic-rich fine fraction is the reason for their disproportionate effect on the biota (Kempe et al. 1988).

Flatfish such as the dab possess a particularly vulnerable lifestyle under these circumstances, since they are likely to be exposed to high concentrations accumulated by their benthic prey, as well as lying cryptically beneath the superficial layer of the fine contaminant-rich floc found in depositional areas (e.g. Dogger Bank). Thus flatfish are exposed to higher concentrations than other demersal fish and, as a consequence, show the adaptive responses of enzyme systems that aid the degradation and excretion of organic contaminants. At higher levels of exposure they are more vulnerable to disease and indeed show increased frequencies of some diseases in parts of the North Sea (Fig. 8.5).

8.6.3
Fish Embryo Abnormalities

As part of the ICES/IOC Bremerhaven Workshop, Cameron and Berg (1992) evaluated the frequency of developmental abnormalities in dab embryos in surface plankton across the German Bight (Fig. 8.5). Subsequently the technique was used for all fish species in a survey of the North Sea. Such teratogenic and chromosomal abnormalities are determined in living embryos at sea. On a transect extending NE across the German Bight frequencies of abnormalities were high at the most inshore stations (32%) decreasing with distance offshore (9%) before increasing again over the Dogger Bank (31%) (Cameron and Berg 1992). Similarly, chromosomal aberrations were highest inshore, lowest offshore, and increased over the Dogger Bank (Fig. 8.5).

It is concluded that the enhanced frequencies of developmental abnormalities and chromosomal aberrations of dab embryos are at least partly due to organochlorines which occurred at elevated concentrations in adult dab livers (see Stebbing et al. 1992, Appendix 1). Experimental work has shown that elevated levels of chlorinated hydrocarbons (PCB, DDE, dieldrin) in flatfish result in malformations during embryonic development which reduce hatching success (Westernhagen 1988). The possibility of abnormalities being caused by the exposure of floating eggs and embryos to contami-


a Log EROD (Female dab liver)
b Log CN–ECOD (Female dab liver)
c Log AChE (Dab liver)
d Anaphase aberrations (%) (Dab embryos)
e Log lysosomal stability (Female dab liver)
f Epidermal Papilioma (%) (Female dab (20–24 cm))
g
Percent survival or growth
Station 0
Station 2
Station 4
Station 6
h
Percent of control
Station 0
Station 2
Station 4
Station 6
i
Malformation rate (%) DAB, stages Ia–II
= 20%
= 10%
j
Malformation rate (%) DAB, stages Ia–II
= 20%
= 10%

nants concentrated in the sea surface microlayer (Hardy and Cleary 1992) is also a strong possibility, since the toxicity of such contaminants on fish embryos has been demonstrated (Kocan et al. 1987).

A more comprehensive survey of developmental abnormalities for all fish species in the surface plankton (including plaice *Pleuronectes platessa*, sprat *Sprattus sprattus*, whiting *Merlangius merlangius*, rockling *Onos* sp., flounder *Platichthys flesus*) was conducted in 1991 and 1992 (Cameron and von Westernhagen 1996, 1997). The results show malformation rates varying with species between 10% and 80%. Highest malformation rates were found in the plumes of the major industrialized estuaries; Weser 43%, Rhine 29%, Thames 58%, Forth 38%. The authors consider it most likely that the abnormalities are due to anthropogenic contaminants, which have been shown to be capable of inducing such abnormalities (von Westernhagen 1988). Whether these effects are due to parental exposure to contamination in benthic surficial sediments, or eggs exposed at the sea surface microlayer, remains unclear, either or both routes are possible. Up to 85% of such embryonic abnormalities are known to be lethal in 5 days (Cameron and von Westernhagen 1997). There is no evidence yet that the mortality of fish embryos in coastal waters is affecting recruitment of fisheries, nevertheless that must remain a principal concern.

8.6.4 UK East Coast Gradient

Deployments of "scope for growth" in mussels (*Mytilus edulis*) in the North Sea (1990–91) have provided the first measurements of a pollution gradient along the UK East Coast from the Shetland Islands to the Thames estuary (Widdows et al. 1993, 1995).

This technique measures an integration of basic physiological processes in the energy balance of the organism in terms of its potential for growth, and has been used to measure pollution gradients for over 15 years. It has been deployed for intercomparison with a wide range of other techniques in workshops organized by the IOC Group of Experts on the Effects of Pollution (GEEP) in Norway (Widdows and Johnston 1988) and Bermuda (Widdows et al. 1990).

During the 1990 exercise in the North Sea, scope for growth was measured at 26 sites down the UK East Coast, then in 1991 mussels were deployed on 9 lightships off the East Coast from the Humber to the Dover Straits. Scope for growth data from all the sites are plotted here (Fig. 8.7) against the calculated age of North Atlantic water in the North from a winter model simulation (van Pagee and Postma 1986). The results fall into three groups: those for sites under the influence of estuarine water, other coastal

◀ **Fig. 8.6.** Selected biological data from the ICES/IOC Bremerhaven Workshop indicating gradients in pollution on a transect running northeast across the German Bight from the mouths of Elbe-Weser estuaries (From Stebbing et al. 1992). Station numbers 1–9 are indicated in *i* and *j* and in Fig. 8.1b as *A* to *I*. **a** to **f** give ecotoxicological indices of response or effect in the dab (*Limanda limanda*); **a–c** biochemical indices; **d** mitotic abnormalities in developing embryos; **e** index of condition of cellular organelles; **f** frequency of external papillomas indicating skin disease; **g** pooled bioassay data from a variety of techniques following exposure to bulked microlayer and subsurface water samples; **h** growth data for the copepod *Tisbe battaglia* exposed to surface microlayer samples; **i** and **j** morphological malformation frequencies in early developmental stages of dab (*Limanda limanda*). (Papers from which data are drawn are in Stebbing et al. 1992)

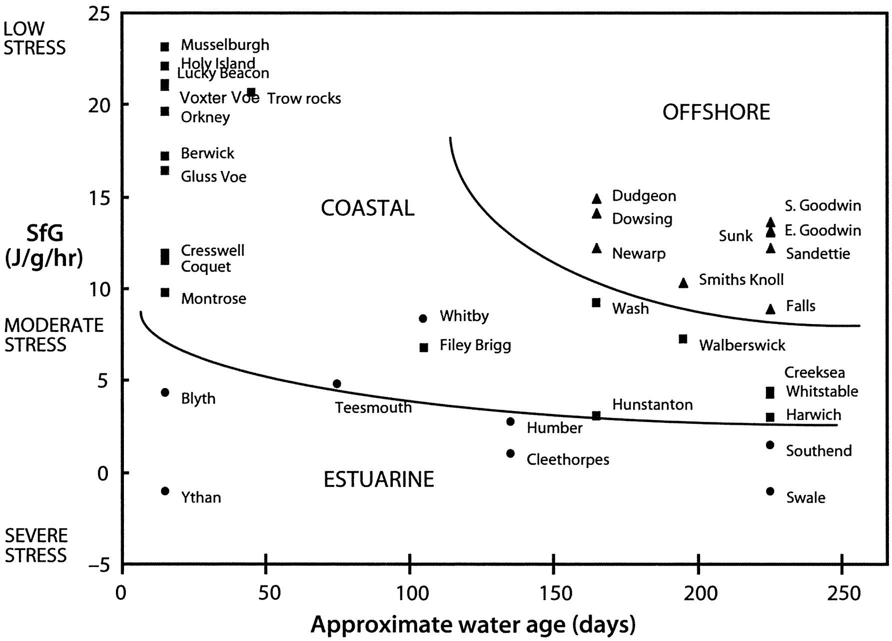


Fig. 8.7. Measured values of scope for growth in mussels (From Widdows et al. 1995) against the simulated age of the water in the North Sea (From van Pagee and Postma 1986) for each site from which mussels were sampled or exposed. *Triangle:* offshore; *square:* coastal; *circle:* estuarine sites whose locations are given in Fig. 8.1b

sites distant from estuaries, and the offshore sites. They show that water quality is poorest in estuaries, improving at coastal sites removed from polluted estuarine inputs, and is best at offshore sites.

More significant are the trends in declining scope for growth from north to south and with age of seawater for all three groups: estuarine, coastal and offshore. The residual currents along the East Coast run from north to south and, as they move south, receive the contaminant inputs from successive major estuaries, the Forth, Tyne, Tees, Humber and Thames. The total burden of the more persistent contaminants is likely to be cumulative and their combined effect on water quality is reflected in declining mussel scope for growth with age of the water and distance south. While less marked in offshore waters, where contaminant concentrations are lower, the same trend is apparent.

Scope for growth, allied to the use of tissue contaminant concentration-response relationships and QSARs, provides a toxicological interpretation of contaminant tissue burdens in mussels. At most of the North Sea coastal sites aromatic and aliphatic hydrocarbons are found in mussel tissues at concentrations high enough to inhibit scope for growth. Such hydrocarbons were the most important class of toxic compounds and are derived from the combustion of oil, coal, wood, petroleum and diesel fuels (see Section 8.5.1). Some details of the mode of toxic action of hydrocarbons, phenolic compounds and TBT are known (Widdows and Donkin 1991; Widdows and Page 1993; Willows 1994). Other biologically significant contaminants detected in this way included TBT and its derivatives.

These data are of especial significant because they show for the first time that pollution in the North Sea is not restricted to the coastal margins (QSR 1987), or localized to areas close to sources or deposition areas (QSR 1993), but affects the North Sea as an entity. They demonstrate that the UK East Coast is a single pollution gradient shown by the decline in water quality from north to south (Fig. 8.7).

At present scope for growth appears to satisfy the various criteria as a biological monitoring technique for general use. It provides in mussels, a sensitive yet robust technique for measuring water quality that is independent of natural stressors, such as salinity and turbidity (Widdows et al. 1995). Combined with QSARs it can provide a toxicological interpretation of contaminant tissue burdens, partitioning the extent of the depression of scope for growth between contaminants. The limiting factor is the availability of QSARs relating tissue concentrations to effects for different classes of contaminants (Donkin et al. 1991, 1997).

8.7 Biological and Ecological Quality Standards

If the regulator's role was set in the context of maintaining assimilative capacity, rather than to serve legislation for individual contaminants, we believe monitoring would be more appropriately directed. Thus EcoQSs should be defined such as to measure and conserve assimilative capacity. That the approach of determining the EQS for individual contaminants is scientifically dubious, and that it would be better to determine and monitor actual effects on the sensitive compartments (i.e., the biota), and use these to direct the need for regulation. The use of biologically defined quality standards (EcoQSs) means that the statutory instrument for regulating pollution can relate directly to the criteria for environmental quality, and the status of biological systems, rather than indirectly through EQSs for specific contaminants based on laboratory toxicity tests.

If the criteria for environmental quality are predominately biological or ecological, then environmental quality objectives should also be expressed in such terms. Such proposals are not new (Elliott 1996), but various factors have prevented their adoption. Defining protocols for biological techniques in a way that yield reproducible results has, in the past, been a problem. There is also the mistaken belief that the inherent variability of biological material prevents its ability to provide precise data. Biological effects techniques typically do not indicate whether they are due to natural factors or to chemical contamination, so the approach must be linked to some means of identifying the chemical causes of significant effects. Their advantage is that they integrate both natural and anthropogenic determinants of environmental quality.

Over the last decade there has been a growing recognition that utilising the integrative capacity of biological techniques is the only way of detecting and controlling pollution by the escalating number of chemical contaminants (Stebbing and Harris 1987). Improved biological techniques are more sensitive and provide more reproducible results. Moreover they now often provide some indication of their chemical causes. We suggest that the evidence presented constitutes a case to develop practical techniques that allow environmental quality to be assessed in biological terms, which should be allied to methods to identify the chemical causes of observed effects. Such techniques will then provide the tools to implement more appropriate legislation, and the regulators with a mandate to apply them.

8.8 Conclusions

1. The perceived state of the North Sea is one of significant local contamination, with evidence of some pollution related to the coastal margins, estuarine inputs, and areas of contaminant accumulation.
2. The definition of pollution is considered from both chemical and biological perspectives; only the latter incorporates a meaningful concept of the environmental effects of pollution.
3. Where biological techniques to measure pollution effects have been deployed on appropriate geographic scale, they demonstrate that significant gradients of pollution exist in the North Sea that have not been defined using chemical monitoring techniques.
4. We propose a definition for assimilative capacity as the balance between those processes that determine the concentration of contaminant in an environmentally meaningful compartment. Assimilative capacity is exceeded when a critical threshold of biological effect is exceeded (i.e. there is pollution), or when the rate of input of a contaminant would lead to such a threshold being exceeded in the future (i.e. there will be pollution). We identify some of the component processes that may act in the North Sea.
5. We argue that the assimilative capacity of the North Sea is a resource of considerable economic value. There may be an optimal economic level of utilisation of this environmental service that does not damage its component processes.
6. The use of biological effects techniques that demonstrate that pollution gradients exist that traverse large areas of the North Sea, and from estuarine plumes to its centre, indicate that assimilative capacity is being exceeded.
7. Existing legislation is orientated to regulating the release of potential pollutants. Further legislation sets chemical EQSs and this determines the use of monitoring effort. This does not provide the most appropriate basis for controlling pollution because links between chemical contamination and its biological impact are often ignored or poorly understood.
8. New contaminants are often not detected as pollutants until they have an impact in the environment; they are recognized through their effects rather than by chemical analysis. Nevertheless investigative chemistry must be included to detect incipient problems.
9. Therefore we advocate the use of biological monitoring techniques that relate to accepted criteria for environmental quality. Such techniques, if strategically deployed, are sufficiently sensitive to provide both detection and early warning of incipient environmental problems. Chemical analyses can then be focussed to establish the causative contaminants.
10. Biologically-based legislation (biological or ecological water quality objectives and standards) that is formulated to protect assimilative capacity, and thereby prevent pollution, would ensure that monitoring effort is more appropriately focussed.

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Chapter 9

Conservation and Management of Latin American Mangroves

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9.1
Man and Mangroves in Pre-Columbian and Colonial America

Pre-Columbian inhabitants of the American continent have traditionally used mangroves for many purposes, including wood and energy production. In various countries, there is strong archaeological evidence of mangrove utilization by pre-Columbian and even pre-historic people. The use of mangroves varied from site to site, depending on the particular characteristics of the population, but apparently began during the transition period from nomad to fixed habits, between 9 000 to 3 000 years B.P.

The American nomads frequently formed semi-permanent settlements along tropical mangrove coasts, close to lagoons and bays, where an abundance of easy to collect protein-rich diet existed in the form of molluscs (Reichel-Dolmatoff 1965). At settlement sites, they left large accumulations of shells, organic waste products, and *cultural* debris, collectively referred to as *conchales* in Spanish speaking countries and *sambaquis* in Brazil. These settlement remains provide important information on the characteristics of pre-historic populations and their food habits and utilization of natural resources (Perdomo-Rojas 1978; von Prahl et al. 1990).

Castaño-Uribe (1989) suggested that, in Colombia, the process of fixation of the population was a continuous chronological sequence, with great implications for the cultural development of the entire continent. One example was the discovery of the most ancient ceramics of the American continent (ca. 2 400 years B.P.), along the Atlantic coast of Colombia in mangroves and adjacent areas, a finding of enormous cultural importance (Reichel-Dolmatoff 1965). Along the extensive mangrove fringes of the Pacific and the Caribbean coasts of northern South America, the development of human groups resulted in distinct patterns of cultural adaptation, which can still be recognized today. Technology was continuously being changed and optimized for the exploitation of resource-rich, non-seasonal wetlands, to provide the necessary infrastructure for the establishment of populous human groups, with an economy based on the collection of molluscs and on fisheries. The experience was diversified and expanded throughout the continent (Castaño-Uribe 1989).

In Panama, there is evidence of human settlement in mangrove areas about 5 000 years B.P. Tools were made out of mangrove wood (D'Croz 1993). It is well documented fishing of euryhaline species from mangrove-bordered estuaries and channels was important for pre-Columbian human settlements located on the central coast of Panama at that time (Cook and Ranere 1992). People from these settlements fished for estuarine and coastal species such as Carangidae, Batrachoididae, Ariidae and Clupeidae, utilizing fences, harpoons, and fish hooks, many made of mangrove wood.

In Brazil, deposits of shells and fish bones from mangroves species were accumulated in coastal mounds by nomad populations of fisherman and collectors from 3 500 to 2 000 years B.P.

In Perú, the Tumbes region played an important role in pre-Columbian America, when a large coastal population dedicated to agriculture, fishing, and commerce, formed the Tumpis Culture. These people were the best navigators of the Peruvian coast. They developed to a high degree the art of carving mangrove bivalves, *Spondius* sp., *Ostraea* sp. and *Anadara grandis*. To the *Spondius* shell, known to the Andeans as *Mullu*, they attributed magical powers, and after carving zoomorph or phytomorph figures, they were offered in religious rituals. This is one of the first records of mangrove uses in Perú (Echevarria and Sarabia 1993).

During the colonization in Middle and South America, Indian opposition lead to the near extinction of native populations along the coast of the entire continent. By the time of the European conquer, mangroves represented such a nuisance to troops and horses that Cristobal de Molina in 1552, described the mangroves in Peru as the "most difficult land of these kingdoms". However, this did not hamper the discovery of the quality of mangrove timber for construction, and the exploitation was soon started, mostly for poles and construction of boats, and later for tannin. Since the 16th century, mangrove timber was exported from Colombia to Peru and reached 6 000 poles a year in the 17th century. In 1677, for instance, thousands of mangrove poles were exported to Cuba from the Pacific coast of Colombia (von Prahl et al. 1990). Bark commerce was also profitable. Ecuador, for example, exported nearly 600 t of bark per year to neighbouring countries from 1879 to 1906 (Bodero 1993).

During the colonial period, the commerce in mangrove products was so important that the colonial authorities produced specific legislation to protect and manage the use of the resource. In 1760, the King of Portugal and Brazil, D. José, issued one of the first, if not the very first law to protect and adequately manage mangrove resources in Brazil. The law determined specific penalties to be applied to people who cut the trees that had not been previously debarked. This is an example of environmentally sound lobbying by leather merchants, who wanted to guarantee abundant high quality material for their tanneries. In fact, as early as the 17th century, the Portuguese made methodical studies of the properties of the tannin of the bark of different species of *Rhizophora*, *Avicennia*, *Soneratia*, and *Xylocarpus* from many places in South India, Molucca and Sri Lanka. These studies enabled them to select the best sources of raw materials for their tanneries. The interest in Brazilian mangroves arouse only after the Portuguese supremacy in Asia was on a downward trend, as the bark mangrove species bordering the Atlantic Ocean was recognized as producing tannin of lesser quality.

Resources derived from mangroves have been utilized from pre-Colombian times to the present. Currently, some mangrove forest products are widely utilized in rural construction, also as sticks in horticultural crops, and they are still used for the extraction of tannin. However, only recently have mangrove wetlands been considered as an ecosystem. This change in evaluating mangroves has in many cases been due to the negative experiences in attempting to manage mangrove resources separately.

9.2 Extent, Distribution and Composition of New World Mangroves

The New World mangrove flora evolved from species of the more diversified mangroves of the Indo-Pacific. The genera *Rhizophora* and *Avicennia* were the first to spread through the Tethys Sea into what is presently the Mediterranean, and thereafter to the east coast of the Americas. They reached the Caribbean by the early Eocene (55–50 million years B.P.) and crossed a still non-existent Panamá isthmus to the Pacific coast (Graham 1989).

Table 9.1. Estimates of mangrove area (ha), ratio of mangrove area/area of country (–), and ratio of mangrove area A (km^2) / length of coastline of country L (km) of continental and insular countries on the American continents

Country	Area (ha)	Area ratio	A/L ratio	Reference
Continental countries				
USA	190000	0.02	10	Odum et al. (1982)
Mexico	524600	0.27	56	Flores-Verdugo et al. (1992)
Belize	73000	3.10	189	Saenger et al. (1983)
Guatemala	16040	0.15	40	Jimenez (1992)
Nicaragua	60000	0.50	66	Saenger et al. (1983)
Honduras	121340	1.08	148	Jimenez (1992)
Costa Rica	41330	0.08	32	Jimenez (1992)
El Salvador	35235	1.65	45	Jimenez (1992)
Panama	171000	2.22	69	D'Croz (1992)
Colombia	358000	0.31	148	Alvarez-León (1993)
Ecuador	161770	0.60	72	MAG (1991)
Peru	4791	0.01	2	Echevarria and Sarabia(1993)
Venezuela	250000	0.27	76	MARNR (1986)
French Guyana	5500	0.06	15	Saenger et al. (1983)
Guyana	150000	0.70	326	Saenger et al. (1983)
Suriname	115000	0.70	298	Saenger et al. (1983)
Brazil	1412376	0.12	134	Kjerfve and Lacerda (1993); Hertz (1991)
Insular countries				
Trinidad and Tobago	7150	1.40	20	Bacon (1993)
Jamaica	10624	1.02	7	Bacon (1993)
Cuba	529700	4.80	142	Padron et al. (1992)
Haiti	18000	0.65	10	Saenger et al. (1983)
Dominican Republic	9000	0.20	7	Saenger et al. (1983)
Puerto Rico	6500	0.71	–	Saenger et al. (1983)
Bahamas	141957	10.18	40	Bacon (1993)
Bermuda	20	<0.01	<1	Ellison (1993)
Guadeloupe	8000	4.49	20	Saenger et al. (1983)
Martinique	1900	1.73	7	Saenger et al. (1983)
Cayman Islands	7268	27.60	45	Bacon (1993)
Lesser Antilles	24571	–	–	Bacon (1993)

New World mangroves currently extend from southern USA to southern Brazil. Only recently, efforts were made to survey mangrove cover in the Americas. Table 9.1 shows recent estimates of the extent of mangrove areas in countries and on islands in the Americas, totalling 4.2×10^6 ha, less than in Southeast Asia but more than in Africa. The largest mangrove forest wetlands in the Americas occur in Brazil, Mexico, Cuba, and Colombia.

The relative importance of mangroves is indicated by comparing the non-dimensional ratio between total mangrove area and total surface area of each country, and also the ratio (km) of mangrove surface area and coastline length (Table 9.1). Among the continental countries, the percentage of the total surface covered by mangroves range from 0.01% in Peru to 3.1% in Belize. The ratio of mangrove area/coastline length ranges from 2 in Peru to 326 in Guyana.

For insular countries the percentage of total mangrove area can reach as high as 27.6% of the total island area, as in the Cayman Islands, and as low as 0.01% in Bermuda. The ratio of mangrove area/coastline length ranges from less than 1 km for Bermuda to 142 km for Cuba. This representation indicates that mangroves are a very important, possibly the most important, forest formation in certain insular countries and should be prioritized in terms of management and conservation.

The Pacific coast with nearly 1.16 million ha of mangroves, contains 28.5% of the total mangrove cover in the Americas. The Atlantic coast has 2.14 million ha or 52.8% of the total, and the Caribbean insular countries 0.76 million ha, or 18.7% of the total (Table 9.2). Using available estimates, New World mangroves represent 28.5% of the world total mangrove cover; African mangroves cover about the same area whereas the Indo-Pacific mangroves represent nearly half of the world total.

In almost all countries on the continent, mangroves are being inventoried to estimate area, density, distribution, and resources. There is growing concern for the importance of the health and survival mangroves. In several countries, mangroves are being cut and replaced by other biological systems, such as large scale mariculture, or developments, such as harbor and industrial complexes. On the other hand, replanting programs are being carried out in degraded mangrove areas in many countries. Therefore, the cover of mangroves in the Americans is likely to change in the future.

Differently from Southeast Asia, New World mangroves are poor in the number of tree species (Table 9.3). Systematic research is needed, due to high population variability among species and the length of the coasts. Basic biological surveys have yet to be done for northern South America and some Caribbean Islands.

New World mangroves include only 11 species of trees and one endemic variety.

Table 9.2. Mangrove forests cover in the Atlantic and Pacific coasts of America, including the Caribbean Islands, compared to world mangrove forests areas. The estimates for Southeast Asia and Africa were given by Saenger et al. (1983)

Continent/country	Mangrove area (ha)	(% of total)	
Latin America			
Atlantic Coast	2 143 356	52.8	
Pacific Coast	1 154 289	28.5	
Caribbean Islands	764 690	18.7	
Total	4 062 335	100	28.6
Africa	3 257 700		22.9
Southeast Asia	6 877 600		48.5
World total	14 197 635		100

Table 9.3. Updated list of species of "true mangrove" trees in Latin America and the Caribbean and their distribution limits (*Sources:* Araújo and Maciel 1979; Flores-Verdugo et al. 1992; Jimenez 1992; Cintrón and Schaeffer-Novelli 1992; Breteler 1969; Bacon 1993; West 1977; Roth 1992; Savage 1972)

	Atlantic Ocean		**Pacific Ocean**	
	North	**South**	**North**	**South**
Family Rhizophoraceae				
Rhizophora mangle L.	Bermuda, N 32°20'	Praia do Sonho, Brazil, S 27°53'	Puerto de Lobos, Mexico, N 30°15'	Tumbes River, Peru, S 3°34'
R. harrisonii Leechman	Estero Real, Nicaragua, N 13°	Rio Preguiças, Brazil, S 2°40'	Chantuto, Mexico, N 15°15'	Guayas R., Ecuador, S 2°20'
R. racemosa G.F.W. Meyer	Estero Real, Nicaragua, N 13°	Rio Preguiças, Brazil, S 2°40'	Chiquirí River, Panamá, N 10°	Guayas R., Ecuador, S 2°20'
R. samoensis (Hochr.) Salvosa	*No occurrence*		*Restricted to the Pacific coast from Ecuador (3°S) to Panamá (10°N)*	
Family Avicenniaceae				
Avicennia germinans L.	Bermuda, N 32°20'	Atafona, Brazil, S 21°37'	Puerto de Lobos, Mexico, N 30°15'	Piúra R., Peru, S 5°32'
A. schaueriana (Stapf. and Leech.)	St. Kitts Is., Carib., N 17°30'	Laguna, Brazil, S 28°30'	*No occurrence*	
A. bicolor Standl.	*No occurrence*		*Restricted to the Pacific coast of Central America*	
A. tonduzii Moldenke	*No occurrence*		*Restricted to the Pacific coast of Central America*	
Family Combretaceae				
Laguncularia racemosa Gaertn.	Florida, USA N 30°	Laguna, Brazil, S 28°30'	Estero Sargento, Mexico, N 29°17'	Piúra., Peru, S 5°32'
Conocarpus erectus L.	Florida, USA N 28°5'	Lagoa de Ararua-ma, S Brazil, 22°55'	Estero Sargento, Mexico, N 29°17'	Tumbes, Peru, S 3°34'
Conocarpus e. sericeus	*Endemic to Northern Caribbean Islands 20°N to 25°N*		*No occurrence*	
Family Pellicieriaceae				
Pelliciera rhizophorae Pl. and Tr.	Prinzapolca, Nicaragua, N 13°	Cartagena, Colombia, N 9°	Gulf of Nicoya, Costa Rica, N9°30'	Esmeralda Ecuador, S 1°

Rhizophora (Rhizophoraceae) and *Avicennia* (Avicenniaceae) dominate with 4 species each. Other genera are *Laguncularia* and *Conocarpus* (Combretaceae) and *Pelliciera* (Pelliceriaceae) with one species each. *Conocarpus* has an endemic variety (Bacon 1993) in the Northern Caribbean islands (Table 9.3). *Rhizophora mangle* L., *Avicennia germinans* L., *Laguncularia racemosa* Gaertn, and *Conocarpus erecta* have pan-continental distributions. The other species are restricted to particular sectors of the continent with taxonomical positions and biogeographical relations still poorly understood.

Many plant species occur associated with mangrove forests on the American continent. The diversity is probably due to climatic conditions and the proximity to other pristine ecosystems. Some of these plant species are associated with mangroves throughout their distribution range and can be considered true mangrove species. These include the fern *Acrostichum aureum* L. and the Malvaceae *Hibiscus tileaceus* L., which form dense belts along the landward edge of mangrove systems, on more elevated sites, and around dry and saline areas inside mangrove wetlands. Numerous species of aquatic plants, including algae, fungi, lichens, and Angiospermae, also occur in mangroves.

Few animal species, however, are exclusive inhabitants of mangroves. Most animals found in mangroves also occur elsewhere in other protected coastal areas. For example, of the 358 macro invertebrates and vertebrates found in a 4 000 ha mangrove system in Trinidad, only the Cerripede *Chthamalus rhizophorae* was confined to the mangrove habitat. On the other hand, many of the other species were mostly found associated with mangroves, and it is in this sense that they can be called mangrove fauna (Bacon 1993). The New World mangrove fauna, whether transient or permanent, includes over 140 bird species, 220 fish species, and hundreds of species of terrestrial and marine invertebrates. This creates high diversity environments along otherwise low biodiversity mudflats.

Due to the accelerated destruction of inland forests in some countries, many mangrove areas have become important sanctuaries and migratory routes for many species, which otherwise would be threatened to extinction. For example the monkey, *Chipodes satanas*, found refugee in the extensive mangroves along the coast of northern Brazil, likewise the manatee, *Trichechus manatus*, and the scarlet ibis, *Eudocimus ruber*. The American crocodile, *Crocodylus acutus*, occurs in many Caribbean islands, where their only shelter are mangroves. In Ecuador, in the Churute Mangrove Ecological Reserve, the only population of the "Canclon", *Anhima cornuta*, occurs west of the Andes.

Several species of penaeid shrimp are related to mangroves of the Pacific coast. As many as 9 species have been reported using mangroves as nursery areas, including *Penaeus vannamei*, *Penaeus occidentalis*, *Penaeus stylirostris*, and *Penaeus californiensis* (D'Croz 1993). These shrimp enter the mangroves as post-larvae, seeking protection and food resource in brackish habitats, and then move offshore as juveniles. Penaeids constitute the major component of the coastal shrimp fishery along the tropical Pacific coast.

9.3 Mangrove Uses

Mangroves play an important role in tropical coastal economies, providing many goods and services. These include coastline protection and stabilization, nursery for many economically important shellfish and finfish, products such as timber, firewood, charcoal, and chemicals, waterways for transport, enrichment of marine coastal waters by input of nutrients, locations for aquaculture (Chapman 1975; Kjerfve 1990). Some of these benefits are still poorly understood or unrecognized in many American countries, but such understanding is significant for the rational management of the coastal wetlands of the coast of the Americas.

Protection of waterways with fringing mangroves is common in Ecuador and Colombia. In Brazil, mangroves have recently been included in the management plans for marinas and condominia in coastal settings. In Panamá, 60% of the total shrimp fishery is based on 5 species, which all depend on mangroves for completion of their development. Along the Maranhão coast, northern Brazil, a huge shrimp production depends on two species of shrimp, which develop in mangrove systems locally. In Ecuador, mangroves provided shrimp larvae for the largest mariculture industry in the Americas, which presently covers more than 140 000 ha.

Apart from indirect benefits, mangrove products are also important for coastal populations in many localities. Firewood and charcoal seem to be the major uses of mangroves in Latin America. In countries like Nicaragua, where nearly 80% of households use wood for cooking, mangroves constitute a significant source of firewood, amounting to 9 000 m^3 annually. More significantly, in Honduras, the use of firewood ranges from 80 000 m^3 to 120 000 m^3, while in El Salvador, with only 350 km^2 of mangroves, 30 000 m^3 of firewood are extracted annually. In Brazil, mangroves are a frequently a source of firewood for bakeries and potteries, even along the most developed areas along the southeastern coast. In Panamá, the annual demand for mangrove fuelwood is 2 000 m^3 and the demand for timber for charcoal production 7×10^6 m^3. More than 1 000 families depend directly on this resource (D'Croz 1993).

Charcoal is another major use of mangrove wood in Latin America, although only a fraction of the total yield is converted to energy due to inefficient extraction techniques. In Costa Rica, as much as 1 300 m^3 of charcoal is produced annually in the Terraba-Sierpe mangroves. The mangrove charcoal production in Panamá is 7 400 m^3. Also, mangrove bark is still an important source of tannin in some Latin American countries. In Cuba, for example, bark production measured 2 700 t annually from 1987 to 1991, although a decrease has recently been detected (Padron et al. 1993). Bark yields range from 1 840 to 4 490 kg ha^{-1} in Costa Rica, while in Panamá 400 t a^{-1}. In Colombia, nearly 30 000 t of mangrove bark were harvested between 1945 and 1970, wasting more than 315 000 m^3 of timber. In the Parnaíba river estuary-delta in Piauí, northeastern Brazil, mangroves support more than 10 000 artisinal crab fishermen.

Despite their importance for most coastal tropical countries in Latin America, mangrove ecosystems have experienced an accelerated rate of resource destruction. Estimates of deforestation in mangrove areas of Latin America are scarce. Central America has significant annual cover losses, estimated to be 385 ha for Nicaragua, 560 ha for Guatemala, and 45 ha for Costa Rica, mostly for conversion of mangrove areas into rice fields, and salt and mariculture ponds. In Ecuador, nearly half of the mangrove area, circa 80 000 ha, has been deforested for construction of shrimp ponds during the past two decades. In Ilha Grande Bay in southeastern Brazil, which harbored nearly 600 ha of mangrove forests in the early '80s, 80% of this area has now been reclaimed to build condominia and marinas. In Colombia, 2 000 ha of mangroves are presently licensed for timber exploitation, with a potential timber yield of 70 000 m^3. Planned utilization for this timber is 80% for wood for construction and 20% fuel-wood and charcoal (Alvarez-León 1993).

Apart from deforestation, degradation of large mangrove areas is taking place in many Latin America countries due to misuse of coastal resources. Diversion of freshwater for irrigation and land reclamation are the major actions leading to mangrove degradation. The mangroves of Guanabara Bay in Rio de Janeiro, Brazil, which measured 50 km^2 in the beginning of the century, is heavily impacted with less than 15 km^2 of pristine forests remaining. The impact has mostly occurred because of clear-cutting of mangroves along creeks and river banks, oil spills, solid waste dumping, and decreased freshwater inputs. In French Guyana, more than 20 000 ha of mangroves have been cut and converted to rice paddies, and large amounts of fungicides, pesticides and fertilizers are used (K. Wood, pers. comm.), which produces an additional stress. In the insular Caribbean, tourism development in coastal regions has been the major destroyer of mangrove areas (Bacon 1993). In Ecuador, mangroves have been reduced from approximately 204 000 ha in 1969 to 160 000 ha in 1991, converted into shrimp ponds, agriculture fields, and cattle ranges (Bodero 1993).

9.4 Management of Mangrove Areas

A summary of management units for the mangroves of Latin America and the Caribbean is presented in Table 9.4. It is important to note that New World mangroves are quite diverse in terms of structure and biodiversity, varying from site to site. The site specific variability should be taken into account when analyzing the data in Table 9.4, and should always be accounted for whenever management policies are to be applied. Notwithstanding, a general classification of management categories for New World mangroves can be attempted. However, this scheme is far from being the ultimate classification scheme. Considering management guidelines, we propose the following four, general categories: (A) mangrove conservation reserves, (B) mangrove forest reserves, (C) mangrove fisheries reserves, and (D) damaged mangrove areas (Table 9.4).

Mangrove Conservation Reserves (MCRs) include those forests set aside for conservation, tourism, recreation, and scientific studies. A sub-category of this unit include fragile areas of significant scientific interest. As an example, the 5 000 ha of mangroves of the Tumbes river estuary on the north coast of Peru are highly dependent on the El Niño phenomena. Inland mangroves of some Caribbean islands also fit in this sub-category. High biodiversity sites comprise another sub-category of MCRs, because of their inherent biological significance and their potential as a refuge for endangered species. Type examples of this sub-category include the extensive mangroves along the Ecuador-Colombia border, various sites along the Pacific coast of Central America, and the unique Amazon river estuary mangroves. Also as a MCR unit, another sub-category includes those mangroves of particular importance in providing indirect benefits to coastal areas, such as maintaining water quality, providing protection against erosion and storms, and stabilization and building of coastlines and islands. Examples of this sub-category include the mangroves of some southeastern Brazilian sites, such as Guanabara Bay, Santos-Bertioga region, and Cartagena Bay in Colombia, where intensive industrialization has lead to a decrease in coastal water quality. Also, the fringe mangroves of small Caribbean islands, which provide effective shoreline protection, e.g. Corales del Rosario National Park in the Caribbean Colombia and the Belize barrier reef mangroves, are examples of mangroves of particular importance in providing indirect benefits.

Mangrove Forest Reserves (MFoRs) is a category including those mangroves designated for sustainable production of timber and other forest products. MFoRs include extensive mangrove stands, which allow economically viable exploitation but still with conservation of functional aspects of mangrove ecology. Multiple sustainable utilization of mangrove resources should be encouraged in MFoRs. Examples of mangroves in this category are the extensive forests along the coast of Amapá State in northern

Table 9.4. Management categories and sub-categories and examples of mangrove forests in Latin America and the Caribbean

Management category and major objectives	Sub-category	Type example
A Mangrove conservation reserves (conservation and scientific studies)	Fragile, of high scientific interest	▪ El Niño dominated mangroves of the
		▪ Inland mangroves of Caribbean islands
	High biodiversity	▪ Mangroves along the Colombia-Ecuador border
		▪ Amazon River estuary mangroves
	Special ecological role or significance	▪ Mangroves in industrialized bays of SE Brazil
		▪ Storm threatened Caribbean islands and coastline
B Mangrove forest reserves (sustainable utilization of forest products)		▪ Mangroves of Amapa, north Brazil
		▪ Mangrove forests along the south coast of Cuba
		▪ Mangroves in the Pacific coast of north Colombia and Chiquiri forests and Panama
C Mangrove fisheries reserves (preserve and maximize fisheries)	Of actual mangrove species	▪ Crab fishing mangrove areas of northeastern Brazil
		▪ Oyster fishing mangrove areas of Caribbean Colombia and Venezuela
	Open water	▪ Shrimp fisheries along the Maranhão Coast, north Brazil
		▪ Anchovie and shrimp fishing in the Gulf of Panama
D Damaged mangrove areas (recuperation of mangrove ecological attributes)	Converted to other uses	▪ Abandoned shrimp farms in the Gulf of Guyaquil, Ecuador
		▪ Abandoned resort areas in southeastern Brazil
		▪ Abandoned silviculture area along the San Juan River, Venezuela
		▪ Abandoned salt pond areas in northeastern Brazil
	Impacted mangroves	▪ Oil impacted mangroves of the Caribbean coast of Panama
		▪ Oil impacted areas in the Gulf Lake Maracaibo, Venezuela
		▪ Industrialized areas along the coasts of southeastern Brazil and Cartagena Bay, Colombia

Brazil, the Pacific coast mangroves of northern Colombia, the Pacific coast mangroves of Chiquiri and the Gulf of Panama, and the extensive mangrove forests on the south coast of Cuba.

Mangrove Fisheries Reserves (MFiRs) is a category, which include those mangroves associated with extensive waterways, with high production and utilization of fish and shellfish species that at least spend part of their life cycle in mangrove areas. We consider two sub-categories of MFiRs. The first includes those systems where catches mostly consist of mangrove species proper, and which do not necessary involve the restriction of activities in adjacent coastal waterways. Examples, are the mangrove crab fisheries in Piauí and other sites along the coast of northeastern Brazil, where over 30 000 people depend on crab harvesting; and oyster collecting along the Caribbean coast of Colombia and Venezuela. A second sub-category includes those areas where large catches of mangrove-dependent estuarine species are harvested, and protection and restriction of activities in waterways and adjacent coastal waters are necessary. Examples, are the Panama Gulf shrimp fishing areas and the extensive mangrove waterways along the coast of Pará and Maranhão along the northern coast of Brazil, where there exist direct, well-established relationship between catch and mangroves areas.

A fourth category consists of *Damaged Mangrove Areas* (DMAs), those which have been converted to non-sustainable uses of mangroves or subjected to ecologically unsound management practices at the expenses of mangroves, and those areas submitted to anthropogenic impacts with negative impacts on mangrove ecosystem functioning. Examples include the abandoned shrimp farms along the coast of the Gulf of Guayaquil, Ecuador, the abandoned large-scale silviculture sites on the San Juan river, Venezuela, the non-productive salt ponds in converted mangrove wetlands along the northeastern Brazilian coast, and the bankrupted tourism projects which caused deforestation of mangrove forests along Ilha Grande Bay in southeastern Brazil. Mangroves which have been impacted by oil spills include mangroves of the Caribbean coast of Panama, Lake Maracaibo in Venezuela, and the Santos-Bertioga coast in São Paulo, Brazil. Also included are the chronically impacted mangroves of Cartagena Bay, Colombia and the industrialized southern Brazilian coast, where a soup of pollutants is constantly been released into local mangroves.

In conclusion, a detailed inventory of mangrove areas of Latin America and the Caribbean is still far from complete. With high probability, it will be necessary to designate new and different management categories, as more data are synthesized, due to the high diversity of mangrove habitats on the continent. Therefore, in implementing plans, it is always necessary to consider the limitations of our present understanding both of how mangrove systems function and how well management strategies will work.

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Chapter 10

Developing and Strategy for an ICZM in Cuba: Bases and Principles

T.B. Hernández

10.1 Introduction

The territory of the Republic of Cuba, is considered an archipelago of 67 831 km^2 that lies within the limits of the Cuban island shelf, which has more than 70 000 km^2. This archipelago is made up by the island of Cuba, which is the largest, the Island of Youth (formerly Isle of Pines) and more than 1 600 keys and that islands mostly are grouped mainly in 5 subarchipelagos that surround the Island.

Our territory is in the tropical zone of the Northern Hemisphere, close to the Tropic of Cancer; it occupies a central position in what is deemed the American Mediterranean, at the entrance to the Gulf of Mexico and separating it from the Caribbean Sea.

Cuba occupies a very important strategic position which controls access to three important maritime routes: The Strait of Florida (180 km), the Windward Pass (77 km) and the Strait of Yucatan (210 km). Also, the Strait of Colon (140 km) is between the island of Cuba and the island of Jamaica. The territorial sea is 12 nautical miles wide, measured from a base line that connects the outermost points of the Cuban territory and all the territory between this line and the shore is regarded as inner waters. The economic or maritime zone next to the territorial sea extends 200 nautical miles (Borges 1996).

Cuba has 5 746 km of coasts, mostly of coral origin, which have open type and sheltered baglike bays. There are excellent sandy beaches at the north coast while the south coast is generally low and partly muddy. Swamps and wetlands cover 8.26% of the total surface of the country.

Cuba, as most islands is highly biodiverse (Table 10.1). Local endemism in the marine environment is very rare due to the continuity and interrelationships existing in the aquatic media. It seems that the Cuban shelf has a bigger species richness than other Caribbean islands. This high diversity in marine species seems favoured by several factors. First, Cuba is the largest island of all the Antilles, with a relatively wide marine shelf in some places, with numerous bays, coves, river mouths and other coastal geographical accidents which allow the existence of a wide diversity of tropical marine biotopes, which include from open rocky shores, mangroves, seaweed fields, muddy or sandy bottoms, up to the coral reefs (which can be found as deep as 80 m) (Estudio Nacional sobre la Diversidad Biológica de la República de Cuba 1995).

As we will see along this paper, the protection and sustainable use of these valuable resources constitutes a real challenge on account of the threats caused by marine pollution, the unregulated development of the coastal zone for touristic and industrial aims, dumping of solid waste and toxic liquids, the inadequate use of fishing arts and the unexistence of legal regulations or frames that foster conservation in the widest sense

Table 10.1. Diversity of marine life (Estudio Nacional sobre la Diversidad Biológica de la República de Cuba 1995)

	Diversity of marine life	
	Number of species reported in Cuba	Probable number
Microalgae	360	1 000
Macroalgae	354	
Monera (bacteria)	533	
Fungi	11	
Yeasts	34	
Protozoa	300	
Porifera	250	600
Coelenterata	160	250
Mollusca	1 479	1 800
Annelida	338	
Crustacea	981	1 600
Echinodermata	393	520
Piscis	906	1 200
Reptilia	4	4
Mammalia	3	3

(National Environmental Strategy 1997). Unfortunately, marine and coastal biodiversity and associated resources everywhere are increasingly subject to a range of human-caused threats, such as land-based sources of pollution, overexploitation of living resources and destructive harvesting techniques, and the introduction of alien species (de Fontaubert et al. 1996).

10.2 Coastal Ecosystems and their Main Problems

10.2.1 General Characteristics of the Cuban Platform

From the geologic, tectonic and geomorphologic points of view, the platform can be considered as a single area split into four different regions, which are separated by narrow zones.

10.2.2 Main Coastal Ecosystems in Cuba

- Coral reefs;
- Sea weed pastures;
- Mangroves;
- Coastal lagoons and estuaries;
- Beaches and sandy bottoms;
- Bays;
- Wetlands.

10.2.2.1
Coral Reefs

Our reefs form ridges, promontories, bars and rocky terraces alternating with sand channels. Sessile organisms are mostly represented by rocky corals, sponges, gorgons, ascidians and algae, and the mobile organisms are a rich fauna of fishes and invertebrates.

Cuban reefs extend along almost all the border of the platform and in some places inside it. About 54% of this border is separated from the Island by wide and shallow marine expansions and by groups of cays that limit human influence on nearby reefs. Although large expanses of the coast are very little urbanized or industrialized, historically they have been deforested, something that contributes to the drainage of sediments to the sea. Because of this, sedimentation rather than pollution seems to be one of the more important things that affect the reefs in Cuba.

Other things that affect our reefs are caused by organic pollution or fertilizers, (which stimulate the growth of algae and plankton causing in turn a decline on the coral through competition); turbidity; pollution with toxic waste (pesticides, herbicides, heavy metals, hydrocarbons); thermal pollution caused by cooling systems from thermoelectric plants; mechanical damage caused by anchors from boats in touristic zones; nonregulated extraction of rock corals; hurricanes; sediments caused by constructions, explosions, waste dumping and abandoned fishing nets and traps.

10.2.2.2
Sea Pastures

Sea pastures, known in Cuba as "ceibadales" are silted bottoms where see weeds (phanerogams) and algae grow. The predominant species in Cuba is *Thalassia testudinum*. The sea pastures are the most extended biotope in our platform, covering more than 50% of our sea bottoms.

These ecosystems have considerable tolerance and elasticity to many stress factors, but they have been widely eradicated in different zones in Cuba through the actions of hurricanes (dragging large amounts of sediments) and partial closure of channels; pollution from sugar mills waste and a torula factory, which make the bottoms muddier; building dams and highways over the sea, causing an increase in salinity, excessive turbidity caused by eutrification and resuspensioning of the sediments; strong erosion suffered by mud coasts on the North due to the disappearance of the protective red mangrove barrier; turbidity caused by intense shrimp fisheries in some zones; organic pollution or through nutrient salts and dragging bottoms.

10.2.2.3
Sandy Areas and Beaches

The coast line of Cuba is 5746 km long, with more than 520 km of beaches of a very high quality and aesthetic beauty, which are its main touristic resource. Many beaches have been affected by building on the dune and bad management, as well as a relative rise on the sea level, excessive extraction of sand, pollution, bottom dragging, reduction of ocean waves or currents due to constructions, which causes an increase in mud content, destruction of plant life on the dune and inadequate introduction of incorrect vegetation and net dragging.

10.2.2.4
Bays

Bays in Cuba are mainly shaped like bags, relatively closed, and where areas of industrial development and the main ports of the country can be found. Some of them also have important populations of fish, shellfish and molluscs which are important fishing resources. Almost all Cuban bays are affected by pollution, in some cases in an intense manner.

The main cause of pollution in bays are terrestrial sources: urban, industrial, mining, agricultural and other kinds of waste. Although waste caused by port-maritime activities has a significant effect in the deterioration of these ecosystems when not handled correctly.

Generally, Cuban bays show a growing deterioration of the quality of its waters and coasts and degradation of the landscape, causing an important decrease in their uses specially as a recreational landscape and its fishing use, and a lose in values in services due to the presence of naval and shore facilities (Chabalina 1997).

To give an example of the conditions of Cuban bays we can mention two of them.

Havana Bay, is highly polluted due to numerous discharges from urban and industrial waste sources that it receives through the rivers Luyano and Martín Pérez at Guasabacoa Cove and other sources that flow into Atares Cove and several direct industrial sources. The main sources are from an oil refinery, a distillery, a yeast plant and two slaughter houses.

Since may 1996 project "Planning and Management of Highly Polluted Bays and coastal Zones in the Great Caribbean Region" from GEF/UNOPS/UNEP is being carried out, which includes studies of feasibility and preinvestiments on a set of solutions for environmental sanitation of Havana Bay. The first objective is to carry out studies that include treatment of industrial liquid waste which is dumped directly into the bay (whether from industrial activity as such, from port activities or from moving sources). The second objective aims at institutional strengthening, to achieve an increase in research, planning and cooperation capacities to carry out corrective measures. The third objective is still being planned, and is aimed at attracting national and international financing to implement the resulting executive projects to carry out the first two objectives.

The second example, the Bay of Nipe: Is a productive, dynamic and healthy ecosystem with high values of dissolved oxygen and with zones that maintain an ecological balance in almost all the bay. It has no problems of pollution from hydrocarbons nor sanitation. However, there is a group of pollution sources that affect the bay:

- Mining runoff through river Mayari and Cajimaya stream, which is causing an important increase in heavy metal content in the sediments and a reddish coloration in the estuarine waters.
- The torula factory and the sugar mill which produce nutrients and organic matter which affect 30% of the bay area and cause a conflict between its use for fishing and as a waste receptor.
- A slaughter house and the sewage drainage from several townships, which have a lesser impact in the deterioration.

To preserve the ecosystem, a set of measures have been proposed, which include: for the torula plant, a previous treatment of the waste and the use of an oxidation lagoon; for the sugar mill and one of the townships, previous treatment and evacuation through an underwater pipe; for the mining runoff, to create antipollution barriers.

10.2.2.5
Mangroves

The greater part of the coasts of the Cuban archipelago are bordered by mangroves, as well as the thousands of lagoons and estuaries which are particularly abundant in the SE region of the island. Cuban mangroves are 4.8% of the national territory and 22.3% of the forests in the country.

Mangrove vegetation in the Cuban archipelago is comprised mainly by four arboreal species, three of them considered true mangroves: *Rhizophora mangle* (red mangrove), *Avicennia germinans* (black mangrove), and *Laguncularia racemosa* (patabán). *Conocarpus erecta* (yana) is considered a marginal species.

The fauna which develops associated with the mangrove forest is very rich and diverse, birdlife is outstanding for its abundance as well as for the presence of endemic species with restricted habitats. Our mangroves act as a refuge and nesting site for many marine species, specially beautiful is the species *Phoenicopterus ruber* (flamingo), with large flocks that carry out their activities in the estuaries and other sites related with the mangrove ecosystem.

Regarding mammals, in our mangroves there are many endemic mammals of the genus *Capromys* (hutia), with five different species, some with a very restricted habitat. A large aquatic mammal is also related with the mangroves, *Trichechus manatus* (manatee), under permanent observation for being an endangered species.

There are two species of large reptiles in Cuban mangroves, *Crocodylus rhombifer* (Cuban crocodile) and *Crocodylus acutus* (American crocodile), both of great economical value.

Also, in the mangrove roots there are many molluscs, sponges, polychaete, coelenterate, biozoos and cirripeds. Among the molluscs, the species *Crassostrea rhizophorae*, also known as mangrove mussel, is very abundant.

The richness of fish life, which develops under the influence of the mangroves and includes many species with economic value, should be remarked.

It is estimated that over 30% of mangrove forests in Cuba have been affected; this is due to two kinds of fundamental causes: natural ones and those caused by human activity. Natural affectations are not extended and are rather local. They include deterioration by the abrasive action of the sea over the coast, desiccation of lagoons, accumulation of sand which covers the roots of the mangrove tree causing its death, the destructive effect of hurricanes and drought.

Anthropic causes that cause destruction of mangroves are the increase in salinity together with a diminution of organic matter in the sediments of the bottoms, all caused by construction of roads, dams, drainage systems and other kinds of constructions that interrupt the normal flow of water in the mangrove; unsustainable forest exploitation and pollution of the littoral zone.

10.2.2.6
Littoral Lagoons and Estuaries

Lagoons are usually shallow water bodies (0.2–2 m deep) with little water exchange with the sea that usually takes place through narrow channels and according to the tides. Generally they are surrounded by mangroves and most of them receive from the land a considerable amount of water, sediments and organic matter, which in part determines their biological productivity. In fact, lagoons and estuaries are the marine ecosystems with the highest fisheries productivity and are the habitat with the highest potential to develop marine culture. They harbor species with a high ecological value, like the manatee, an endangered species.

They are affected by pollution through dumping from agroindustries (mainly the sugar industry), agriculture (pesticides, herbicides, etc.), sewage, river damming, reduction of water exchange with the platform due to constructions in the littoral zone, mangrove deforestation and illegal fishing.

10.2.2.7
Wetlands

In our country, wetlands need a special mention as coastal systems. Because of being an island, Cuba has important wetlands which are prioritized sites for preserving biological diversity and the stable functioning of important ecosystems, both for their economic production as well as for its natural values.

Because of their natural values, there are three particularly important wetlands in Cuba: the Zapata Swamp, the mouth of the Cauto river and the Lanier swamp. To these could be added the Sabana-Camagüey archipelago and others. Due to its size and richness, the Zapata Swamp is recognized as the most important wetland among the Caribbean islands.

Around 60% of Cuban wetlands have suffered medium to high anthropic modification; around 25% are modified to a medium degree and 15% are in a natural state or little modified. The main actions that affect Cuban wetlands are: creation of dams, drainage systems and other hydraulic constructions; overexploitation of surface waters; reduction of forest cover and changing the natural vegetation to a monotypic forest; introduction of exotic species; creating human settlements and their networks of facilities without proper integration to the peculiarities of the zone.

The main impacts resulting from these actions are changes in the water cycle with a tendency to desiccation in some areas, destabilization of the natural vegetation, mainly in mangrove areas, loss of habitat for important species of the fauna and the flora, eutrophication processes in channels and other water bodies, salinization of soils and water reservoirs, and an increase in the silting process in lagoons, both littoral and inland.

Of all the above affectations mentioned in each of the Cuban coastal ecosystems, pollution from land sources demands special attention, as it is the most important threat to the marine environment and the main obstacle for the sustainable use of oceans and coastal zones and their resources. Land sources produce 77% of ocean pollution, while maritime transport and spills represent only 10% each.

10.3
Coastal Protection: Precedents and Current Situation

10.3.1
Protection of Fisheries Resources

Among the main characteristics of fisheries in Cuba we can mention (Consulta Nacional Río+5 1997):

- a very large number of exploited species,
- the artisanal character of the fishing arts,
- the use of fishing boats that rarely exceed 20m in length, typical of local fisheries.

The Decree-Law N° 164 "Fishing Regulations" (Gaceta Oficial de la República de Cuba 1996) is the main legal document that regulates exploitation of fisheries resources and preservation of the environment. This Decree-Law came in effect in September 1996 and its main characteristics are the following:

1. It establishes a system for granting fishing licenses or permits to any person, natural or juridical, that wishes to practice commercial, sporting or recreative fishing.
2. It creates a national consultation organ with a wide representation to advice the Ministry of Fisheries regarding management and administration of fisheries resources.
3. It forbids fishing, shipment, transportation, industrial processing and commercializing a group of endangered or threatened species (sea turtles, manatee, black coral, etc.).
4. It establishes a set of fines and severe penalties to any person that does not practice a responsible fishing.

In an institutional manner, the Ministry of Fisheries has created the national Office for Fisheries Inspection, charged with enforcing all the regulations stipulated for the conservation, fostering, and rational use of aquatic resources that live in the economical zone, territorial waters, and aquatic ecosystems.

The environmental policy for the fishing sector is based on the "Sustainable use of aquatic resources and the creation of conditions for establishing clean productions in the Cuban fishing industry with the aim of increasing economic efficiency, maintaining biological diversity, protect the aquatic ecosystem and insure consumer protection".

For over 30 years studies and actions to preserve coastal zones and oceans have been carried out, and although they were not integrated in a national strategy of integral coastal management, they allowed to accumulate a wide experience and information, train scientific personnel, carry out important rehabilitation tasks and establish the bases for the elaboration of the strategy and the legal frame where the strategy will be based for its implementation.

10.3.2 Scientific Research in Coastal Areas

At a national level, the country has 8 scientific institutions in charge of research and development of marine science. To deal with the problems on this sphere, these institutions count with highly qualified human resources. There are delegations of these institutions in the East, Center and West of the country, working in marine and coastal environmental problems.

The institutions at the national level are:

- Institute of Oceanology, Ministry of Science, Technology and Environment;
- Centre for Fisheries Research, of the Ministry of Fisheries;
- Centre of Marine Research, Havana University;
- Geomar Enterprise, Ministry of Heavy Industries;

- National Aquarium, Ministry of Science, Technology and Environment;
- GEOCUBA, Ministry of the Armed Forces;
- Centre for Research and Environmental Management of Bays, Ministry of Transport.

The main research lines of these institutions are:

- Biology, ecology and behaviour of fishing resources;
- Studies on marine biodiversity;
- Marine and coastal ecology;
- Causes and impact of marine pollution;
- Studies of coastal processes, specially on sandy beaches;
- Marine geomorphology, for the prospection of arids on the platform;
- Projects of coastal engineering;
- Integrated studies for developing sustainable tourism on small insular groups;
- Effects of climate changes, particularly sea level rise.

As a result of these studies the country has a wide and diverse data base on ecological, economical and social elements of the coastal zones.

10.3.3 Territorial Planning

For over two decades, a coherent policy of territorial planning has been developed, in which protection of the environment has been always an essential element. This planning policy is also applied in coastal zones. Coastal zones with activities for socio-economical development have been regulated by territorial plans jointly elaborated by different national ministries and supported by scientific research for decision making. In this sense, and with special emphasis, studies for the development of tourism in coastal zones were carried out.

10.3.4 Coastal Rehabilitation

Cuba is a well known tourist destiny. The Cuban Archipelago has several attractive features, specially the coastal zones, with thousands of kilometres of sand beaches and coral reefs, the tropical climate and the variety of landscapes. But, as it is stated in the Barbados Programme of Action "... if not properly planned and managed, tourism could significantly degrade the environment on which it is so dependent" (CDS 1996).

There is a wide experience and wonderful results have been achieved in the rehabilitation and remodelling of beaches. The most important example is Varadero, where more than 15 years of studies on the dynamics of the beach and the characteristics of its profile allowed a successful process of rehabilitation.

Plans for the conservation and restoration of other critical habitats have been carried out, specially in altered bays and wetlands, where national institutions related to the coastal environment have been involved. Besides, several national innovations have been established to relieve the negative effects of different anthropic actions on the coastal zone.

10.3.5
Strengthening of the Institutional Basis

The Ministry of Science Technology and Environment was created in 1994, its main functions related with environmental protection are (IX Reunión de Ministros de América Latina y el Caribe 1995):

- To increase and strengthen environmental inspection to insure compliance with legislation.
- Redefine procedures for assessing environmental impact and insure control of any recommendations issuing from it.
- To update and complete national environmental legislation.
- To achieve greater integration between environmental management and national science.

Organizational Structure of the Ministry to accomplish these the functions:

- Direction of Environmental Policy;
- Environmental Agency:
  - Center for Environmental Management and Inspection;
  - Center for Protected Areas;
  - Center for Environmental Information and Education;
  - Research Centres:
    - Institute of Meteorology;
    - Institute of Oceanology;
    - Institute of Ecology and Systematics;
    - Institute of Tropical Geography;
    - Institute of Geophysics and Astronomy;
  - Centres for Recreation and Education:
    - National Zoo;
    - National Aquarium;
    - National Museum of Natural History "Felipe Poey".

10.3.6
Improvement of the Legal Framework

Current laws that rule the use, management and protection of the coasts are very diverse and heterogeneous, and the regulations do not include all the necessary aspects for a proper protection, making it necessary to pass new regulations that will warrant defence of the balance and physical progress of these resources, protection of its natural and cultural values, their sustainable exploitation, public use and actions aiming at their restoration and improvement.

Also, it is necessary to define precisely the concepts of coastal and buffer zone, the frame for environmental licenses and their possible uses, as well as insuring compliance with the principle of integrated management by all entities involved.

Already a draft of a Decree-Law for coastal zone management aiming at the conservation and sustainable development of coastal zones and their buffer zones has been presented to be discussed by the Cuban Authorities. It includes among others the following regulations:

- Protection and sustainable use of their components and natural characteristics;
- Monitoring and government environmental inspection to warrant their integrity and to achieve the use it was aimed at;
- Establishment of measures aimed at insuring the free use and public enjoyment, without charge, of the coastal and the buffer zone;
- Assessment of the environmental impact of the works, facilities and other actions that take place in it and to grant Environmental Licenses for developing the first;
- Environmental planning of the uses of the coastal and buffer zones;
- Actions for improvement and rehabilitation, whenever convenient;
- Implementation of mechanisms to guarantee the rational use, protection and "in vivo" conservation of coastal and marine biological diversity;
- Development of multidisciplinary scientific research;
- Planning of economic activities.

The Decree-Law project includes, in the first place, a group of basic definitions of the elements that constitute the coastal zone. The aspects regulated by this Decree-Law are the following:

1. Management;
2. Establishing landmarks;
3. Limiting property rights;
4. Allowed and forbidden uses;
5. Environmental licenses for construction projects or other activities;
6. Constructions;
7. Economic activities;
8. Pollution from land and other sources;
9. Waste dumping;
10. Extraction of building material;
11. Mining activities;
12. Human settlements;
13. Protection and use of biological diversity;
14. Fragile ecosystems (beaches, coral reefs, wetlands, mangroves, keys and peninsulas);
15. Economic regime;
16. Misdemeanors and sanctions;
17. Administrative competence.

It is important to point out that a new frame law for the Environment was approved by the Cuban Parliament in 1997 (Ley de Medio Ambiente 1997). A whole chapter in it is devoted to the protection of marine waters and marine resources. It establishes clearly that the protection of marine waters includes marine inner waters, territorial waters, the adjacent zone and the economic adjacent zone.

Also, important for coastal zone protection are other legal bodies, most of them already approved related to the following items: Environmental Impact Assessment, State Environmental Inspection, Hazardous Wastes, Ozone Layer Depleting Substances, Protected Areas, Toxic Chemicals, Implementation of CITES, Biodiversity Protection, and Climate Change.

10.3.7
International Activity

In the international field, among others, Cuba has ratified the following important international environmental treaties related directly or indirectly to coastal and marine protection:

- Convention on the High Seas, Geneva, 1958;
- International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties. Brussels, 1969;
- Convention for the Protection of the World Cultural and Natural Heritage. Paris, 1972;
- Convention on the Prevention of Marine Pollution by Dumping Wastes and Other Matter. London, 1972;
- Convention on International Trade of Endangered Species of Wild Flora and Fauna (CITES). Washington, 1973;
- International Convention for the Prevention of Pollution from Ships (MARPOL). London, 1973–1978;
- United Nations Convention on the Law of the Sea (UNCLOS). Montego Bay, 1982;
- Convention for the Protection and Development of the Marine Environment in the Wider Caribbean Region, Cartagena de Indias, 1983;
- Vienna Convention for the Protection of the Ozone Layer, Vienna, 1985;
- Montreal Protocol on Substances that deplete the Ozone Layer, Montreal, 1987;
- Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal. Basel, 1989;
- Convention on Biological Diversity (CBD). Rio de Janeiro, 1992. Representation in the Subsidiary Body on Scientific, Technical and Technological Advise (SBSTTA);
- United Nations Framework Convention on Climate Change (FCCC). New York, 1992;
- Barbados Programme of Action for the Sustainable Development of Small Island Developing States. Bridgetown, 1994;
- United Nations Agreement on Straddling and Highly Migratory Fish Stocks. New York, 1995;
- FAO Code of Conduct for Responsible Fisheries. Rome, 1995;
- Global Programme of Action to prevent, reduce and control marine pollution from land-based activities. Washington, 1995.

10.3.8
Facing the Climatic Changes

Being Cuba an island, with wide coastal plains and because of its geographic position, is very vulnerable to climatic phenomena, specially storms and hurricanes as well as to sea level rises.

A national group was created since 1991, made up by institutions related to the causes, processes and effects of the increase in atmospheric temperature, which has been assessing and identifying measures to be applied in order to mitigate this problem.

Cuba has taken an active participation in the International Committee for the Negotiation of the Frame Convention on Climatic Changes, to which it has adhered since January 1994, as well as to the works of the Intergovernmental Panel (IPCC) and to the International Global Biosphere Program (IGBP).

Making reliable weather forecasts is a state priority, both on the part of the Ministry of Science, Technology and environment and on the part of the National Civil Defence, in coordination with all state organisms and local governments. Results have been positive, being able to count with qualified staff and an intense international collaboration in this sense. Cuba has a high level of development in emergency plans, which have been proved to be efficient under extreme situations.

Recently the National Scientific Program "Global Changes and Evolution of the Cuban Environment" was approved to be set in action. 45 institutions take part in this program in one or more of the following topics, according to their profiles:

- Pollution and atmospheric chemistry;
- Climate variability and climate change;
- The ocean and the ocean-atmosphere interaction;
- Coastal zone and land-ocean interaction;
- Biodiversity;
- Land ecosystems;
- Agricultural ecosystems and soil;
- Hydrological cycle;
- Human dimension in global changes;
- Data systems and information.

As estimates indicate that nearly two-thirds of all human beings live or have activities in the coastal zone (Gómez 1996), an important study about this issue was carried out within the frame of this program. An assessment of the vulnerability of the coastal zones was made in it, with special emphasis on the coastal settlements located below a level of 1 m above sea level. The study includes recommendations to protect the population that might be affected (Pérez et al. 1996).

10.4
Final Objectives and Actions

The challenge imposed by the imperative need to protect the country's coastal and marine resources demands materialization of a strategy for the integrated management of our coastal zones. ICZM is a continuous adaptive, day-to-day process which consists of a set of tasks, typically carried out by several public and private entities. Together the tasks produce a variety of products and services from the available coastal resources. ICZM involves continuous interaction between human systems and natural systems, between human systems and between natural systems, as these systems "coevolve" over time (Turner and Bower 1996). To be "sustainable", ocean and coastal management, based on the new "ocean economics" will have to contribute to a solution of the most pressing socio/economic problems in coastal areas where the majority of human populations are concentrated: the problem of employment in the industrialized states; the problem of poverty alleviation in the developing countries (Borgese 1997).

The basic premises for these strategy must be:

1. To promote the adequate use of knowledge about the physical, biological, social and economical elements of our coasts accumulated over 30 years;
2. To insure that managers of coastal and marine resources acquire a conscience upon the importance of their sustainable use;
3. Constant updating of the information upon the status and use of the marine and coastal resources that officials who are to make decisions about these resources and the communities that inhabit coastal zones must have, so they can make favourable decisions;
4. To have an effective legislation and legal regulations in order to protect the coastal and marine resources.

The fundamental elements of the strategy must be:

1. To develop the capacities of national institutions to put into practice research and surveillance on marine pollution, as well as devising and putting into practice mechanisms to control and reduce pollution;
2. To consolidate the Cuban system of protected marine areas, equipping it with legal, technical and financial instruments for its efficient functioning;
3. To promote involvement of local communities in the management of the coastal and marine zone, through the development of programs to educate, and mobilize in this direction and to use all their traditional knowledge;
4. To improve the management of the coastal and marine resources, as well as the adequate mechanisms and institutions for it, making use of environmental impact evaluation as an essential tool;
5. To continue and increase coastal and marine rehabilitation works through regeneration projects and fostering conditions for them;
6. To protect fishing resources through sustainable use, by increasing the efficiency of officials that manage these resources, insuring that established fishing quotas are observed for each species, area and season, and observing regulations regarding fishing arts;
7. To constantly update the contingency plans against spills and maintain active the mechanisms for their execution;
8. To continue developing interdisciplinary scientific-technical research, to continue encouraging the use of geographical information systems and other advanced technologies regarding coastal and marine studies;
9. To strengthen international bonds in the coastal and marine environmental sphere, promoting joint research in order to monitor and protect the environment, with special emphasis in the Great Caribbean region (Ramírez 1995);
10. To increase research and develop new methodologies that allow answers to the forecasts of climatic changes.

The needs for the coexistence of economic development and ecosystem functioning cannot be underestimated. However, it remains that ecosystem management and protection are inevitably a compromise among competing alternatives; many are not transferable from one setting to another, with different technical needs, opportunities and constraints (Eagle 1996).

10.5 Conclusions

In order to elaborate a strategy for the integrated management of coastal zones it is essential to achieve a joint and coordinated work by all the different parties, eliminating the usual practice of managing the natural resources according to sectorial interests.

The coastal zone is a multifunctional system with numerous resources that can be exploited by different users with different functions. At the water-land interface there are terrestrial, aquatic and transitional subsystems that interact strongly among themselves, and support different and shared resources. For this reason, entities that manage the lands and coastal resources should not work independently from those that manage marine resources.

To achieve an efficient use of coastal resources, a strong and clear interaction between the ecological, economical and institutional aspects is needed, and managers must know the detrimental impact that unplanned use of a subsystem can have upon another and the resulting negative impact upon economy and nature.

Likewise, it is of vital importance the conception of an organization or legal and institutional frame inside which decisions are made and applied in mutual agreement, with an adequate sharing of implicit responsibilities and costs. A proper combination of regulations and economic instrumentation needed for the management of natural resources must be achieved.

Conservation of the environment is a responsibility of all, therefore the need to strengthen public participation in this context. The population must be warned of the consequences of its actions and of its own role through environmental education at all levels of schooling and through mass media. This way its active participation in conservation and sustainable development can be encouraged.

Management is a complex and expensive task, and susceptible of failure if the aspects involved are not properly applied. Without such conviction at all levels and institutions, management will not achieve its goal and the disastrous consequences to economy and quality of life will not take long to appear. Conservationist management must also imply economic, social and cultural aspects.

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Chapter 11

Coastal Zone Management in India – Problems, Practice and Requirements

S. Ramachandran

11.1 Introduction

Coastal environment plays a vital role in a nation's economy by virtue of their resources, productive habitats and rich biodiversity. India has a coastline of 7516 km of which the mainland accounts for 5422 km, Lakshadweep coast extends 132 km and Andaman and Nicobar islands have a coastline of 1962 km. Nearly 250 million people live within a distance of 50 km from the coast. The coastal areas are assuming greater importance in recent years, owing to increasing human population, urbanisation and accelerated developmental activities. The coastal region is thus, a place of hectic human activity and the coastal ecosystems are now highly disturbed and threatened tremendously. Current approaches to the management of coastal resources were not capable of sustainable development and the coastal environments and resources are rapidly degraded and eroded in India. In this paper, the coastal environment, its resources, its problems and management initiatives and requirements for integrated coastal zone management in India are discussed.

11.2 Indian Coastal Environment

The mainland coastline of India is remarkably unintended and generally emergent. The Indian coastal zone comprises of

i. the east and west coasts of the mainland and
ii. three groups of islands, the Lakshadweep in the southern Arabian sea and the Andaman and Nicobar island groups in the eastern Bay of Bengal.

The east and west coasts are markedly different in their geomorphology. The west coast is generally exposed to heavy surf and rocky shores and headlands. The east coast is generally shelving with beaches, lagoons, deltas and marshes. It is also situated relatively low with huge alluvial plains and deltas. Furthermore, the coastal zone is also endowed with a very wide range of coastal ecosystems like mangroves, coral reefs, sea grasses, salt marshes, sand dunes, estuaries, lagoons, etc. which are characterized by distinct biotic and abiotic properties and processes. The areas under major wetland categories of the coast are given in Table 11.1.

Table 11.1. Areas under major wetland categories of the coast (*Source:* SAC 1992)

Categories	Area (km^2)
Mudflat	22961
Beach/spit	1465
Shoal/bar	93
Coral reef	1270
Mangroves	3979
Marsh vegetation	370
Mudflat with vegetation	6125
Beach vegetation	290
Lagoon/backwaters	2132
Flood prone area	3437
Coastal dunes	2509
Reclaimed area	1212
Paleo beach ridges	434
Paleo mudflats	6821
Strand plain	1378
Salt affected area	697
Salt pans	1617

11.3 Coastal Zone Problems in India

The coastal areas in India face wide range of problems. A recent regional survey conducted by International Ocean Institute, Operational Centre at Madras revealed several problems and the results obtained are shown in Fig. 11.1. The problems were rated according to their importance from 5 to 1. As per the survey, in India, population pressure has been considered as the most important problem. Environmental degradation such as destruction of mangroves along with pollution and urbanisation are considered as the next serious problem. Surprisingly, the much talked about aquaculture received a low rating. Similarly, sea level rise is also not considered as a major issue (Rajagopalan 1996).

11.3.1 Population Pressure

Traditionally, coastal areas are highly populated and developed because they are the places where trade, transport, communication and civilisation are well developed. It is estimated that by A.D. 2000, out of the total of 25 global mega cities, 15 would be on the coast. In India, out of the 3 mega cities with population more than 10 million, Delhi (13.2 million), Bombay (16 million) and Calcutta (16.5 million), two are coastal cities, i.e., Bombay and Calcutta (Sinha 1996). The population density is also much more in coastal areas than the national average. For example, in the state of Tamilnadu, the population density in coastal areas is 527 km^{-2}, against 372 km^{-2}, which is state average. In parts of coastal metropoles like Bombay, Calcutta and Madras the population density ranged from 20000 to 50000 km^{-2}. The increased population pressure led to resource depletion and environmental degradation.

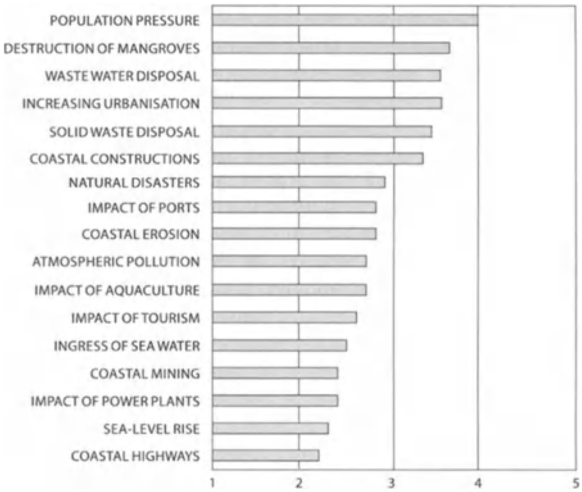

Fig. 11.1. Coastal zone problems in India (*Source:* Rajagopalan 1996)

11.3.2 Coastal Pollution

The major activities that are responsible for coastal pollution in India are discharge and disposal of untreated domestic and industrial wastes, discharges of coolant waters, harbour activities such as dredging, cargo handling, dumping of ship wastes, spilling of cargoes such as chemicals and metal ores, oil transport, fishing activities such as mechanized fishing vessel movement, draining of waste oil, painting of fishing vessels, inflow of fresh water into this part of Sundarbans as a result of the construction of the Farrakka Barrage in 1971, designed to divert fresh water southwards to alleviate the rapid siltation in the port of Calcutta. Inflow is now confined only during the monsoon period. In the state of Tamilnadu, between the years 1986 and 1993, 0.36 km^2, of mangroves in Pichavaram was lost and over a period of 20 years 2 825 km^2, were lost (Ramachandran et al. 1995). Mangrove destruction in the Andaman and Nicobar islands is described by Singh et al. (1986) and Balga and Menon (1989). About 10 000 ha have reportedly been cut since 1960, mainly for fuel. The reports of Ministry of Environment and Forests, Government of India (1987) have shown

Table 11.2. Distribution of mangroves along the Indian coast (measured through remote sensing)

State/union territory	Area (km^2) (1994)
1. Andaman and Nicobar groups	966
2. West Bengal (Sundarbans)	2119
3. Orissa	195
4. Andhra Pradesh	378
5. Tamil Nadu	21
6. Karnataka	n.a.
7. Goa	3
8. Maharashtra	155
9. Gujarat	419
Total	4256

that India has lost 37% of mangrove forests between the years 1987 and 1994. According to the recent data from the Space Applications Centre, mangrove areas are only 3 960 km.

11.3.2.1
Disposal of Domestic Waste

Domestic wastes are discharged mostly in untreated conditions due to lack of treatment facilities in most of the cities and towns (Ramachandran et al. 1991). It has been estimated that approximately 18.24 million l d^{-1}) of domestic waste water reaches the coastal waters of the country (Department of Ocean Development Report 1996).

11.3.2.2
Industrial Wastes

India is one of largest industrialized nations in the world. Major industrial cities and towns of the country such as Surat, Bombay, Cochin, Madras, Vishakapatnam and Calcutta are situated on or near the coastline. The estimated total quantity of waste discharged by these industries is estimated to be approximately 700 million m^3. (DOD 1996). The Central Pollution Control Board (CPCB) has recently compiled a report on the pollution potential of the industries in coastal areas of India (CPCB 1996). The data from this report are presented in Table 11.3.

Table 11.3. Pollution potentials of coastal industries (*Source:* Ministry of Environment and Forests 1994)

State	Number of industries	ETP provided	N° ETP	Effluent qty. (10^6 m^3/day)	Discharge Type	Solid waste qty. (MT/d)	Discharge type
Gujarat	35	34	1	0.566	ID (32) D (3)	9506	LF/D/I
Maharashtra	167	150	17	0.08	ID (130) D (37)	2628	LF/D/I
Goa	2	2	–	0.012	ID (2)	1.4	n.a.
Karnataka	3	3	–	0.043	ID (2) D (1)	76	D/I
Kerala	26	26	–	0.151	ID (19) D (7)	2431	LF/D/I
Tamilnadu	30	29	1	0.125	ID (12) D (18)	9112	D/I/S
Aquafarms	20	(untreated 90%)		0.253	D (20)	–	D
Pondicherry	4	4	–	0.006	D (4)	1.25	LF/S
Andhra Pradesh	30	29	1	0.35	ID (26) D (4)	7191	LF/D/I
Aquafarms	88	(untreated 100%)		2.116	ID (46) D (42)	–	D
Orissa	4	4	–	0.001	ID (4)	3505	n.a.
Aquafarms	20	(untreated 100%)		–	D	–	D
West Bengal	7	7	–	0.022	ID (7)	25	LF
Aquafarms	10	(untreated 100%)			D	–	D

ID Indirect, *D* Direct, *LF* Land Filling, *D* Dumping, *I* Incineration, *S* Stored, *n.a.* Not Available, *ETP* Effluent Treatment Plant.

11.3.3 Coastal Environmental Degradation

11.3.3.1 *Degradation of Mangroves*

The mangroves constitute an important coastal resource in India and mainly function as the most ideal spawning, breeding and nursery grounds for economically important fish and crustaceans. They also act as "Coastal Stabilizers" and "Shelter belt areas". These formations protect the coasts and the landward areas from erosion and cyclonic destructions to some extent. Mangroves constitute a significant portion of the coastal wetland in India and a fairly large percentage of the coastal population is dependent on mangroves. In India, damage to mangroves has been particularly serious on the west coast where there is no established forest industry. Indiscriminate exploitation fro timber, firewood, charcoal and tanning, conversion of mangrove areas to residential and industrial estates, extension of harbours and docks, uncontrolled pollution from tankers, sewage, industrial effluent discharge and pesticides from agricultural runoff all contribute to the degradation of mangroves. In the coast of Gulf of Kuchch, over 110 000 t of mangrove trees were cut down between 1948 and 1978 (Untawale and Sayeeda 1987). On the east coast, the mangroves are degraded by conversion to agriculture, aquaculture, for fuel needs and as fodder for cattle. Damage to Sundarban's mangroves is summarized by Scott (1989). In the western part of Sundarbans, large areas are settled and cultivated and very little natural mangrove forest has remained. Furthermore, there has been a major reduction in the human use or impact occurs directly and intentionally in harvesting reef resources such as fish, shells, or collecting corals or coral sand for building or for industrial use. Several coral reefs have almost disappeared because of the collection of the coral debris and live corals for use as a raw material in the cement industry, while other have died due to their constant exposure to pollutants such as oil (Wafar 1986). The development of Tuticorin harbour and associated oil pollution and industrial discharges have caused significant damage in the Gulf of Mannar and Palk Bay area (UNEP 1985). Reefs of Gulf of Kuchch are said to be under serious threat from sand mining and industrial pollution. Coral mining industry has caused major damage to the reefs of the Gulf of Mannar, Gulf of Kuchch, Andaman and Nicobar islands. In Tamilnadu, over 400 people are employed in the Gulf of Mannar area where 10 000 t of lime are produced per year. For this purpose, about 15 000 t of corals are taken a year. This continues even though it was banned in 1979. The massive corals are mined for building and roads. These activities have damaged reefs both in the Gulf of Mannar and in Palk Bay (Ramachandran 1997).

11.3.3.2 *Degradation of Coral Reef*

Coral reefs are biologically diverse in comparison with other ecosystems. Reefs are an essential supplier of protein to subsistence communities, a valuable currency earner for low income countries through exploitation of their resources and through tourism, a protector of land and a naturalist's paradise. India has a total of 1 270 km^2 of coral reefs in the following coastal states: Gujarat – 130 km^2, Tamilnadu – 10 km^2, Lakshadweep – 71 km^2

and Andaman and Nicobar islands – 1 200 km^2. Disposal of domestic and agricultural wastes into coastal waters, poor landuse practices that include sedimentation of rivers and then of reefs, and overexploitation of reef resources, often in combina tion with practices such as harvesting with dynamite and poison – all are constantly degrading the reefs (Ramachandran 1997).

11.3.4 Coastal Fisheries

India has 3 638 fishing villages and 2 251 fish landing centres. The total fishermen population is about 5.8 million (Ministry of Agriculture Government of Inidia 1995). The total marine fish production is about 2.692 million t out of which nearly 50% come from nearshore waters and contributed by traditional fishermen. The major problems in coastal fisheries are overfishing, habitat destruction and degradation, pollution, post-harvest damages due to lack of infrastructure, fishing during monsoon, conflicts among mechanized and traditional sectors, inter-state problems etc. In addition to these, fishing communities also face competition from other resource users. For example, coastal tourism interferes with traditional fishermen in their activities by replacing them and denying access to their traditional fishing ground and beaches. Thus, the livelihood of the fishermen is threatened.

11.3.5 Coastal Erosion

The coastal erosion is caused wave breaking, reduction in sediment input to coasts, tectonic upheavals and rise in sea level. These causes are not only natural, but also, due to human interference. In west coast, erosion is very severe along Kerala coast. About 80% of the entire coastline of Kerala is affected by erosion (about 400 km out of 530 km coast). In Gujarat, Goa and Maharashtra, there is no large scale erosion. In Karnataka, about 73 km of the coastline is affected. Along east coast erosion occurs in all the states, but only moderately. In Tamilnadu, about 80 km of the coastline is affected. In Orissa, about 30–40 km are affected. In West Bengal, erosion occurs in 180 km along the coast line stretching from the confluence of the rive Hooghly in the west to the confluence of the river Jadgan in the east. The rate of erosion is as high as 30 m a^{-1} (Joshi 1995).

11.3.6 Conflicting Uses

In recent years, one of the conflicting uses that has caused greater concern in coastal environment is the development of coastal aquaculture, especially the shrimp culture. The unplanned development of coastal aquaculture and lack of scientific management has significantly affected the agricultural lands and labourers in the two southern states, namely Andhra Pradesh and Tamilnadu. The pumping of sea water into aquaculture farms has resulted in the salinisation of soils and groundwater and the untreated aquafarm discharges affected the coastal water quality and ecosystem characteristics. The socio-economic impacts of development of aquaculture industry was studied by the National Environmental Engineering Research Institute. This study reported that the economic loss due to conversion of agricultural lands and mangroves for aquaculture in Tamilnadu (1 600 ha) is Rs. 1 400 million (US $40 million) and in Andhra Pradesh (9 500 ha) is about Rs. 8 030 million (US $230 million). The major losses were due to loss of agricultural land, labour, fuel wood, mangrove destruction and fishing (NEERI 1995). The lack of scientific management and degradation in water quality has led to large scale outbreak of viral diseases and most of these industries are now being closed due to heavy financial losses and as per a directive from the APEX Court of the country in response to public litigation petitions in view of their pollution and environmental and socio-economic impacts (Ramachandran 1996).

11.3.7
Natural Hazards

In India, nearly 150 million people are prone to natural hazard in coastal areas. Bay of Bengal is one of the five cyclone prone areas of the world. The coastal regions surrounding this bay are frequently affected by flooding from the sea as well as from the rivers due to tropical cyclones and related storm surges and heavy rainfall. Between the years 1990 and 1995 in the southern state of Andhra Pradesh, more than 1 100 human lives were lost and property worth of Rs. 23 000 million (US $700 million) were damaged. In Tamilnadu during the years 1990–1995, the damages caused to property were worth of Rs. 5 800 million (US $170 million) and the loss of human lives was more than 500. The early warning systems and coastal protection methods being a part of ICZM are expected to minimize the loss and control the human interference that increases the degree of severity of these natural hazards (Ramachandran and Pundarikanthan 1996).

11.4
Coastal Zone Management Initiatives in India

11.4.1
International Legal Instruments

India has signed and ratified several international conventions relating to oceans and related to marine environment and applicable for coastal area also. The important ones are the following: MARPOL, 1973/1978; London Dumping Convention, 1972; Convention on Civil Liability for Oil Pollution Damages (CLC 1969) and its Protocol, 1976; Fund, 1971 and its Protocol, 1979. Convention on Biodiversity (1992) includes coastal biodiversity as well.

11.4.2
National Legal Instruments

Many acts and rules related to coastal activities exist in the country. The following are the important ones:

Indian Fisheries Act 1897 and its Amendments 1920 and 1980; Indian Ports Act 1902; Merchant Shipping Act 1974; Wildlife Protection Act 1972; Water (Prevention and Control of Pollution) Act 1974; Indian Coast Guard Act 1974; and Maritime Zones of India (Regulation of Fishing by Foreign Vessels) Act 1981 and Environment Protection Act 1986.

11.4.3 Coastal Regulation Zone Rule

The most important rule that is concerned with coastal zone is the notification under EPA 1986 issued in February 1991 declaring coastal stretches of seas, bays, estuaries, creeks, rivers and backwaters as Coastal Regulation Zone (CRZ). The details of this notified act and the Ocean Regulation Zone Act to be notified by Department of Ocean Development to cover ocean part of the coastal zone are presented below.

11.4.3.1 *Coastal Regulation Zone*

Boundary. From the high tide line up to 500 m in the land-ward side. Area between the low tide line and high tide line. In the case of rivers creeks and backwaters, the distance from the high tide level shall apply to both sides and this distance shall not be less than 50 m or the width of the creek, river or backwater whichever is less.

Category I (CRZ I). Areas that are ecologically sensitive and important such as national parks, marine parks, sanctuaries, reserve forests, wildlife habitats, mangroves, corals, coral reefs, areas close to breeding and spawning grounds of fish and other marine life, areas of outstanding natural beauty, historically important and heritage areas, areas rich in genetic diversity, areas likely to be inundated due to rise in sea level consequent upon global warming and such other areas as notified by government from time to time.

Category II (CRZ II). The areas that have already been developed up to or close to the shoreline. For this purpose, developed area is referred to as that area within the municipal limits or other legally designated urban areas which is already substantially built up and which has been provided with drainage and approach roads and other infrastructure facilities such as water supply and sewerage lines.

Category III (CRZ III). Areas that are relatively undisturbed and those which do not belong to either category I or II. These will include coastal zone in the rural areas (developed and underdeveloped) and also areas within municipal limits or in other legally designated urban areas which are not substantially built up.

Category IV. Coastal stretches in the Andaman and Nicobar islands, Lakshadweep and other small islands except those designated as category I, II and III.

11.4.3.2 *Ocean Regulation Zone*

Boundary. From the lowest low water line up to territorial sea water boundary (12 nautical miles)

Category I. Territorial sea areas adjacent to mainland and Andaman and Nicobar and Lakshadweep islands that are ecologically sensitive and important such as those prescribed for CRZ I.

Category II. Territorial sea areas adjacent to the coastal areas that have already been used for development such as

1. Construction of berths, warfs, navigational channels etc. in major and minor ports;
2. Sea off coastal industries, power plants, refineries and other industries;
3. Reclaimed areas, oil/gas transfer facilities;
4. Municipal limits of cities and towns;
5. Ship building and breaking areas;
6. Sea off beach resorts and marinas etc.

Category III. Territorial sea areas adjacent to the coastal areas which are yet to be used for developmental purposes (not used for activities mentioned under category II) and which have been used for developmental purposes to a limited extent (construction of fishing harbours and navigation) and also the sea areas between two developed areas.

As per CRZ notification, the coastal states must prepare a coastal zone management plan identifying and classifying the CRZ areas within 1 year from the date of CRZ notification i.e. February 1992, but in reality, till 1996 most of the states did not do it. The CRZ notification also stated that during the interim period till the coastal zone management plans are prepared and approved, all developments and activities within CRZ will not violate the provisions of this notification.

11.4.3.3
Prohibited and Regulated Activities in Coastal Areas

Land Part

- Prohibited activities:

  As per the EPA 1986, Coastal Regulation Zone Notification 1991, the following activities are banned:
  - Setting up and expansion of new industries, fish processing except those which require water front;
  - Manufacture or handling or storage of disposal of hazardous substances and discharge of untreated waste and effluents from industries, cities or towns and other human settlements;
  - Dumping of fly ash from thermal power stations and other solid waste dumping;
  - Land reclamation, bounding or disturbing the natural course of sea water;
  - Mining of sand, rocks and other substrate materials other than raw minerals;
  - Drawal of ground water within 200 m of HTL;
  - Any construction activity between the low and high tide line;
  - Altering of sand dunes and other natural features including landscape changes.
- Permissible activities:
  - Construction activities due to defence;
  - Construction of ports, harbours and light Houses;

- Construction of thermal power plants;
- All activities with investments exceeding Rs. 5 crores.

Ocean Part (proposed)

- Prohibited activities in category I:

  In the ecologically sensitive areas, construction of civil and other man-made structures like breakwaters for harbour, floating industries, laying of pipelines, reclamation of sea and its bed, sea bed mining and ship breaking activities are prohibited. However, they can be permitted at a no-impact distance from the outer limit of ESA.

  Discharge of untreated and treated domestic, industrial, aquaculture wastes, nuclear and thermal power plants, dredged materials and operational discharges are prohibited in ESA (may be permitted beyond no-impact distance from the outer limits).
- Permissible activities in Category II and III:
  - Waste disposal after proper treatment as per standards;
  - Disposal from marine and brackishwater aquaculture as per the guidelines and standards;
  - Construction of ports, harbours, breakwaters and dredging of navigational channels can be regulated according to the guidelines;
  - Sea bed mining based on EIA Studies;
  - Construction and operation of OTEC plants;
  - Construction and operation of oil platforms;
  - Movement of ships and tankers.

11.5 Conservation Measures

To protect ecologically sensitive areas, the government has declared three national marine parks.

11.5.1 Gulf of Mannar (Tamilnadu) – 78°08′E–79° 30′E Long. and 8° 35′N–9° 25′N Lat.

The Gulf of Mannar Marine National Park was established in the year 1983 to conserve and restore the ecosystems of the Palk Bay and the Gulf of Mannar in the southeast coast of India. Subsequently, the Gulf of Mannar marine biosphere reserve was set up in February 1989 jointly by the Government of Tamilnadu and Government of India. It is the first of its kind in India and probably, in southeast Asia. Lying between India and Sri Lanka, covering an area of about 10 500 km^2, it runs along (mainland) India coast to about 170 nautical miles and includes about 21 islands in the 560 ha. The Gulf of Mannar area is known for its biological wealth. Along the east coast of India, the coral formation is mainly confined to Gulf of Mannar and Palk Bay only. A total of 94 species of corals belonging to 37 genera have been recorded here. Although the coral reef formations are estimated to cover an area of 100 km^2 (Wafar 1986), the actual reef area is only 10 km^2. More than 106 species of marine algae and 11 species of sea grasses occur here. A variety of marine invertebrates are found in abundance. The Kurusadai island in this region is commonly known as the paradise of zoologists. The endangered marine mammal *Dugong dugong* was found in abundance once, but became rare now. The current problems in Gulf of Mannar include coastal pollution from domestic, industrial and aquaculture discharges, illegal mining of corals, indiscriminate picking of budding seaweeds, use of dynamites to kill the fish and export oriented indiscriminate large scale fishing of rare marine living organisms such as Gorgonians, sea cucumbers, ornamental echinoderms and other molluscan forms (Ramachandran 1997).

11.5.2
Gulf of Kuchch (Gujarat)

Gulf of Kuchch is the largest coastal habitat in the east coast of India in the state of Gujarat. In 1980, about 45 792 ha of the Gulf of Kuchch were declared as a Marine Sanctuary and in 1982, an additional 16 289 ha were declared as a Marine National Park. The Marine National Park and Marine Sanctuary are situated along the southern shore of the Gulf of Okha (22°30′N, 69°00′E) eastwards to the vicinity of Khijadia (22°30′N, 70°40′E) This includes 42 islands and a complex of fringing reefs backed by mudflats and sand flats, coastal salt marshes and mangrove forests, sand and rocky beaches which represent a great diversity of fauna and flora. The gulf is the home for more than 800 species of organisms, 32 hard (Scleractinia), 12 soft (Alcyonaria) corals, 150–200 species of fish, more than 100 species of algae, great diversity of sponges and worms, brittle stars, marine turtles and other reptiles, over 200 species of migratory and resident birds and the endangered marine mammal *Dugong dugong*. The Gulf of Kuchch marine ecosystem is threatened tremendously by the various developmental activities such as chemical industries, construction of new ports and harbours, oil transport, ship building and breaking activities etc. However, after establishment of the national park, the coral reefs have expanded and afforestation programmes have increased the mangrove cover (Ramachandran 1997).

11.5.3
Andaman and Nicobar Islands

The Andaman and Nicobar islands comprise about 340 islands of volcanic origin situated on a submerged mountainous hill range arching from Arallal Yoma in Burma in the north to Sumatra in the south between 6°–14°N lat. and 92°–94°E long., occupies

Table 11.4. Marine faunal diversity at Andaman and Nicobar islands

Name of group	N° of species	Endemic species
Sponges	70	2
Soelentrates	147	–
Corals	179	–
Polychaetes	161	–
Pycnogonids	8	–
Molluscs	790	–
Meiofauna	324	193
Fish	500	–
Reptiles	83	23
Mammals	3	–

an area of about 8 249 km^2. Sixteen national parks covering an area of about 36 157 ha have been established for the protection and preservation of various unique rare species of plants and animals. The marine national park at Wandoor covers an area of 28 150 ha and is located at 11°22′–11°36′N lat. and 92°30′–92°40′E long. The marine faunal diversity at Andaman and Nicobar islands is given in Table 11.4.

The environmental issues are removal of sand and dead corals from beach for construction and deforestation of mangroves for developmental activities (Ramachandran 1997).

11.6 Fisheries Management

The existing Indian Fisheries Act was passed in 1897 and later amended in 1927 and in 1980. The objectives of these legislations are:

a to prohibit the use of dynamite in all waters within its jurisdiction,
b the prohibition or regulation of the use of fixed engines for the capture of fish and construction of weirs,
c the prohibition or regulation of the use of nets with a mesh below a minimum size,
d the prohibition or regulation of the capture of OR sale of all or any kinds of fish during any closed season,
e the total close of any water for a period not exceeding 2 rules thereunder,
f vesting with the government the exclusive privilege over chanks and chank fisheries.

However, in spite of all these regulations because of their non-implementation, the fisheries management is not so effective. Other than these regulations no management policies are practised. Consequently, the economical and social benefits derived from the coastal fisheries are significantly lower than they could be, if more effective fisheries management measures were implemented. A national fisheries management policy involving the stakeholders must be evolved. Some of the immediate requirements are improving the education and living conditions of the fishermen. The fishery activity should be promoted for the sustainable living of the fishermen, through improved infrastructural facilities, training in modern technologies and participatory management approaches.

11.7 Research and Development Programmes

The Department of Environment and Forests and the Department of Ocean Development of Government of India are the two nodal departments that have initiated several sponsored research programmes in the country involving the various governmental, academic and research institutions. Notable among them are the following: Nationally coordinated projects initiated and funded by Department of Ocean Development (DOD 1997).

- *Marine Satellite Information Services* (MARSIS). This programme was initiated in 1990 to develop capabilities for utilising remote sensing data of ocean and coastal zone to promote the optimal utilisation of marine and coastal resources and to help in coastal zone management.

- *Sea Level Monitoring and Modelling* (SELMAM). This project envisages assessment of variations in the sea level due to climate and other changes and impact of such variations on the coastal belt of India.
- *National Ocean Information System* (NOIS). Under this programme National Marine Data Centres (NMDC) have been established in 13 specialist institutions in specific areas of activity located in different parts of India. The objectives of the NMDCs are collection, validation, collation, storage and dissemination of data and information to users. These data are living and non-living resources, protecting from coastal erosion and accretion; and help the scientists and decision makers in the coastal management practices.
- *Coastal Ocean Monitoring And Prediction Systems* (COMAPS). This programme was initiated in 1991, under this programme, data on 25 water quality parameters (physical, chemical and biological) are collected at 77 locations with the help of 11 Research and Development organisations on a routine basis. Based on the data collected under the COMAPS programme, the areas of concern were identified and intensive monitoring of marine pollution is done.

11.8 Requirements in India

11.8.1 Integrated Coastal Zone Management Plan

As in most of the developing nations, the coastal environmental problems and issues in India are also concerned with the following three main conditions; environmental degradation, resources reduction and user conflicts. The integrated coastal zone management plan has been recognized as a tool for addressing these issues and identified as a means to achieve the sustainable development options that ensure livelihood security and environmental stability in coastal zones. India is still lacking a comprehensive ICZM plan.

In developing an ICZM plan, many approaches are possible, depending on the status of coastal resource use and areas to be covered. Where the conflicts have already surfaced it is most pragmatic to use a "problem oriented" approach. In case where coastal resources are not under threat, the more classical system of a resource based approach is possible.

The primary focus of the planning effort should be identifying the problems and the issues to be addressed, deciding on the type of management mechanism to be used, determining the points at which management intervention will be exercized and ways and means by which such management interventions will be integrated with the existing framework.

It is necessary that consultative processes are built into the planning effort. Coastal zone management planing requires the cooperative effort of State and Central Governments. If adequate consultations are not carried out from the commencement of the planning effort, serious conflicts may arise at the implementation stage, thereby making the plan unimplementable (DOD 1996).

11.8.1.1
Sectoral Studies and Experts

The institutional methodologies for development of ICZMP will depend upon a variety of factors. If the problems are limited, one or two experts can be assigned to study the problems and prepare a report. However, if the problems are manifold and complex, a number of sectors such as socio-economic and resource profile, geomorphology and coastal process, fishery and aquacultural forest and wildlife management, agriculture, water resources, energy, industrial development, tourism, port and shipping, water supply, sanitation and environmental health, environmental pollution, regulatory measures and institutional aspects of environmental management etc. may have to be studied and synthesized into one report. This cannot be completed by one or two experts. It, therefore, necessary that once the sectors have been identified for study, it may be appropriate to also identify the most appropriate experts who could understand the study in respect of specific sectors. Before sectoral studies are commissioned to the experts, detailed instructions, including terms of reference and general guidelines for experts, may have to be worked out (DOD 1996).

11.8.1.2
Ministerial Coordination and Cooperation

In any case, it would be appropriate to establish and inter-agency/inter-ministerial/inter-departmental steering committee vested with the authority for coordinating the planning effort and promoting inter-ministerial operation. It should have the responsibility for overseeing and supporting the development of the plan and its subsequent implementation. One of the important tasks of the steering committee would be to consolidate the study prepared by different sectoral experts with a view to reducing overlap and evolving a coordinated approach. It would also be necessary for the committee to review the draft report, and ensure overall consistency and uniform style in the presentation, approach, data and conclusions. It should clearly lay down policy directions, advice and recommendation on the various aspects regarding the plan. The inter-ministerial steering committee should hold periodic meetings of its experts and review the draft chapters prepared by them generally following the outline and the terms of reference provided for the study (DOD 1996).

11.8.2
An Agency for ICZM

An agency for ICZM should not be merely an authority for regulatory measures, but also should work as an agency for development. Participatory approach is an important concept that the agency should promote at all levels.

11.9
Conclusions

ICZM combines development management and resources management. It considers, coordinates and integrates the interests of all appropriate economic sectors. It is accomplished by managing the coastal area as a single unit. To accomplish its purposes, ICZM in India requires several national actions including the following:

- A policy commitment to support coastal resources management and environmental conservation;
- Achieving an understanding on resources and environmental objectives among the various coastal stakeholders;
- Establishment of agencies for coordination of coastal affairs;
- Initiation of a system for review of development projects, including environmental assessment;
- Accumulation of technical information;
- Design and development of effective planning and management programmes (Planning Commission Government of Tamilnadu 1994).

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Chapter 12

Integrated Coastal Zone Management (ICZM) in Indonesia

S. Sukardjo

12.1 Introduction

Indonesia is an archipelago country with 17 085 islands and has more than 81 000 km of coastline (Table 12.1). Coastal resources in Indonesia are used by the local communities for obtaining food, fodder, fuel wood, shelter and a variety of other services. With high biological diversity and endemism, coastal zones are used as repositories for the effluent of industrial processes and domestic wastes and also as prime sites for reclamation to create land for industry, agriculture and settlement. In areas such as Java, expansion of large cities disturb the coastal zone. The Indonesia's population is increasing at an alarming rate and will be 215 million in 2000 and so demographic pressures are pronounced more in Indonesia. About 64% of Indonesian people live in and around the coastal areas.

12.2 Status of Coastal Environment

In Indonesia, coastal ecosystems in each island strongly modulate the different environmental effects of land on ocean and vice versa. Various biotic and abiotic processes in the coastal ecosystem affect the hydrological cycle and coastal geomorphology. The temporal and spatial scales of physical, chemical and biological processes determining the fluxes of materials into and out of the coastal zone in Indonesia extend to the landward and seaward limits of marine and terrestrial influences respectively. The coastal zone in Indonesia have some of the world's richest ecosystems characterized

Table 12.1. Indonesia: Marine areas (Anonymous 1978, 1979)

	Area or length	Remarks (%)
Indonesia (total area)	5.0 million km^2	
Territorial seas	3.1 million km^2	62 of total area
Territorial land[a]	1.9 million km^2	
Enclosed marine waters	2.7 million km^2	87 of total seas
Open ocean waters	0.4 million km^2	13 of total seas
Continental shelf waters	1.5 million km^2	47 of total seas
Estimated coastline	80 791 km	

[a] Indonesian government statistics on the precise land area vary, figures of 1.904, 1.942, 1.944 and 2.019 have been reported by various departments.

by extensive mangrove forests, coral reef and sea grass beds. The mangrove forests (4.25 million ha) constitute the dominant ecosystem in marine and brackish coastal areas and produces litter fall of about 20.50–29.35 t $ha^{-1} a^{-1}$ (dry weight) (Sukardjo 1995). Coastal ecosystems in Indonesia are very productive and support major marine fisheries and mariculture activities.

12.3 Coastal Zone Problems in Indonesia

Being the major part of Indonesia's territory (see Table 12.1) the exploitation of the coastal zone is closely linked with the concern for economic development. The consequences of coastal exploitation in Indonesia are very complex. Increasingly, it is being realized that a man induced effect on one ecosystem can have far reaching consequences on another. Increasing demand from within the provinces with different social set-ups and from the coastal villages along with their rapid population growth compound the coastal zone management problems. Further, faster rates of coastal degradation and over-exploitative uses of land, water and other coastal resources and disruption of environmental processes through degradation of environmental quality and loss of critical terrestrial and aquatic habitats lead to serious and deleterious impacts on the health and productivity of coastal ecosystems adversely affecting the food availability, health and economic welfare of coastal people. The key resource use problems and conflicts in the coastal zone in Indonesia include

- loss of mangrove forest and tidal swamp lands which support traditional fisheries,
- improper utilisation of coastal zone by "money holders" (not coastal inhabitant – example conversion of mangrove forest for Tambak),
- declining socio-economic/livelihood status of the already poor inhabitants of coastal villages,
- increasing coastal population,
- overfishing and use of destructive methods,
- lack of comprehensive ecological information concerning the coastal zone/resources for developers and decision makers at the provincial level,
- the relevance of agricultural policy for income and food security.

The coastal zone in most of the Indonesian islands are subjected to population (transmigration, resettlement etc.) and economic pressures manifested by a variety of coastal activities, notably, fishing, coastal aquaculture, waste disposal, salt making, tin mining, oil drilling, tanker traffic, construction and industrialisation. All are in many cases, threatening ecological stability. This situation is aggravated by the expanding economic activities attempting to uplift the standard of living of coastal people, the vast majority of them live below the poverty line. Obviously, human interactions in the coastal zone in Indonesia are often more critical. This is an aspect that has begun to receive attention only in recent times (e.g. Program Pengentasan Kemiskinan) by Government along with IDT (Inpres Desa Teringgal). Because economic benefits could be derived from them, the coastal zones in Indonesia teem with dense human settlements. The effect of human settlement on the ability of coastal systems to retain the ecological stability and their multiple use attributes is of the ecological stability and their multiple use attributes is of great importance. Further, attractive coastal areas with unique scenic views have always existed in Indonesia. Consequently, tourism poses serious pressures on some settlements along with their agricultural lands in the coastal zone. A pattern of increasing use of coastal resources in each province continue up to now to yield a very impressive picture of economic development at the present. But, the rapid changes occurring in the nearshore areas and lands in the coastal zones, is not adequately understood and hamper development in Indonesia. The most critical point in sustainable development as enunciated in the GDHN (Garis Besar Haluan Negara) is the generation of new employment opportunities. The coastal zones offer possibilities of enabling more and more people to engage in meaningful activities in a development oriented society. Furthermore, maritime activities can help solving problems like unemployment and underemployment in Indonesia. So, integrated coastal zone management is very important today in Indonesia.

12.4 Integrated Coastal Zone Management in Indonesia

Coastal zones in Indonesia need to be managed as complete systems in which the many complex relations among the different environments and their interactions with local

Table 12.2. Necessary conditions and policy principles for the ICZM in Indonesia

1. a	Maintain coastal environmental quality
b	Conservation of cultural (ethnic group) and biological diversity (e.g. mangrove forest) and ecological integrity
2. a	Technical and economic efficiency
b	Efficiency of coastal resources use by all societies
3.	Avoid government failure
4. a	Maintain future options
b	Maintain political stability
5. a	Stop population growth
b	Strong community participation in policy and practice in the process of transition to an ecologically sustainable society
6. a	Maintain conditionally renewable natural capital
b	Constant natural capital and sustainable income
7. a	Deplete non-renewable capital
b	Inter-generation equity: providing for today while retaining responses and options for tomorrow
8. a	Redistributing wealth to per capita-poor villages
b	Pricing of environmental values and natural resources to cover full environmental and social costs
9. a	Using resources rights (e.g. traditional right, „marga" etc.) to create ecosystem-coupled markets
b	Resource use in manner that contributes to equity and social justice while avoiding social disruptions
10.	Building a sustainable economy (PELITA VI, PJP II)
11.	Environment-friendly market mechanisms

Table 12.3. The Nation's Ocean Council (Based on the KEPPRES Republic Indonesia N° 77 Tahun 1996)

Chairman		President, Republic of Indonesia
Vice Chairman and Member		Minister Coordinator for Political and Security Affairs
Members	1.	Minister of Home Affairs
	2.	Minister of Foreign Affairs
	3.	Minister of Defence and Security
	4.	Minister of Justice
	5.	Minister of Mining and Energy
	6.	Minister of Agriculture
	7.	Minister of Communication
	8.	Minister of Tourism, Post and Telecommunication
	9.	Ministry of Education and Culture
	10.	Minister of Finance
	11.	Minister of Health
	12.	Minister of State for Environment
	13.	Minister of State for Research and Technology Chairman for the Agency for the Assessment and Application of Technology
	14.	Minister of State for National Development Planning Chairman of the National Development & Planning Agency
	15.	Commander in Chief of the Armed Forces
	16.	Attorney General
	17.	Prof. Dr. Mochtar Kusumaatmadja S. H.
	18.	Dr. Hasyam Djalal

community in each province are properly taken into account (Table 12.2). Recognising that the coastal zones in Indonesia contain a wide array of ecological, biological, economical, political, cultural and moral factors and that the consensus affirmed by opposing theoretical religious, philosophical and moral doctrines is like to be just and much more resilient than one that is based on a single paradigm, the search is on for an overlapping consensus about the type of social and economic policies that promote sustainable forms of coastal resources use and their investment. But, economics, it must be remembered, is not the only criteria by which sustainable development are maintained.

ICZM systems, therefore, in Indonesia are closely related to and dependent on the coastal environment, they are also very vulnerable to changes in land use. Therefore, it is essential to understand the functioning and ecological relationship of various resources and the degree of tolerance in the functioning processes. Further, as a multi-disciplinary approach, ICZM requires comprehensive data concerning all aspects of the coastal zone for establishing a centre at the top decision makers level (inter-ministerial link) and at DKL (Deqwan Kelautan Nasional), the national oceans council (see Table 12.3) with president as its chairman. The implementation of ICZM in Indonesia will involve all levels of government (Pusat – Daerah – Kelurahan) and coordinated research in organisations (LIPI, BPPT, NGOs, University etc.) in a number of disciplines to devise and carry out coastal

Table 12.4. Failure and success in communication: a summary for ICZM in Indonesia with special reference to the results of P-3 Oseanologi LIPI (A view from mangrove ecologist) (*Note:* Good communication need not imply that the parties are agreed as to the present situation or on priorities for the future)

Level of understanding reached	Possible reason
Virtual incomprehension (apathy or hostility likely)	Widely different assumptions (unrecognised); Unthinking rejection of alternative views; Foreign or second language barrier; Use of highly technical words, long words, abbreviations without explanation; Speaking for too long, too fast, too quietly; „Waffling", mixing with irrelevant material; Intentional „blinding" with „science"; Patronising and/or servile attitudes; Not attending.
Narrow comprehension (misunderstandings likely)	Scope of subject not introduced; Easy dismissal of alternative explanations; Not seeing the food for the species; Not appreciating facts relevant to the situation; Not being aware of limitations; Inability to adapt ideas for other circumstances.
Wide comprehension (successful communication likely)	Using straight forward language; Using practical examples; Recognising limits on present knowledge; Setting subject in its background; Recognising mutual contribution; Building on existing methods; Talking in terms of the listener's interests.

resources survey and to link it with the coastal zone development. At government level, there is a need for the development of coastal zones as well as marine resources in Indonesia, so that good lines of communication are established (Table 12.4). Its additional responsibilities should entail the developments within a set of principles, as a basis for planning and training of managers as a part of a wide educational programme. The planning of ICZM consists of four major steps:

- Identification of contemplated resource use in the coastal zone;
- estimation of the benefits anticipated, costs involved goals, needs and time schedules;
- evaluation of a technological, legal, economical, sociological and political factors;
- implementation through arrangement for funds, authorisation and assignment of responsibilities for management and regulation.

Although the importance of coastal zone is widely recognized, the particular significance attached to it is often a matter of individual perspective. Therefore, appropriate institutions are need at national and provincial levels to promote, develop, manage and coordinate elements of the ICZM in Indonesia. National plans and programmes prepared by government, in general, proved to be very satisfactory. There are also a number of departments committed for these. This can enhance prospects for sustainable development and involves divergent approach to the distribution of coastal resources, ways to pay for conservation (e.g. in Java for mangrove forest – Sukardjo 1990; Sukardjo and Yamada 1992) and to distribute profit from the involvement in land and forest management (e.g. prosperity approach for the MAMA, MALU projects of the Perum Perhutani – in coastal land use planning. Therefore, in "PELITA V" ahead, the government of Indonesia have the opportunity of making significant progress towards the achievement of truly sustainable development. Clearly, ICZM can make a great contribution to the welfare of humanity at large.

12.5 Conclusions

The vast majority of the people of the coastal zones of Indonesia live in poverty. To provide adequate supplies of food and sufficient employment in the future for the expanding population in Indonesia, all of the present potential coastal resources must contribute to the general welfare of the country. Therefore, the goals of the ICZM in Indonesia and strategies for achieving them will be a continuing source for debate in the years ahead. The future behaviour of the coastal system in response to changes in climate and other environmental factors is of direct socio-economical importance in terms of both biological feedback effect on the global environment and the availability and sustainability of the living resources. It follows therefore that successful ICZM in Indonesia will depend on careful blending of scientific knowledge about the functioning of coastal ecosystem and of the factors both natural and manmade which influence their stability and functions. Because of the special nature and fragility of the coastal zone the policy makers, politicians and economists are not always aware of the socio-economical complications of promoting the sustainable development of fisheries, agriculture and forestry on the coastal zones in Indonesia. Integration of fisheries with other forms of agriculture diversifies farm productivity which in turn provides opportunities for intensified production with more efficient allocation of land, water, labour, equipment and other enterprises which operate independently. I believe that some of the planning and guiding of the development of the coastal zones in Indonesia along sound ecological lines are exceptionally difficult. Hence, we need to increase and strengthen the dialogue between Science (natural and social), management and decision-making.

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Chapter 13

Coastal Zone Management: Issues and Initiatives in Small South Asian Nations

R. Ramesh · S. Ramachandran

13.1 Introduction

Coastal ecosystems strongly modulate land-ocean interactions. The coastal environment is constantly being altered by population pressures, inevitably affecting its use by future generations. The exploitation of many coastal ecosystems is presently so intense and so weakly regulated, that major economic investment is likely to be required for their maintenance or restoration in the future. The creation of long-term, sustainable policies for coastal management requires an understanding of the impacts of changes in environmental quality along the coastline.

By the year 2000, it has been estimated that about 75% of the human population will live in the coastal regions of the world (United Nations 1985). Even now, in South East Asia, 65% of cities with populations greater than 2.5 million are located along the coastline. Coastal areas are a magnet for tourists, as is evident from the fact that the Mediterranean coastline alone attracts one third of world tourism. All coastal zones are under increasing pressure from expanding human populations. We have only recently begun to realize the extent of damage caused in coastal waters, since environmental deterioration is not as obvious under the surface of the sea as it is on land. It is essential that every country develops an integrated coastal systems management strategy, based on considerations of ecological sustainability, economic efficiency and social equity. For integrated coastal systems management to occur on this scale, plans and programmes of the governmental, non-governmental, and corporate sectors need to be closely integrated. Above all, there is a need for the active participation of coastal communities. Local community participation will only be forthcoming if an integration between ecological security of coastal regions and the livelihood security of coastal communities is fully achieved.

The coastal zone is characterized by a rich diversity of natural habitats, such as mangroves, coral reefs, beaches, continental shelf areas, sand dunes, grasslands, rocky shores, marsh lands, flood plains, salt marshes, estuaries, mudflats, wetlands, seagrass beds and seaweed areas. A variety of natural resources, including corals, seaweeds and algae, fish and other aquatic life, plants, minerals, water, sand oil and gas, provide food, fuel, construction material and other resources indispensable for human existence.

Coastal habitats and resources are also vital because of their role in stabilising the shoreline and in protecting coastal areas and habitations from cyclones, tidal waves and other natural disasters, as well as because of their natural capacity to assimilate and absorb waste and pollutants. In addition there are a diversity of natural processes occurring in coastal areas, such as upwelling, seasonal sand banks, sand dune formation, sea erosion and accretion, siltation and sedimentation, the lunar and diurnal cycles,

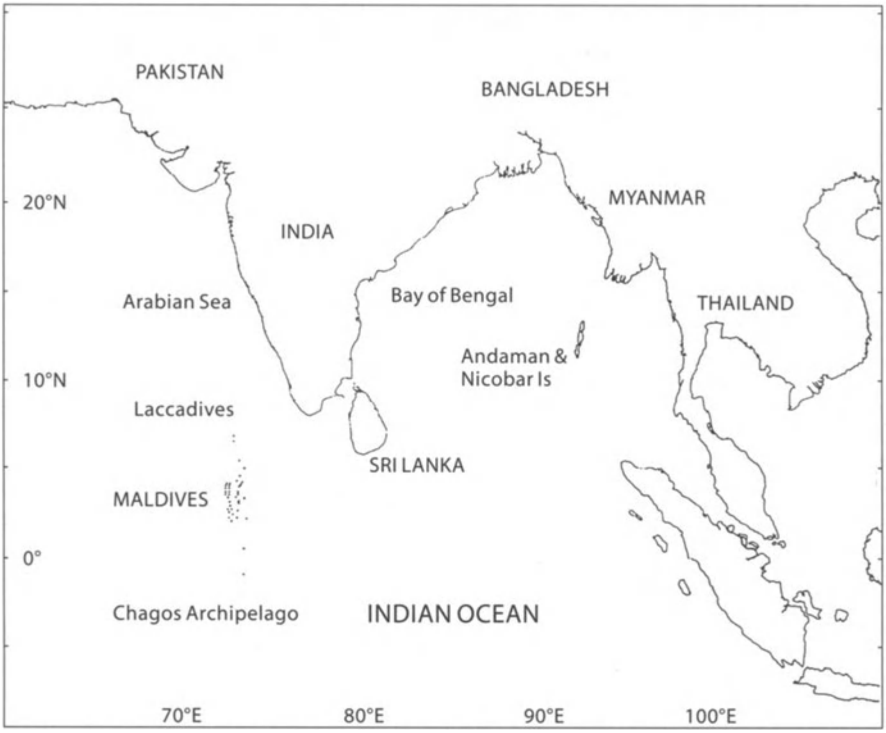

Fig. 13.1. South-Asian Sea region

seasonal winds and cyclones, sea breeze, waves, tidal bores and flows, salinity changes, seasonal migration of fish and birds, algal blooms and fish kills, all of which contribute to maintaining the coastal ecosystem in complex, and often unknown ways. The main objective of this paper is to present a comprehensive assessment of issues and initiatives in coastal zone management in three small south Asian nations (Fig. 13.1 and Table 13.1) viz. Bangladesh, Maldives and Sri Lanka.

13.2 Human Activities in the Coastal Zone

The coastal ecosystem is fragile, unique and complex. Important human activities such as those relating to agriculture, fishing, salt extraction and production, rare earth mining, mining of coral, limestone and beachsand, groundwater extraction, land reclamation, oil exploration and extraction, aquaculture, tourism and recreation, chemical and power industries, discharge of urban sewage and other effluents, construction and dredging of ports and harbours etc., take place in coastal areas. However, the impact of human activities on the coastal ecosystem is often highly negative. They deplete and destroy natural resources and habitats and interfere with processes occurring naturally in the coastal zone. While some human activities in the coastal zone can be clas-

Table 13.1. Statistics on the area of the coastal zone for small South Asian countries (After Brown 1997)

Country	Area (km^2)	Coastline (km)	EEZ (km^2)	Population
Bangladesh	144 054	710	76 800	110 000
Maldives	~300[a]	Not Known[a]	843 247	214 088
Sri Lanka	65 610	1 770	256 410	17 000 000

[a] The land area and coastline length of the Maldives are not known accurately because figures have not been published for this archipelagic state.

sified as livelihood-related, others are primarily profit- motivated, commercial activities. Some parts of the coasts are particularly bad, affected by industrial and municipal effluents as well as by indiscriminate development of brackishwater aquaculture. The damage done is often unintentional, being a consequence of bad planning, lack of basic knowledge and little coordination between agencies and authorities. The first step towards remedial action needs to be the collection of relevant data on the state of coastal environment and the processes that are changing it. In this paper some of the coastal zone management issues in Bangladesh, Maldives and Sri Lanka have been highlighted.

13.3 Coastal Zone Management in Bangladesh

Bangladesh has a land area of 144 054 km^2 and a population of over 110 million. Landlocked on three sides, it is in the South that it has a coastline. Geographically, Bangladesh lies at the junction of the Indian and Malayan subregions of the Indo-Malayan realm. Most of the country is low-lying, about 10 m above mean sea level.

The Bangladesh coastline extends 710 km along the northern edge of the Bay of Bengal, from the mouth of the Naaf river in the southeast, to the mouth of the Raimangal river in the southwest. In the dry season, the salt water limit follows an irregular line (Khan and Karim 1982). During monsoon season, floodwater pushes the salinity limit to near the coast except in regions where seasonal salinity variations are small. According to Pramanik (1984), the coast of Bangladesh can be classified into three distinct regions on the basis of geographical conditions:

- The eastern region (includes the Big Feni river and the southern tip of the mainland);
- The central region (from Tetulia river to the Big Feni estuary, including the mouth of the Meghna river);
- The western region, (covering the coastline from the Tetulia river to the international border at Hariabhanga river).

The coast for the most part is on the cyclonic tracks which form over the Bay of Bengal and suffers almost annually from severe damage caused by storms and tidal waves (Ali 1979, 1980). The Meghna estuary in fact act as a funnel which draws the cyclones in. The coastal zone of Bangladesh enjoys a tropical maritime climate. Its four distinct seasonal weather patterns is principally governed by the southwest and northeast monsoons. Normally about 90% of the annual rainfall is confined to the monsoon months (June to September).

13.3.1 Mangroves

The coastline of Bangladesh is dominated by mangrove and estuarine systems. The western coast of Bangladesh is covered with dense mangrove forests called the Sunderbans. There is heavy sediment deposition in the central region. Here, the coastline is dynamic, subject to continuous process of erosion and accretion. Besides being a source of different renewable resources, the mangroves also serve as buffer zones against cyclones and tidal surges. The Bangladesh coast supports ≈ 587 400 ha of natural mangroves (Mahmood 1986) and a further 100 000 ha of planted mangroves.

The Sunderbans represent a complex estuarine ecosystem, dominated by dense forest cover and periodical tidal inundations. The structure and composition of the Sunderbans are maintained by a strong salinity gradient extending from the freshwater environment of the northeast to the saline environment of the southwest (Saenger et al. 1983). In mangrove areas, trees reach a height of up to 20 m, but the main canopy is about 10 m. The natural Sunderbans vegetation is composed of halophytic tree species dominated by *Heriteria fomes*, *Excoecaria agallocha*, *Ceriops decandra* and *Sonneratia apetala*. In the coastal afforestation areas, the most widely planted species are *Sonneratia* sp., *Avicennia officinalis*, *Avicennia alba*, and *Acacia* sp. The densely forested swampy islands are the home of a variety of animals ranging from large mammals, including tiger to innumerable mud crabs which, although common at the water's edge can also be found throughout the intertidal zones. Major afforestation programmes have also been underway since 1966 with the objective of

- accelerating the process of siltation and stabilisation of soil,
- create forest buffer belts to protect inland life and property from extreme events like cyclones and tidal surges,
- create urgently needed resources to add to the national wealth,
- create job opportunities for rural communities and
- create a healthy environment for wildlife, fish and other fauna.

The Sunderban mangrove forests in the southwestern part of the country cover almost 600 000 ha. It is the largest single compact mangrove resource in the world. An Overseas Development Administration (ODA), UK sponsored survey in 1985 showed that the standing volume of the main species has declined alarmingly in the Sunderbans since the previous inventory 20 years earlier (Holmgren 1994). Over cutting and overestimation of regeneration times were reasons for a smaller inventory being recorded. The Farakka Barrage across the border, which diverts as much as 40% of the dry season flow of the Ganga, causes increased salinity and this is another reason given for impaired growth of the mangroves.

13.3.2 Coral Reefs and Seagrass Ecosystems

St. Martin's Island is the only coral reef island in Bangladesh. This gradually decaying island is about 10 km south of the mainland, extending to a little over 7.5 km^2 (Haque et al. 1979). There is little information on the Bangladeshi offshore coral. A recent study (Haider and Mahmood 1992) recorded four species of the genus *Acropora* in the neritic waters of the St. Martin's Island.

Information on the existence of seagrass beds is also lacking. Nevertheless *Halodule uninervis* has been reported from the sandy littoral zone around St. Martin's Island (Islam 1980). It is generally noticed that the sea fronts of the newly formed islands as well as some low lying coastal areas are often carpeted with seagrass.

13.3.3
Threats to the Coastal Environments

Environmental concerns such as pollution, ecological imbalance, environmental protection etc., are among the priorities for environmental conservation.

13.3.3.1
Pollution

The numerous rivers that run across the country carry pollutants from the entire drainage area which encompasses not only Bangladesh, but also parts of Nepal, India, Bhutan and China. Pollutants include municipal and industrial wastes, agrochemical residues and pollutant discharges from ships and boats. Although Bangladesh is not an industrialized country, in recent years, industrial growth has had significant environmental impact. Treated and untreated wastes find their way into the coastal waters, especially since most of the industries are located along the banks of the rivers. Similarly, municipal wastes are also discharged untreated into the coastal waters (Table 13.2).

In addition, large quantities of fertilizers and pesticides are also used in agricultural operations in Bangladesh (Table 13.3).

It is believed that agrochemical pollutants from India and Nepal are washed down through shared rivers. The other major concern for the coastline of Bangladesh is through oil pollution. Oil pollution damages the mangrove ecosystem and also has a

Table 13.2. Category wise distribution of polluting industries of Bangladesh (After Mahmood et al. 1994)

Type of Industry	N° of Industries
Textiles	298
Tanneries	176
Pharmaceutical	166
Jute	92
Iron and steel mills	57
Rubber and plastic	34
Insecticides and pesticides	25
Chemicals	23
Sugar mills	16
Paper and pulp	5
Fertilisers	5
Distilleries	3
Cement	3
Total	903

Table 13.3. Estimated amount of pesticides and other persistent organics used in agriculture in Bangladesh and probable pollution load in sea water (After Mahmood et al. 1994)

Type of persistent organics	Sale of pesticides July 1984–June 1985 (t)	Amount received by coastal water through river run-off (t/yr)
Organomercurial fungicides	0.0	0.0
Halogenated hydrocarbons	40.6	10.5
Carbonates	891.8	223.0
Polychlorinated biphenyls	0.0	0.0
Organophosphorous	1991.3	498.1
Other toxic agrochemicals	74.3	18.6
DDT	1038.0	250.0
Total	4036.0	100.2

qualitative and quantitative impact on marine fisheries and fish productivity. Thin layers of oil on water surfaces hamper light penetration and photosynthesis, as well as air-sea gas interaction.

13.3.3.2
Destruction of Natural Habitats

The 687000 ha of mangroves protect the coast from storm surges and cyclones and provide nurseries to numerous wildlife and fishery resources. Mangroves are at a point of severe depletion due to overexploitation by increasing population growth and greater demand for forest products. Ecological changes caused by biotic and edaphic factors as well as the horizontal expansion of shrimp farming has further exacerbated the situation. Destruction of mangroves in Bangladesh has been a consequence of several factors importantly, the conversion of mangrove sites for aquaculture and felling of mangrove for fuelwood and timber. Natural calamities such as cyclones and tidal waves also cause damage to these forests along the sea. The construction of dikes, embankments and hydraulic sluices for control of floods and tidal waves, damming of rivers for irrigation and power generation and diversification of channels have also had significant impact on freshwater and sediment supplies for mangrove forests. The resultant salinity increase has affected mangrove growth.

There is also growing conflict among mangrove forests, shrimp farms and rice cultivation. The Chakaria Sunderbans in the delta of the Matamuhari river, in Cox's Bazaar District in eastern Bangladesh, has been virtually cleared for aquaculture. But the very low productivity of shrimp – only 50 kg $ha^{-1}a^{-1}$ – indicates that the conditions were not optimal. On the other hand, felling of mangrove forests has entailed loss of protection from cyclones and tidal waves, increased salinity due to tidal water being retained longer and greater evaporation and acidification of surface water. The conversion of mangrove forests for aquaculture would appear to be uneconomic if the potential yields are compared with the combined yields, now both lost, of the forests and the traditional fisheries.

The only coral reef island in Bangladesh, St. Martin, is also threatened by sedimentation, cyclones and storm surges, destructive fishing methods, coral mining and pollution.

13.3.3.3
Aquaculture

The rapid irrational and unplanned growth of shrimp aquaculture has often been at the cost of the mangroves. At present, a majority of shrimp farms are located in the dense, remaining mangrove areas on the west coast and there is no legislation to control the aquaculture of shrimps. The growth of shrimp aquaculture in coastal brackishwater areas has also been responsible for pollution and environmental degradation in coastal and inshore areas. Indiscriminate collection of shrimp fry also damages the nursery grounds of many species and harms newly afforested mangrove areas.

Nearshore fisheries are overexploited. The extensive use of destructive set bagnets is believed to be responsible for this in the estuarine and neritic waters. In the absence of an adequate number of hatcheries, the collection of wild tiger shrimp post-larvae in estuaries and nearshore waters by this fishing methods lead to destruction of other shrimp and finfish species. Estimates indicate that more than 1 600 individuals of non-target macro-zooplankton were killed while collecting one tiger shrimp post-larva.

13.3.3.4
Natural Disasters

Bangladesh is highly vulnerable to cyclonic storms, tidal wave activity and floods. Besides the huge losses to life, property and natural habitats caused by such natural calamities, they also often lead to inundation of freshwater ponds and canals with saline water, affecting freshwater fish.

13.3.3.5
Siltation

The high sedimentation load in rivers is a consequence of increased erosion in the Himalayas and Assam Hills, frequent floods as well as the increased erosion of topsoil due to coastal and inland deforestation and depletion of vegetation. Construction of embankments and earthworks, undertaken as a part of coastal development projects are also believed to interfere with the natural patterns of siltation. This has resulted in the siltation of inshore waters, habitat degradation – especially of the benthic region – high turbidity and reduced pattern of light.

Siltation at the mouth of the Ganga-Brahmaputra-Meghna river systems is actively reshaping the coastal and nearshore habitats. As the rate of sedimentation has increased exponentially during the last century, this is believed to have had a great impact on fisheries. Change in the topography, increased turbidity, entrapment of pollutants are some of the detrimental effects.

Based on the above coastal issues, it has become essential to prioritize the coastal zone management programmes for sustainable development of the coastline of Bangladesh. As yet, Bangladesh has no legislation specific to coastal area management. Although there is a coastal environment management plan, currently this has no legal status. Now, a National Environment Action Plan has been formulated to address environmental issues in an integrated manner. This programme identifies the management of coastal and marine resources as an important issue calling for appropriate action.

13.3.4 State Initiatives and Legislation

Bangladesh has no legislation specific to coastal area management. Although there is a coastal environment management plan, currently, this has no legal status. The Department of Environment (DOE) under the newly formed Ministry of Environment and Forests, is the main government institution responsible for all environmental planning, management and monitoring, including those relating to the marine sector. Overall coordination on environmental issues is the responsibility of the DOE. It also works as the technical arm of the Ministry of Environment and Forests.

The national conservation strategy adopted by Bangladesh in 1987, identified the following ecosystems as important: coastal zones, hill forests, the Sunderbans and wetland. In 1992, a National Environment Policy was adopted along with an environmental action plan. This policy addresses to some extent, issues related to the marine environment. In the monitoring, control and prevention of coastal and marine environmental problems, the Action Plan envisages the involvement of the Ministry of Environment and Forests, Ministry of Land, Ministry of Shipping and the Ministry of Defence.

A National Environment Management Action Plan (NEMAP) has also been formulated to address environmental issues in an integrated manner. The plan builds on the general principles set out in the National Environment Policy. A participatory approach was adopted in developing it. NEMAP identifies the management of coastal and marine resources as an important issue calling for appropriate action (Sharma 1996).

The national environmental legislation provides guidelines relating to the control of environmental pollution, conservation of natural resources and the protection of environmental health. According to a study by the International Union for the Conservation of Nature (IUCN) Bangladesh has about 45 laws on different areas that have a bearing on environmental issues, including those related to coastal and marine environmental resources. However, there are no specific standards and enforcement mechanisms. There is as yet no appropriate and comprehensive legislation for the protection of the country's marine environment and related ecosystems. The principal legislation dealing with control and prevention of environmental pollution is the Environmental Pollution Control Ordinance of 1977. This however, does not deal with the marine environmental pollution or pollution caused by ships.

Laws related directly or indirectly to coastal and marine environmental protection and resource development are:

- Territorial Waters and Maritime Zone Act, 1974 and the rules formed under this Act in 1977, for the management of maritime activities within the territorial waters;
- Environment Pollution Control Ordinance, 1977;
- Marine Fisheries Ordinance, 1983;
- East Bengal Protection and Conservation of Fish Act, 1950;
- Petroleum Act, 1934, to regulate petroleum exploitation in the offshore areas;
- Pesticide Ordinance, 1971 (amended in 1980 and 1983);
- Water Supply and Sewerage Authority Ordinance, 1963 and the Factories Act, 1965.

Bangladesh is also a part of the Convention on Biological Diversity (CBD), the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES), the Ramsar Convention on Wetlands of International Importance especially as Waterfowl habitat, the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, the International Convention on Civil Liability for Oil Pollution Damage (CLC) and OILPOL (1954). The articles of association of the United Nations Convention on the Law of the Sea (UNCLOS) and the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) have, however, not been ratified by Bangladesh.

13.4 Coastal Zone Management in Maldives

The Maldives comprise about 1190 low-lying islands of which ≈ 200 are inhabited. The country is rich in coral reefs which provide the living base on which these fragile ecosystems are established. The small size and relative isolation of these islands make them particularly vulnerable. The economic and physical survival of Maldives hinges on its ability to maintain its coastal ecosystem. The two most important industries in Maldives – tourism and fishing – are both directly dependent on coastal resources and a healthy coastal environment. Ironically, the few recent instances of coastal degradation in the Maldives are a direct consequence of unsustainable resource-use practices pursued by the tourism and fisheries sector.

13.4.1 Marine Resources and Exploitation

The reef life is very diversified and is rich in species and number of organisms. Fish, lobsters, sea cucumbers, giant clams and many other organisms are present in the reef, while the reef corals themselves are very diversified. Reefs are indispensable for fisheries and the construction industry. Until recently, coral rocks had been used as building materials, the coral usually being mined from reef flats.

13.4.2 Environmental Threats to the Coastal Environments

Coastal resources in Maldives are currently being exposed to several threats, important are the following.

13.4.2.1 *Coral and Sand Mining*

Living coral is stripped from shallow reef tops to meet the demands of the construction industry. Tourism has increased the demand for coral rock for construction of resorts. Coral mining increases the vulnerability of coastal areas to tide and wave-induced erosion and sand movements. It also reduces the diversity and quantity of coral reef fishes, including that of baitfish essential for tuna fishery. Sand has been traditionally mined from shallow lagoons around the islands and from beaches (Brown and Dunne 1988; Naseer 1996).

13.4.2.2
Coastal Erosion

In Maldives, the islands are continuously exposed to processes of accretion and erosion. Vulnerability to erosion is high, due to several factors – loss of sources of sand, increased exposure to wave action due to coral mining and changes in nearshore current patterns either due to natural causes or man-made changes, such as construction of coastal infrastructure.

13.4.2.3
Dredging and Land Reclamation

Dredging associated with harbour deepening, land reclamation and mining for construction material, is damaging to the marine ecosystem. It disturbs the bottom substrata and benthic resources and results in turbidity due to suspended sedimentation, increased nutrient level in the water column and reduction in dissolved oxygen. Consequently, fish growth and productivity are affected. Moreover, land reclamation, to increase the habitable land area of densely populated islands, increases the susceptibility of the islands to flooding.

13.4.2.4
Sewage and Solid Waste Disposal

The dumping of sewage and solid wastes in the more densely populated islands, has the potential of leading to problems of marine pollution, nutrient enrichment and deoxygenation. It can also lead to siltation, the smothering of corals and reduced availability of reef fishes. However, pollution by sewage and solid waste disposal remains a minor localized problem with negligible effects on reef-associated fisheries.

Some of the environmental hazards associated with sewage disposal into the sea are:

- Inadequate sewage dispersion at outfall sites may result in eutrophication of the water, leading to local coral death and local reduction in fish biomass and biodiversity.
- As bacterial decomposition of sewage occurs, oxygen is depleted from the water. Coral growth requires very high levels of oxygen in water and suffocate at low oxygen levels.
- Sewage covers coral with fine silt, which most often results in the death of the coral colony.
- Microbial agents from sewage discharged into the sea can affect human health as a consequence of sea bathing, ingestion of contaminated sea water or consumption of contaminated sea food.

Pollution caused by sewage and solid waste disposal, as well as by other means is still a major localized problem. One factor that prevents nutrient accumulation and hence heavy pollution is the dynamic open water around the island. Nutrients which tend to accumulate around heavily-populated islands are disposed of in the open sea by water currents and wave action.

13.4.2.5
Overfishing

In Maldives, fishing is almost entirely carried out by small motorized craft using pole-and-line for skipjack and other tuna and longlining for shark. As a consequence of the use of non-destructive fishing gear, the Maldivian Exclusive Economic Zone (EEZ) is largely underexploited, except by fishing gear from neighbouring countries. The use of illegal fishing methods, lethal chemicals and destructive gear, though not very common does, however, pose a threat. Some of the species exported are very rare and vulnerable to overexploitation.

Any threat to the Maldivian fisheries would affect the country's economy, as natural resources are very limited and the country is highly dependent on this particular sector. Based on a review of the status of the environmental threats, the following conclusions are made:

- Coral and sand mining, land reclamation and sewage disposal create local environmental degradation in shallow reef habitats. These activities have negligible effects on deep sea habitats and open sea, which are the grounds for commercial fishing.
- Mined reef flats, when compared to the unmined ones, support fewer varieties and less biomass of reef fish.
- Reef-associated species, excluding fish are susceptible to overexploitation. Present threats to fisheries are connected to this problem rather than with pollution or other forms of environmental degradation.

13.4.3
Coastal Area Management Initiatives

Only in recent years has the environment become an issue in Maldives. Compared to the other countries in the region, it remains relatively free of urgent environmental problems. Most environmental efforts in the country have focused on coral reef conservation and management, given the fact that the country depends for its existence on these fragile ecosystems. While coastal area management initiatives are more appropriate for large continental masses, for a country like the Maldives it is the concept of coral reef management that has more relevance.

The Environmental Affairs Division in the Ministry of Home Affairs and Social Service was created in 1984, in recognition of the growing importance of the environment sector. At present, the responsibility of all environment-related matters rests with the Ministry of Planning Human Resources and Environment (MOPHERE) formed in 1993. MOPHERE is also responsible for enforcing the Environmental Protection and Preservation Act of 1993. This Act aims at protecting and preserving the environment for the benefit of the future generations. It makes an Environmental Impact Assessment (EIA) mandatory for any new project that has a potential impact on the environment. It also regulates the disposal of wastes, oil, poisonous gases or environmentally harmful substances within the territory of Maldives and stipulates fines for damage to the environment as well as compensation for environmental damage. However, the provisions of this Act have been poorly enforced and many illegal practices persist. The geographically scattered nature of the country and its population makes effective implementation of laws difficult.

13.5 Coastal Zone Management in Sri Lanka

Sri Lanka is an Indian Ocean island with a 1760 km long coastline and is serrated by a number of estuaries, lagoons and river basins. The Sri Lankan economy is highly dependent on coastal resources. Most of its vital sectors such as tourism, industry, mining and fishing are concentrated in coastal areas and over half of its population are settled in coastal districts. The fishery sector in Sri Lanka faces serious threats from degradation of the coastal environment, especially since the most important fishery resources are derived from lagoons and estuaries, coral reefs and nearshore shallow waters, which are highly vulnerable to coastal degradation.

13.5.1 Coastal Marine Habitats

Ecosystems such as the mangroves, coral reefs and seagrass are common along the Sri Lankan coast. Mangroves are found all along the sheltered coastline. A rough estimate of Sri Lanka's total mangrove area would be 10 000 to 13 000 ha, including the disturbed northern part of the island (Table 13.4). Amarasingha (1988) reported 21 mangrove species and 17 mangrove associated species in the island. Many present activi-

Table 13.4. Distribution of mangroves in Sri Lanka (After Dassanayake 1994)

District	Extent (ha)
Colombo	9
Gampaha	723
Puttalam	2970
Trincomalee	1070
Batticaloa	1520
Amparai	53
Total	6345

Table 13.5. District-wise distribution of coral reefs in Sri Lanka (After Dassanayake 1994)

District	Reef	Linear extent (km)
Mannar	Vakulai	4+
	Arippu	7
	Silvathurai	2
Jaffna	Point Pedro–Keerimalai	10
Trincomalee	Foul Point	6
	Coral Point	2
Mullaitivu	Nilaveli	1–2
	Pigeon Island	2–3
Batticaloa	Thennadi Bay	8
	Palavi Point	–
	Palavai Bay	–
	Elephant Point	4
	Vandeloos Bay	–
	Pasikudah	–
	Kalkudah	–

Table 13.6. Distribution of coral reefs in Sri Lanka (After Dassanayake 1994)

Area	**Extent (km^2)**
Trincomalee	2.0
Hikkaduwa reef	1.6
Sallidnor	1.0

Table 13.7. Major causes of reef degradation in Sri Lanka (After Rajasuriya et al. 1995)

Human disturbance

Coral mining

Coral mining from the sea for lime production.

Fishing

Blast fishing;
Overharvesting;
Bottom-set nets to catch spiny lobsters and reef fish;
Using nonselective fishing gear;
Indiscriminate netting in reef areas.

Ornamental fish collection

Uncontrolled collection of live marine organisms for the aquarium trade;
Using 'moxy nets' for ornamental fish collection;
Excessive collection of shells and other invertebrates.

Pollution

Pollution from land-based sources;
Sewage disposal;
Pollution from shipping.

Sedimentation

Sedimentation due to unplanned land clearance practices and coastal erosion;
Sedimentation due to construction of ports and harbours.

Boats

Damage caused by boats and anchors;
Glass-bottom boats and fishing crafts colliding against reefs,
Discharging waste oil and bilge water from boats.

Natural impacts

Starfish

Crown of Thorns Starfish (*Acanthaster planci*).

Storms

High wave action and storm surges during the monsoons.

ties threaten the future of the mangrove habitats. Protection of specific mangrove areas is therefore necessary.

The coral reefs are located in relatively undisturbed shallow areas (Tables 13.5 and 13.6) which do not receive large river dischargers of freshwater and the areal estimates have not been estimated as yet. However, 171 coral species belonging to 65 genera have been recorded in Sri Lanka.

Corals are extracted and used for the construction and lime extraction, as well as for ornamental purposes. Fishery activities such as angling, dynamiting, spear-fishing and anchoring of fishing boats, apart from pollution due to land-based activities, all threaten the reefs (Rajasuriya et al. 1995). The major causes for reef degradation in Sri Lanka is given in Table 13.7.

The seagrass beds are found in open sea as well as in river basins, estuaries and lagoons. Extensive seagrass beds are reported from Jaffna lagoon to Dutch Bay and from Mannar to Rameshwaram island in India. In the southwestern part of the island, smaller seagrass beds are found on the leeward side of the coral reefs. Seagrass bed areas in Sri Lanka have not however, been precisely determined, but 12 species of seagrass belonging to 9 genera have been identified. Seagrasses are very sensitive to turbid water caused by pollution and sediments. Bottom trawling and dragnetting also cause damage to seagrass bed communities. The collection of Polychaete worms (feed for brood shrimp) also affects the seagrass beds negatively.

In addition there are two types of estuaries found in Sri Lanka: the basin and the riverine types. Estuaries and lagoons are distributed all along the national coastline and there are about 45 basin estuaries 40 lagoons in Sri Lanka. Their total area is estimated at 40 000 ha and the major urban centres on the coast are all associated with estuaries. The Puttalam estuary is one of the principal estuarine systems in Sri Lanka. It sustains a thriving commercial fishery, which gives a livelihood to large number of people engaged in fishery-related activities. The estuaries and lagoons are also used as harbours, waste disposal sites for recreation, education, sand mining and aquaculture purposes. Waste disposal, aquaculture and mechanized fishing boats are the major causes for the degradation of the estuary (e.g. Kelani) and lagoon (e.g. Lunawa) environments. Further, decreases in salinity due to the discharge of freshwater diverted from irrigation work has been responsible for the depletion of fish and shrimp catches in the lagoons.

13.5.2
Environmental Threats to the Coastal Environments

13.5.2.1
Domestic and Industrial Wastes

Densely populated human settlements are the primary cause of organic pollution of both inland and marine waters. Lack of waste water treatment facilities, is a common problem. There are approximately 60 000 industrial establishments in Sri Lanka ranging from large scale industries to small mining and quarrying operations. Most of the industries are in the Greater Colombo area covering almost 8 000 units. Of these, 3 000 were considered non-polluting, while the rest had polluting potential. Of the latter, 300 were high-level polluters.

13.5.2.2
Agriculture

Pesticides are used extensively in agriculture. However, the use of the more persistent type of organochlorine pesticides is banned or restricted. Information on the levels of pesticide residues in water and organisms is not available. Pesticides such as Arsenates, Arsenites, Chlorodimeform, DBCP, DDT, EDB, Endrin, Heptachlor, Parathion and Methyl Parathion have been prohibited for import.

13.5.2.3
Aquaculture

The development of pond aquaculture has been encouraged by the Sri Lankan government in the last decade by initiating various incentive schemes. Most of the shrimp culture sites are located in the northwestern coastal belt of the island. The impacts of this development activity are:

- Increased concentration of nutrients;
- Production of toxic metabolites such as ammonia, hydrogen sulfides etc.;
- Increase in suspended solids;
- Land salinization;
- Soil and water acidification;
- Natural wetlands siltation and
- Changes in coastal land use.

13.5.2.4
Siltation

The reclamation of coastal flats and flood plains was previously a common practice in Sri Lanka, which have now been suspended. Heavy siltation is caused by the clearing of forests and encroachment of river banks. Most of the estuaries and lagoons are in fact very shallow due to the high sedimentation. Another result of sedimentation is the formation of sand bars across the sea outlets of the coastal water bodies. This reduces the exchange with the sea and sand bars are formed as a result. In addition, the shrimp and fish recruitment is restricted due to these sand bars. Extraction of sand from the lower reaches of the river beds during the dry season causes sea water intrusion. In the flood season, trapping of bed load materials occurs in places where sand has been extracted. The loss of sediments affects coastal sand replenishment. However, this activity is now regulated and coastal sand mining is prohibited under the Coastal Conservation Act.

13.5.2.5
Tourism

Most of the tourist resort areas are distributed along the coastal zone of the island. The construction of hotels and resorts, has caused occasional erosion of beaches. These hotels have also cleared natural vegetation in some areas. There has also been discharge of sewage and waste water into the water bodies without proper treatment.

Information on marine environmental research in Sri Lanka is extremely scarce and research carried out in nearshore waters has not been aimed at studying the pollution hazards. Pollution problems affecting coastal and inland waters are widespread in Sri Lanka. Lunawa lagoon, Walawe Ganga, Velachchenai lagoon represent classic examples of the impact of organic waste and nutrient enrichment causing fish kills. The most significant negative impact faced by the marine environment however, comes from industrial pollution; proper measures must clearly be taken to curb the degradation of the marine ecosystem.

13.5.3 Coastal Area Management Initiatives

With a history of 15 years, Sri Lanka's coastal management programme is considered successful amongst developing countries. The programme was first adopted in response to Sri Lanka's highly visible coastal problem, that of coastal erosion. The mandate of the Coastal Protection Unit set up under the Colombo Port Commission in 1963, was consequently to seek an engineering solution to the erosion problem. The Unit concentrated on the construction of coast protection structures designed to meet site-specific requirements. There was however, no mechanism to coordinate the activities of other departments with jurisdiction over coastal areas, so that efforts at coastal protection were often piecemeal and ad hoc.

In 1978, a Coast Conservation Division was established within the Ministry of Fisheries with the responsibility of handling all matters related to coastal conservation. However, it was only in 1981 that the Coast Conservation Act (CCA) N° 57 was enacted to deal specifically with coastal problems in a more comprehensive manner. The existing Coast Conservation Division was upgraded into the Coast Conservation Department (CCD). The CCA also established the Coast Conservation Advisory Council (CCAC), an advisory body, to review coastal management problems of significant concern and to give appropriate advice. The CCAC consists of 14 members drawn from various departments with responsibilities for coastal zone management and development, universities, NGOs as well as from the fishing community.

The Act aims at regulating development within a narrow zone (lying between a limit of 300 m landward of the mean high water and a limit of 2 km seaward of the mean low water line), to prevent environmental degradation, pollution and erosion. The CCA assigns the CCD with three primary responsibilities within the designated coastal zone:

a Policy formulation, planning and research;
b Administration of permit procedures regulating coastal activities; and
c Construction and maintenance of shoreline protection works.

The Act prescribes two important tools for the regulation of development activities by the CCD namely, the permit system and the Environmental Impact Assessment requirement for managing development projects in coastal areas. Non-regulatory tools include the construction of coast protection structures and awareness generation about coastal problems through environmental education.

The Act also calls for the setting up of environmental impact assessment (EIA) procedures for large development activities potentially affecting the coastal zone. The EIA procedure involves seeking the cooperation of the general public as well as the NGOs. In 1988, the CCD was amended in response to the growing threat posed by coral mining. The Coast Conservation (Amendment) Act N° 64 of 1988 prohibits engaging in the mining, collecting, processing, possessing, storing, burning and transporting – in any form whatever – of coral within the coastal zone. However, without the support of broader measures to provide alternative means of livelihood for people traditionally dependent on coral mining, this remains a complex issue.

The other initiatives in coastal management in Sri Lanka are the Special Area Management (SAM) projects currently under way in two areas, the Hikkaduwa Marine Sanctuary and the Rekawa Lagoon. These projects aim at facilitating resource management within a defined geographical setting and with defined user groups.

Thus, while coastal management has been recognized as priority and several initiatives have been undertaken in Sri Lanka, lacunae exists both in the legislation and in its implementation. Some suggestions to strengthen Sri Lanka's coastal management initiatives have been put forth. These include:

- Narrow geographic definition of the coastal zone must be broadened to recognize the interconnections within coastal ecosystems and resources.
- Single agency and sectoral approaches to solving coastal resources management problems in Sri Lanka must be replaced by a more comprehensive perspective and coordinated approach.
- Coastal management initiatives should be proactive rather than reactive and regulatory, and should also focus on the development of important coastal resources, such as fisheries.
- Participation of local and provincial officials and coastal communities in the formulation and implementation of plans and strategies must be strengthened.

Sri Lanka is now preparing a second-generation programme which is intended to address coastal issues that were not addressed under the earlier coastal management initiatives. There will be greater emphasis on Special Area Management Projects, where resource management issues can be addressed in holistic, integrated manner, within a demarcated geographical area. It appears, also, that greater community participation will be sought through the Special Area Management planning process.

13.6 Summary and Conclusions

Table 13.8 summarizes the pollution problems in Bangladesh, Maldives and Sri Lanka. Major coastal zone management issues in the three small South Asian nations and also probable solutions are presented in Table 13.9. However, in depth scientific research on many of these problems are needed if the suggested remedies are to be effective.

Some of the major threats that have been well documented are summarized below.

Table 13.8. Major anthropogenic influences (listed in order of importance) in the coastal zone of South Asian countries (After Brown 1997)

Bangladesh	Maldives	Sri Lanka
Marine resource exploitation	Marine resource exploitation	Sedimentation (land development and mangrove clearance)
Sedimentation (mangrove clearance)	Sedimentation (dredging)	Marine resource exploitation
Pollution	Tourism	Pollution
Tourism	Pollution	Tourism

Table 13.9. Coastal management issues and probable solutions in small South Asian countries

Country	Issues (as prioritized)	Solutions
Bangladesh	Promote quality research relating to environmental issues	
	▪ Dumping of untreated sewage into rivers, estuaries and neritic waters ▪ Destruction of mangrove and other forests ▪ Siltation causing turbid water and leading to the formation of sand bars and closure of estuary mouths	Creation of data bases
	▪ Discharge of industrial effluents of various origins ▪ Overfishing-capture fisheries and shrimp seed collection ▪ Release of agrochemical: fertilizers and pesticides ▪ Solid water disposal in aquatic systems	EIAs should be made before implementation of activities which might effect the environment
Maldives	Education and Awareness	
	▪ Coral mining	Strict enforcement of laws
	▪ Sewage/industrial/aquaculture and agriculture discharges ▪ Solid waste disposal ▪ Overexploitation of marine living resources ▪ Land reclamation/siltation ▪ Sand mining ▪ Dredging ▪ Construction of unplanned structures on the coast ▪ Mangrove destruction ▪ Oil pollution	▪ Feasibility studies locations available for sand-mining ▪ Support to sewage treatment disposal plan proposal in critical areas ▪ Improving existing sewage farms and ensuring better management ▪ Improving collection/handling systems of solid waste ▪ Establish suitable land- fill sites
Sri Lanka	Control land filling	
	▪ Coral mining	EIA before dredging
	▪ Sewage/ industrial/ aquaculture and agriculture discharges	Develop management plans for maximum sustainable yield
	▪ Solid waste disposal ▪ Construction of unplanned structures on the coast ▪ Sand mining ▪ Mangrove destruction ▪ Overexploitation of marine living resources ▪ Land reclamation/siltation ▪ Oil pollution ▪ Dredging	▪ Remove subsidies on boats and gears ▪ Control over destructive fishing methods ▪ Strict enforcement of forest ordinances ▪ Rehabilitation of mangroves ▪ Water quality monitoring in chronic areas of oil pollution ▪ Implementation of coastal zone management plan ▪ Guidelines for resort development

Destruction of marine habitats has been causing great concern in these countries. Coral reefs and mangroves are degraded in all countries bordering the Bay of Bengal and many coastal areas are overexploited. The delicate balance between marine life and such coastal habitats as lagoons, estuaries, mangroves and coastal wetlands is disturbed in all the counties studied.

Siltation, causing reduced primary production and obstruction of the outlets of lagoons and estuaries, is a major problem. Large amounts of fertile soils are lost due to existing agricultural and forestry practices. Some studies indicate that the sedimentation loads in the large rivers entering the Bay of Bengal have increased a hundred times in the last century. This reduces carrying capacity, both in the terrestrial and aquatic habitats, and the long-term consequences can be disastrous in view of the continued population growth.

Sewage pollution, is of particular concern in all countries around the Bay of Bengal. Wastes, without any treatment, are directly discharged into the waters of the densely populated coastal regions. Rivers, lakes, lagoons, bays etc., are anoxic for shorter and longer periods during the year, causing fish kills. In addition, serious health problems connected with such pollution are also prevalent. About three quarters of all diseases in the developing countries are caused by waterborne microorganisms. The most promising remedy suggested is sewage-fed fish farming and biological treatment in oxygen ponds and ditches. These methods offer a revenue in addition to serving as waste treatment process.

Overexploitation of the marine living resource and the environmental impact of aquaculture are also major concerns of the region and need new management plans, and a closer attention to habitat destruction. It is evident from the above facts that small South Asian nations such as Bangladesh, Maldives and Sri Lanka have taken some steps to better protect and manage their coastal resources. However, such initiatives are not adequate since they remain narrow and sectoral in focus. There is a greater need for a comprehensive integrated coastal area management and for greater interdepartmental coordination.

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Part III

Case Studies

Chapter 14

Tourist Development in the Costa Brava (Girona, Spain): A Quantification of Pressures on the Coastal Environment

R. Sardá · M. Fluviá

14.1 Introduction

The "tourist industry" will be the world leader economic sector by the year 2000, representing in 1987 the 12% of the world GDP (WTO 1993). Tourist activities bring income and jobs, increased understanding of other cultures, investment in infrastructure, which in turn brings social and cultural benefits. However, on the other hand they can cause destruction of habitats, degradation of landscapes, and competition for scarce resources and services, such as land, freshwater, energy, and sewage treatment (Stanners and Bordeau 1995). In Europe, coastal areas are the most popular tourist destinations. Vellinga and Braat (1994) identified the development of tourism and urbanization, with an annual growth rate of 3–4% for the next 20 years, as one of the main variation trends on the pressure exerted on the coastal systems. This trend parallels the development of a greater preoccupation of the public with the environment and the implementation of the sustainable principles in the Western economy. A requirement for the future would be the establishment of criteria and policies that assure the coexistence of both the tourist economic growth and the functioning of the natural systems. Therefore, new challenges in the management of the coastal zones are needed, but first it is necessary to recognize and analyze all the associated pressures that the coastal environment is suffering today.

The Costa Brava comprises the NW Mediterranean coast in Catalonia which extends from the Spanish-French border (Portbou) to the mouth of the Tordera river (Blanes) (Fig. 14.1). Along this 220 km stretch of shoreline, a series of mountain ranges run headlong into the sea, forming small, secluded pine coves and beaches. Long sandy beaches at the mouth of several rivers provide a contrast in scenery. This picturesque and beautiful region, together with their climate, historical monuments, and the mercantile and social life offer visitors a large range of attractions (http://www.cbrava.es), and have converted this European coastal area into an ideal summer resort, one of the most common sites in the agenda of tourist operators. The Costa Brava is located in Girona, one of the four provinces of the Autonomous Territory of Catalonia. It is administratively composed by five regions (L'Alt Empordà, Baix Empordà, La Selva, Gironés, and Pla de l'Estany), but only the three former ones have a direct contact with the Mediterranean Sea (Fig. 14.1).

Adverse impacts on natural coastal systems are usually the result of industrialization, urbanization, and the use of agriculture at industrial-scales (Ros 1994). The small rivers of the region (Tordera, Ter, Fluviá, Daró, and Muga) are polluted by discharges from several industries and agricultural practices, however, the most important pressure on the natural systems of the Costa Brava is from the tourist industry and all its

Fig. 14.1. Map of the Costa Brava region

associated impacts. Tourism, as used by the WTO, includes all travel by people to destinations outside the place they normally live, for any purpose (pleasure, professional, health, of others). Although it is not so obvious for many people, tourism is an industry, or rather a diverse group of industries (travel, accommodation and catering, entertainment, …) which have the potential to harm the environment. In this paper we will describe the recent development of tourism in the Costa Brava, the main pressures exerted on the natural systems, and the current management of its littoral zone together with the principal associated problems. We will then describe how integrated coastal zone management (ICZM) can help to manage tourism in a sustainable manner.

14.2
The Development of the Tourist Industry in the Costa Brava

Anthropogenic influence on the coastal system is increasing steadily. In Spain 30% of the population live in coastal areas, but in addition the coastal area is the destination of 82% of the incoming tourist. Tourism is the most dynamic sector in Spain, accounting for 9.4% of the GDP in 1993. With annual growth rates around 1–3% (1990–1995),

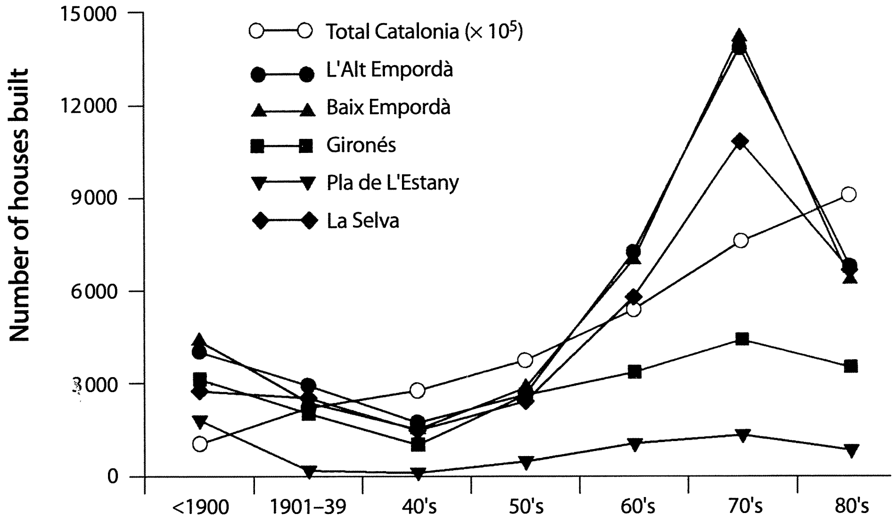

Fig. 14.2. The construction of new houses in the five administrative regions of the Costa Brava since 1900 by decades. The number of built houses for all Catalonia (*open circles*) is included for comparison

Spain is the second European country (after France) in arrivals of foreign visitors (WTO 1993). Tourism generates millions of Spanish pesetas in transportation, food, lodging, services, and local purchases, supporting thousands of jobs. Spain almost tripled in the number of foreign visitors between 1980 and 1992, and more than 55 million crossed our borders in 1992. This increased tourism similar to other regions of Southern Europe, has been widely related to the development of a mass tourism of "sun and beach". Several general statements can be outlined today in relation with the development of this type of tourism:

a At present, an important part of the coastal tourist zones, have reached their maturity;
b Tourist operators maintain a strong control over demand and generate strong pressures above all the associated industry (more than 50% of the tourist trips are associated with these operators); and
c Although tourism depend deeply on the quality of the environment for their continued success, the pressure of the tourism industry is conducive to a very limited concern over the quality of the coastal environment, and is still highly atomized with medium quality products, a typical externality result.

Tourism is the main economic sector in Catalonia (12% of the economic activity). In 1995, around 16 million visitors arrived in Catalonia (ACTT 1996); an increased rate of 1.13% over the previous year. Approximately one third of these tourists elected the Costa Brava as their final destination. Tourist supply grew very fast in the '60s, '70s, and early '80s, mainly based on family businesses, with a parallel growth in the urbanization of the Costa Brava (Fig. 14.2). While the construction of houses in Catalonia has been in a process of a constant growth, since the '60s, the construction of new

Table 14.1. Population statistics and the evolution of the touristic offer in the three waterfront towns of the La Selva region (Southern Costa Brava). Data is included for 1960, 1981, 1991, and 1997). Data obtained from Priestley (1986), EUPG (1993) and the Tourist Information Offices of Blanes, Lloret and Tossa de Mar (1997)

	Blanes				Lloret de Mar				Tossa de Mar			
	1960	1981	1991	1997	1960	1981	1991	1997	1960	1981	1991	1997
Population												
a Year round	9492	20353	25663	28090	3627	10463	15018	17800	1778	2979	3439	3853
b Peak at the season			108967[b]				110482[b]			45352[b]		
Accommodation												
a Number of hotels	9	38[a]	–	30	73	174[a]	–	166	66	94[a]	–	89
b Number of beds	517	3748[a]	–	4859	3532	28299[a]	–	38317	2590	5564[a]	–	7584
c Camping sites		8030[a]	–	11272		1736[a]	–	3373		2988[a]	–	6342
d Number of campings				10				4				5
Coastal length of La Selva region:	28.3 kilometers											
Length of beaches of La Selva region:	9.5 kilometers											

[a] Data was taken in1979.
[b] Data was estimated by the authors of EUPG (1993).

houses in the shoreline regions of the Costa Brava grew almost exponentially during two decades ('60s and '70s), being reduced thereafter. The same pattern can be observed when we analyze the accommodations offer in the three waterfront towns of the La Selva region (Southern Costa Brava) (Table 14.1), a tremendous increase in the number of hotels and camping sites, as well as in the year round population was observed between 1960 and 1980, being reduced thereafter. This process of fast growth lacked specific coordination and planification, resulting in a widespread damage to the natural resources. The growth of the tourist sector lead to crowded and cheap tourism, characterize by a remarkably low concern for the environment. The growth have been greatly reduced during the last decade. The increased cost of living, higher prices, the old associated image, the appearance of low-cost competitors in other parts of the world, together with the inadequacy of the "business as usual" management and the incapacity of an adaptation to the new situation are some of the problems (Valls 1996). These problems are actually in the basis of the tourist crisis in the region.

Mass tourism in the Costa Brava has the additional problem of being concentrated, not only in terms of the number of tourist but also in time and space (Fig. 14.3). The increased population at the coast during the summer months (the resident population is multiplied several times, 4 to more than 10, during these months) (Table 14.1), has generated large seasonal environmental problems, and has rapidly modified the littoral zone with the construction of new hotels, residential developments, recreative, leisure, and sports installations, new marinas, roadways, etc.

Tourist managers have found it necessary to develop a strategic model of development for the future; one in which environmental needs are incorporated. In 1997, the Touristic Patronage of the Costa Brava released a highly controversial document, the Action Plan of Sustainable Tourism in the Girona regions. The plan emphasizes the tourism of quality to warranty the future of the sector, and recommends an increase of prices in the offer to improve general services, and changes in the way in which tourism is managed. The plan has been classified as excessively theoretical and based mainly

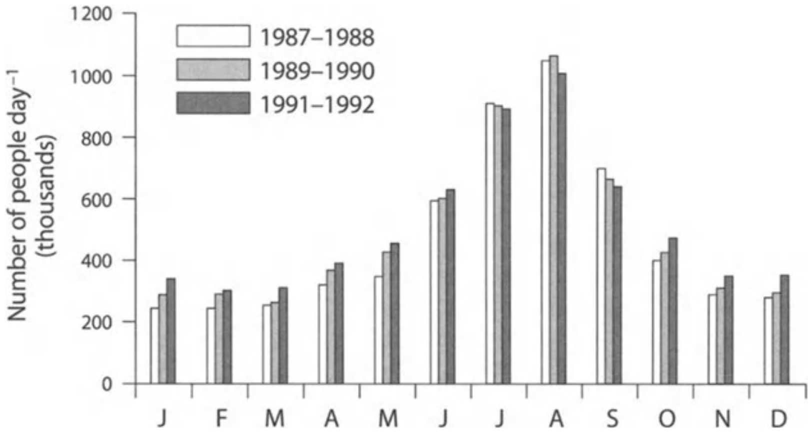

Fig. 14.3. Monthly seasonal occupation of the Costa Brava region (resident population in 1994 was calculated around 250 000 people). Adapted from "Estudis Estadístics Informàtics de l'Index Ocupacional de la Costa Brava (1987–1992)", EUPG (1993)

on long-term goals. Besides economic and competitive circumstances, whatever Plan would be adopted for the future will not be possible without detailed environmental and sociocultural measures to avoid further environmental degradation.

14.3 Environmental Impacts of the Tourist Industry in the Costa Brava

Tourism's relationship with the environment is complex. Tourists arriving "*en masse*" in a specific territory can destroy the very qualities that attracted them to the site in the first place if local managers or stakeholders do not act in consequence, making decisions in order to alleviate the pressures exerted on public goods. In the Costa Brava, direct and indirect environmental impacts related to coastal tourism can be catalogued into: environmental pollution and deterioration of the natural heritage (Fig. 14.4)

14.3.1 Environmental Pollution

Increased tourism leads to a higher demands for transport facilities, water supply, sewage, and waste disposal facilities (see environmental indicators for the Costa Brava in Table 14.2). It therefore implies increased contamination of the atmosphere by traffic congestion, the land by inappropriate waste disposal, and the water by the effluents of sewage and sludge. The seasonality of waste production, characterized by a peak during summer (the tourist season), and lower production the rest of the year, clearly reflect tourist activities in the area (Fig. 14.5a). Solid waste disposal has been a major problem in the past when many uncontrolled dumps were observed throughout the territory. Most of this dumping sites have been recently sealed off, and remediation practices have been applied. Landfill practices have evolved considerably during the last years and proper management is now been conducted. Old landfill sites has been

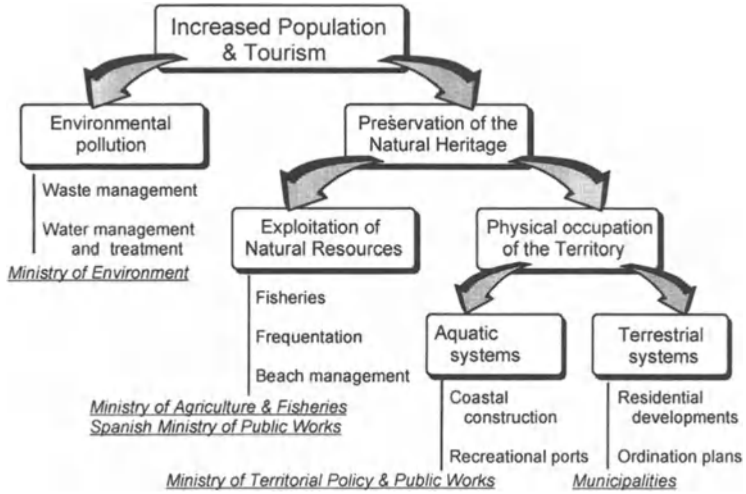

Fig. 14.4. Schematic diagram of the environmental problems derived of the tourist industry in the Costa Brava

Table 14.2. Environmental pollution indicators for the Costa Brava region from 1987 to 1992 (Adapted from EUPG 1993)

	1987	1992	Δ (1987–1992, in %)
Waste production (t)	146204	152320	+4.1
Water consumption (10^3 m^3)	27518	28132	+2.2
Treated sewage water (10^3 m^3)	20562	26823	+30.4
Telephone rates (millions)	1.148	1.387	+20.8
People occupation (person d^{-1})	440292	509402	+15.7
Personal waste production (kg person^{-1} d^{-1})	0.89	0.81	-9.0
Personal water consumption (l person^{-1} d^{-1})	172	152	-11.7
Personal sewage production (l person^{-1} d^{-1})	128	134	+4.7
Personal telephone rates (rates person^{-1} d^{-1})	7	7.46	+6.6

also sealed and, in some cases, other uses have been introduced. In Lloret de Mar, the old landfill site has been rehabilitated into a Golf court (pitch and putt) where environmental education courses are also provided.

Water resources must be correctly managed to ensure a correct supply and quality of water (fresh- and saltwater), and to accomplish the environmental needs for water requirements, treatment, and disposal of sewage. It has been widely recognized that fresh water supply can be a limiting factor for the development of a mass tourism in many areas of the Mediterranean. Water requirements increase greatly during the tourist season (Fig. 14.5b). The seasonality in the consumption of water mirrors the production of solid waste. The Costa Brava receives water from the Catalan basin. Although there is enough water to fulfil its requirements, resources of the basin (1532 hm^3 a^{-1})

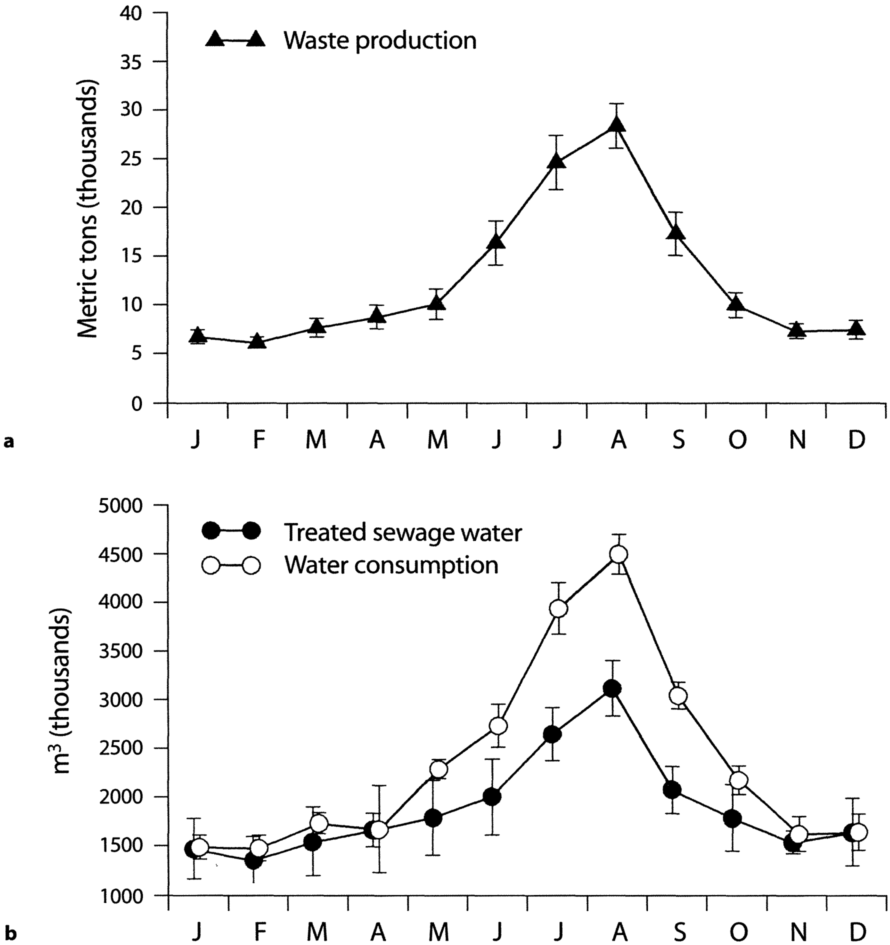

Fig. 14.5. **a** Waste production, and **b** water consumption and treated sewage water in the Costa Brava region. Data shows the average from 1987 to 1992 (±s.d.) (Adapted from EUPG 1993)

are heavily used (water consumption averaged 1 210 $hm^3 a^{-1}$) and soon it will be necessary divert freshwater from the Ebro or the Rhone basin to meet domestic needs.

In relation to water treatment, the Autonomous Government is managing a sewage treatment plan which will provide all municipalities greater than 2 000 inhabitants to have a biological treatment system by the year 2005 in order to accomplish the 76/160/CE Directive, to improve the quality of the sewage released into the water. Although the development of new plants have improved the quality of our running waters as well as the aquifers of the region, it is also true that we still have problems derived of ominous practices, and the unsuitable use of the river biological flows. Treatment plants of littoral municipalities are being scaled to the maximum population size at the tourist season (Fig. 14.5b). The relationship between sewage treatment and the quality of the bathing water is clear. In 1992, 147 beaches were monitored in Catatonia, 89.1% accomplished the EC Directive, and 9 were awarded with blue flag certification (i.e. excellent quality). In 1996, out of the 184 beaches that were monitored, 98.1% accomplished the Directive, and around 70 merited the blue flag. Almost all of the beaches at the Costa Brava fulfilled the Commission's Directive on bathing water, and many of them are awarded with the blue flag each year. Compared to the rest of Europe, the Costa Brava is far above the average.

The Autonomous Government is also responsible for enforcement of the MARPOL Convention to treat waste of marine vessels. Collection systems are deposited in commercial, fishing and recreational ports along the coast. In addition, quality environmental programs are developed for the management of ports (Sardá and Pinedo, unpublished).

14.3.2
Preservation of the Natural Heritage (Exploitation of Natural Resources)

The increased population in the coastal area leads to high pressure on the natural heritage. The maintenance of healthy coastal ecosystems is highly dependent on the correct exploitation of natural resources, the protection of key sensitive areas, and the preservation of natural habitats (Fig. 14.4).

Direct exploitation of coastal resources is threatening many populations (shellfish, sea-baits, sea-urchins, littoral fishes, corals, ...) and habitats in the area (dunes, beaches, seagrass meadows, ...). Unsustainable fisheries and irresponsible trawling, as well as the absence of environmental attitudes from the public, are drastically damaging the Costa Brava ecosystems. Probably, *fisheries* is the most evident one as the Spanish population have a high demand for sea-products.

Table 14.3. Minimum legal capture size and female size at maturity for some of the most common marine captures in the Catalan Mediterranean littoral. Data are extracted from the Real Decreto S60/1995 of the Spanish legislation and the document "Captura y consumo de pescado ilegal en Espana" (Greenpeace, 1996). Size refers to total length, except for the common littleneck and the carpet clam (shell width)

	Minimum legal size (cm)	Size at maturity (cm)
Sea bass (*Dicentrarchus labrax*)	23	35 – 40
Anchovy (*Engraulis encrasicolus*)	9	11 – 13
Grouper (*Epinephelus* sp.)	45	40
Angler fish (*Lophius piscatorius*)	30	35
Commongrey mullet (*Mugil cephalus*)	16	21 – 35
Red mullet (*Mullus* spp.)	11	12.5 – 13
Breams (*Pagellus* spp.)	12	10 – 20
Common sole (*Solea vulgaris*)	20	30 – 34
Gilt-head bream (*Sparus aurata*)	20	22 – 33
Mackerel (*Trachurus* spp.)	12	15 – 18
Norway lobster (*Nephrops norvegicus*)	7	
Spiny lobster (*Palinurus* spp.)	24	
Common littleneck (*Chamelea gallina*)	2.5	
Carpet clam (*Venerupis* spp.)	2.5	

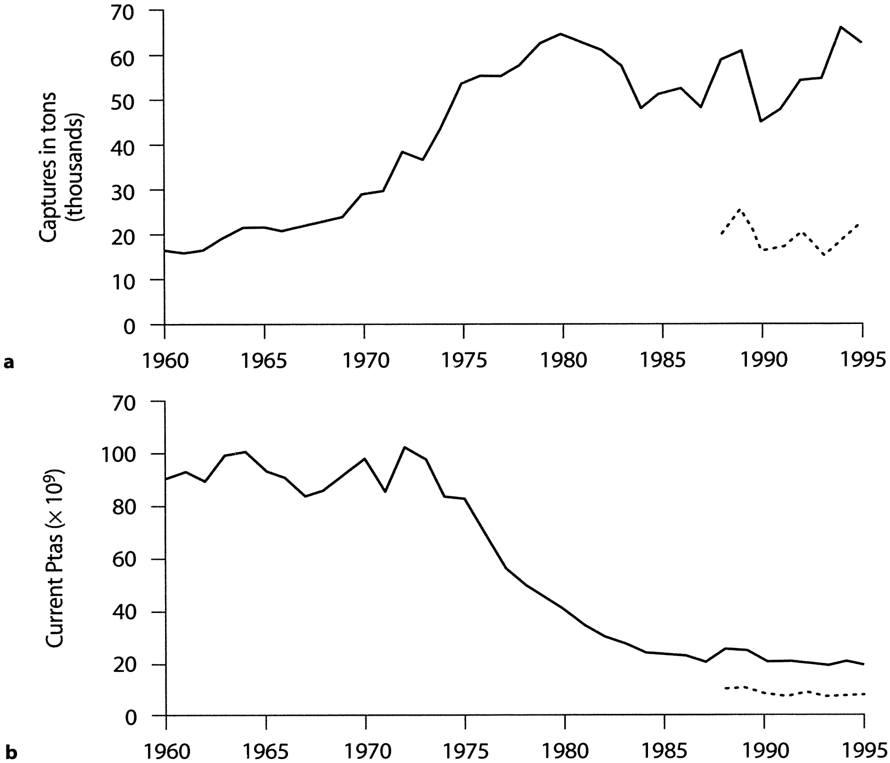

Fig. 14.6. a Total captures and **b** fisheries earnings since 1960. Straight line indicate total Catalonia, dotted line indicate Costa Brava (Adapted from Irazola et al. 1996)

The Costa Brava fleet is mainly dedicated to littoral fishing (Table 14.3). During the last years (1985–95) the fleet has been reduced in number, but the average size and power has been greatly increased (Irazola et al. 1996). Despite that, catches are stabilized at 55 000 t a^{-1} (±10 000) (Fig. 14.6a), and fisheries earnings are declining (Fig. 14.6b). As a result, the fishing sector is actually in crisis, and it is asking desperately for more and better regulation. Fisheries resources in the Costa Brava can be catalogued in three groups:

a Large pelagic species such as the tuna (*Thunnus thynnus* and *Thunnus alalunga*), the Atlantic bonito (*Sarda sarda*), and the swordfish (*Xiphias gladius*), which accounted for 3 662 t in 1995;

b Small pelagic species, the most important ones being the European pilchard (*Sardina pilchardus*) 25 023 t, and the anchovy (*Engraulis encrasicolus*) 10 135 t in 1995; and

c demersal species, probably the most valuable ones, such as the hake (*Merluccius merluccius*), 2 037 t, the deepwater shrimp (*Aristeus antennatus*), 456 t, and other species like the red mullet (*Mullus barbatus*), the octopus (*Octopus vulgaris*), the Norway lobster (*Nephrops norvegicus*), the common sole (*Solea vulgaris*), and the anglerfish (*Lophius piscatorius*).

Although cyclical fluctuations can complicate the observations on pelagic species, it is widely accepted that demersal stocks, except in few cases, are overexploited (Farrugio et al. 1993). Some of the most important problems concerning the management of fisheries in the region, similar to those observed in other parts of the world, are listed below.

a The overexploitation of stocks, based on the increased demand for marine products, which goes up during the tourist season (the demand for sea-rice, the popular "paella", increases highly during these months), the improved fishing technology and power (even if most part of the fleet can be considered as "artisanal") without a reduction in the time-effort of captures, and the use of illegal practices such as trawling on forbidden shallow bottoms, and illegal nets;
b The present fishing law that allows fishermen to catch immature fish (Table 14.3). In most cases, a decreasing trend in individual lengths of the fish caught per unit effort is observed in the ports, and in general, juveniles are under the most important fishing pressure. This problem is accentuated by the popular and at the same time ominous habit of the Spanish people to consume "small fish", regarding its life cycle;
c The presence of other national or foreign fleets in the zone which put higher pressures on the local fleet. During the last years, the Southern anchovy fleet, after depleting anchovy stocks in Southern regions of Spain, have moved to catch the species in the Northern part of the country, getting at the same time high governments subsidies;
d The lack of better regulations and the application of the "tragedy of the common principle". A fisherman who tries to conserve the stock by leaving fish in the sea has no reason for thinking that he will gain by his investment: the fish he has spared, or their offspring, will probably be caught by someone else, and
e The lack of a complete compilation of the entire catch in the littoral zone, including sportive and underwater fishing activities, and the absence of a clear compilation of a common data base on catches, as well as biological and economical information.

The above problems can be observed during the analysis of the following examples (Fig. 14.7). The anchovy occupies the second place with respect to the volume of captures obtained in Catalonia, while is located in head insofar as the income that it provides. Scientists consider that in the NW Mediterranean fisheries there is no overexploitation of the anchovy, but it would be convenient to prevent recruitment overfishing (Pertierra and Lleonart 1996). Though it has had strong oscillations during the last 30 years, the presence of other fleets in the region have caused the local fleets to work intensively during winter, the time of the year when the average size of the species is small, and the captures are below the legal size and the mature size (Fig. 14.7a). The Mediterranean hake is one of the most important demersal species in the Gulf of Lions (the third single species in fisheries earnings). The stock is actually overexploited (Recasens 1992) by four different types of gear (Fig. 14.7b). Overfishing of this species derives from the use of trawling and the effect on the small juveniles, commercialized (many times illegally) under the name of "llucet" (Fig. 14.7b).

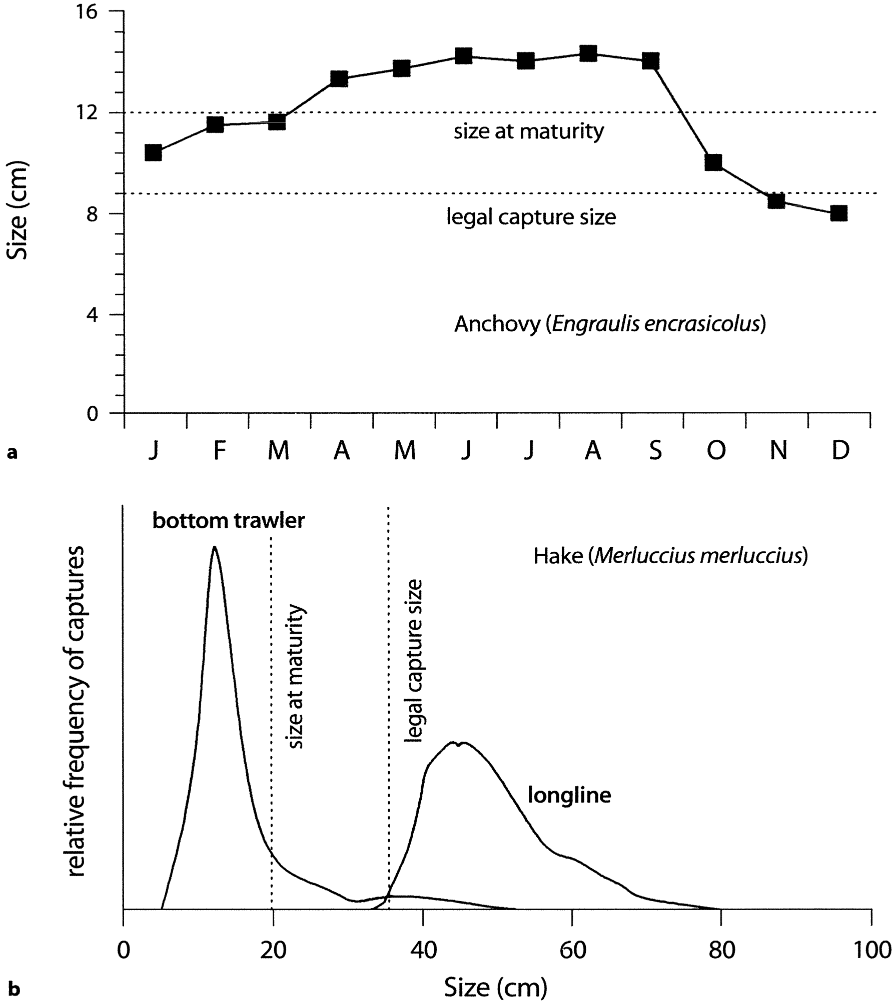

Fig. 14.7. a Monthly average capture size of the Anchovy in the Costa Brava. Data obtained by Pertierra and Lleonart during the course of the EC-DG XIV project "Northwestern Mediterranean Anchovy: distribution, biology, fisheries and biomass estimation by different methods. **b** Relative frequency of Hake captures in the Gulf of Lions by means of bottom trawler or longline (Adapted from Aldebert and Carries 1988)

Industrial fisheries are not unique factor in overexploiting natural resources in the Costa Brava, other important species such as selfish, sea-baits, sea-urchins, actinias, or littoral fishes today suffer overexploitation due to direct collection (lucrative or not) or sports fishing; it is almost impossible to carry out a compilation of such kind of catches. These kinds of highly seasonal exploitation also have importance in modifying habitats and in alter coastal ecosystems. Studies conducted in the Marine Reserve of the Medes Islands (Zabala et al., unpublished), in which a protected zone was com-

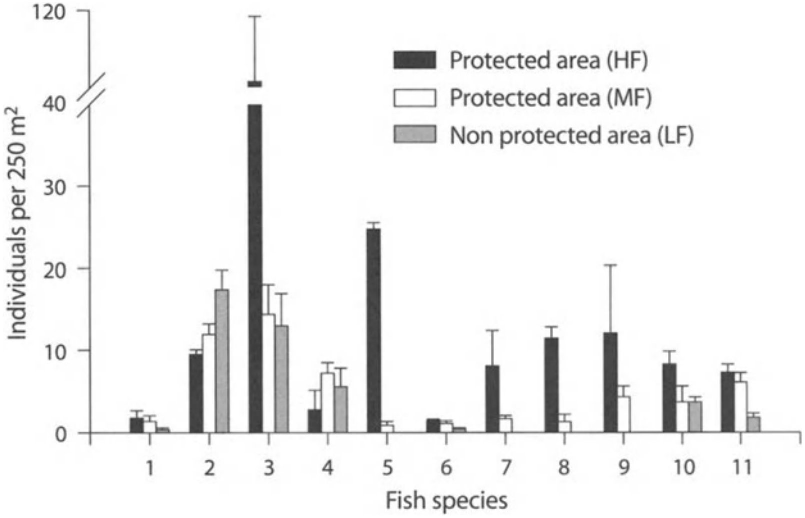

Fig. 14.8. Densities expressed as mean number of individuals per 250 m^2 (±s.e.) of different common fish species in protected areas of the Medes Islands with high fish densities (*HF*) and medium fish densities (*MF*), and compared with non protected (*LF*) areas of the vicinity. Fish included are: *1 Scorpaena porcus*, *2 Serranus cabrilla*, *3 Diplodus sargus*, *4 Diplodus vulgaris*, *5 Diplodus cervinus*, *6 Diplodus annularis*, *7 Diplodus puntazzo*, *8 Sparus aurata*, *9 Sciaena umbra*, *10 Symphodus tinca*, and *11 Symphodus mediterraneus* (Adapted from García-Rubiés and Zabala 1990)

pared against control zones on the Coast, demonstrated the positive effect of the creation of marine reserves. In the absence of human predation, the number of littoral fishes and their size increased greatly (Fig. 14.8). Furthermore, the presence of more or less fish on the coast can control other species such as the sea-urchins. Increased fishing pressure may directly reduce the populations of herbivorous fishes and indirectly mediate an increase in sea-urchin populations, by eliminating sea-urchin predators, which then remove fleshy alga communities. The scenery then changes to a community dominated by encrusting calcareous algae (Sala 1996), which has altered the natural habitat.

Recreational use of coastal areas may have other adverse ecological consequences derived from the frequentation of habitats. In some Marine Protected Areas (MAPs) the acceptability of damage by divers has been calculated (Dixon 1993; Ramos-Esplá and Bayle-Sempere 1989). Diver impacts appear to become significant above a certain critical visitation level. The effects of divers on Mediterranean sublittoral and circalittoral habitats have been studied in the protected area of the Medes Islands where diver licenses have been established on 450 visits per day in 1997. The density and size of the colonies of the bryzoan *Pentapora fascialis* were significantly lower at frequented sites than at unfrequented sites (Sala et al. 1996). Mortality rates of the gorgonian *Paramuricea clavata* were also higher at frequented sites (Coma and Zabala 1994). The mean size of the red coral *Corallium rubrum* also appeared to be larger at unfrequented sites (Sala and Garrabou 1994, unpublished.). Diver visitation is a causal factor that plays a major role in determining the structure of coralligenous communities at higher frequented sites. Economic activities associated with the use of MAP's produced yearly gross revenues. Adequate management should be emphasized to minimize damage, however it is necessary to recognize by all the social agents involved, that the application of measures usually requires money and legal authority.

Other common changes related to human frequentation have been studied elsewhere. Effects of human trampling on marine rocky shore communities of Oregon (USA) (Brosnan and Crumrine 1994), show the shift of the community composition to an alternate state dominated by low profile algae. No similar studies have been conducted in our zone, but the direct collection of mussels (*Mytilus galloprovincialis*) in their habitats have changed in many localities the typical NW Mediterranean rocky mediolittoral zonation.

Another good example of problems of frequentation is the seasonal dispersal of recreational boats along the entire coastline. *Posidonia oceanica* is the dominant seagrass in NW Mediterranean. It is a climax species that develops large stable meadows in sublittoral soft-bottom areas. There is evidence that *Posidonia oceanica* meadows are declining everywhere (see revision in Marbá et al. 1996). Several causes have been suggested: eutrophication, siltation, trawling, infections, coastal engineering and marinas ..., and frequentation. Anchorage in meadows have important repercussions on these meadows. Anchorage of boats, as well as trawling in the meadows, have the potential effect to form anchor scars which facilitate erosional processes in the meadow. Studies conducted in the marine reserve of Port-Cros (France) showed that shoot size and density were considerably larger in zones where anchorage was forbidden than in other areas (Garcia-Charton et al. 1993). Anchorage of boats on *Posidonia oceanica* meadows today have another potentially dangerous effect. In 1989, the invasive green algae *Caulerpa taxifolia* was observed in the open sea at Monaco (Meinesz and Hesse 1991). Since then, the area colonized by this algae went from one square metre to thousands of hectares in Western Mediterranean, specially in the French littoral. *Caulerpa taxifolia* is able to colonize with a dense mat on all kinds of substrates, even over *Posidonia oceanica* meadows; the new assemblage dominated by this algae show a reduced number of other algal species, and a very low diversity. *Caulerpa taxifolia* is now present in many localities of the littoral in France and Italy as well as several Mediterranean islands (Elba, Sicily and Majorca). The dispersion over long distances seems to be result of propagation through cleaning of anchoring systems of recreational boats and fishing nets since the algae is able to survive several days under the conditions prevailing in a boat anchor locker (Sant et al. 1996).

The tourist industry of the Costa Brava is very dependent on beach management. The beach is the most frequented space. Undoubtedly the beach is the basic asset of any touristic resort on this coast. Beach changes are mainly related to variations in the incident wave energy along the beach, the selective sorting of sediment during transport or changes in the amount and size of sediment supplied to the beach (Guillén and Palanques 1996). Natural beach processes continue to mold the shore, but because beaches are attractive for a wide variety of recreational purposes, increasing populations in coastal towns have usually located near or over them disturbing the natural equilibrium of erosion and accretion "the equilibrium profile". In many cases, this equilibrium has been disrupted, and corrective actions are needed to restore the resort. Engineering solutions to control erosion are to built groins, or to replenish beach sediments through beach nourishment.

As opposed to what has been occurring in other parts of the Catalan Coast, beach nourishment techniques are not commonly used in the Costa Brava. Nevertheless, during the last years, sublittoral shallow soft-bottoms in front of S'Abanell beach (Blanes) have been used to regenerate beaches located some kilometres South of Blanes (Maresme region). Although it is not mandatory, and no major management commitment is necessary, the EC Directive 97/11 (3rd March 1997) recommend to the EC State Members (Annex II) to conduct an Environmental Impact Assessment previous activities of shoreface nourishment and sand extraction. Beach nourishment is an expensive activity and important associated risks to these techniques should be careful evaluated such, namely:

a The loss of beach stability by redistribution onshore, offshore, and alongshore, in the zones where sand is extracted;
b The irreversible changes such as destruction of *Posidonia oceanica* seagrass meadows; and
c The depletion of the (zoo)benthic community in the sand extracted sites, the later can be coupled with the disappearance of commercial bivalve banks, with associated risks for other consumers up in the food chain.

Next to the dredging activities in front of the S'Abanell beach, an important loss of the beach surface was observed by the accentuation of the beach profile, and a commercial bank of the clam *Callista chione* almost disappeared of this shallow bottoms (unpublished data). *Callista chione* was measured in 1992–94 at an annual average biomass of 0.6 g dry weight m^{-2} (11.0 t wet weight without shell) in the Bay of Blanes (density of 6 individuals m^{-2}) just before the last dredging activities. Two years after the dredging, the biomass of *Callista* in the Bay was measured as 0.1 g dry weight m^{-2} (1.9 t wet weight without shell) with a density of 3.5 individuals m^{-2}. The loss of surface beach by tourist, or the compensation measures for the clam fishermen of Blanes (they need to go to other regions now to fish) were not considered before the processes of restoration of the Maresme beaches.

14.3.3
Preservation of the Natural Heritage (Physical occupation of the Territory)

Tourist demand in our country led to a rapid and often disorderly *urbanization* of large stretches of our coast. The main consequences of mass tourism has been the appearance of a huge hotel web, apartments, individual houses and camping grounds that they have profoundly modified the landscapes of the Costa Brava. The individual initiative combined with local policy have been key factors for this rapid growth, and account for the different models of development found in this coast, ranging from those observed in Lloret de Mar or Playa de Aro to those observed in Cadaques or Tossa de Mar. Figure 14.9 show the landscape transformation of the shoreline (two first kilometres inland from the sea) in the three waterfront municipalities of La Selva region (Southern Costa Brava). In this figure we compare the percentage of land uses in 1956, 1981, and 1995. In this 40 year period, the three municipalities have experienced a contrasting evolution. This evolution is based on their recent past. Blanes is the most populated town, and has a fishing port, a deltaic flats, and industrial activities of cer-

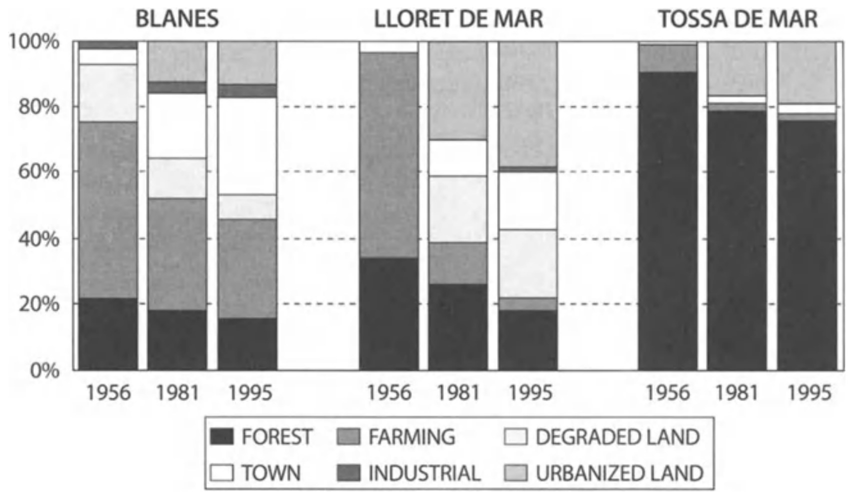

Fig. 14.9. Percentage of land-use (1956, 1981, and 1995) in the three waterfront municipalities of La Selva region (Adapted from Priestley 1986 and Aeroguías Planeta 1995)

tain importance. Lloret de Mar and Tossa de Mar are small villages whose form of life was related to the artisanal fishing and agriculture practices, being at the same time more retired from the territorial roadways. The recent evolution of these three towns, has been based on their different tourist development. Lloret de Mar is a good example of the result of a "laissez-faire" policy and mass tourist promotion. Tossa de Mar has had greater control of construction and now has a greater advantage to get a tourism of quality (high-budget tourism). In Blanes, the past economic basis has conditioned the actual land uses. In spite of the greater extension of forest in Tossa de Mar, it is possible to observe several common standards in the evolution of soil uses in these three municipalities, there is a: progressive lost of forestry, the abandonment (except for Blanes) of agricultural practices and their reconversion into urbanized and degraded zones, and a tremendous increase in the urban town and in the surrounding urbanization and condominiums.

Besides *recreational* and *fishing ports* and *marinas*, and some promenades directly constructed on the beach, no other important projects based on coastal construction have been located in the shoreface of the Costa Brava, other than small private piers and docks. From the '60s to the '80s many recreational ports and marinas were constructed in this region in conjunction with the urban development of their towns. Seventeen recreational ports, wharf's and/or marinas are now set on the Costa Brava, six of them with commercial activities (fisheries and transport of goods). One recreational port is actually in construction and other three are being enlarged. The total moored fleet is composed of approximately 8 400 boats.

Environmental considerations for ports and harbor developments have been outlined by several authors (Clark 1983; Davis et al. 1990; Mauvais 1991). For all of them it has been clear that the effects which occurred during the construction phase need to be separate from the effects observed in the operational phase. The presence of a port on the shoreline changes the property of the soil (from public to private), strongly modifies the landscape, and can hide speculative activities that bring higher impacts on the coastal front-line. In addition, it has direct and indirect impacts on the marine environment. Because of that, the CE strongly recommends an environmental impact assessment before a new development is constructed. Moreover, the CE has given advice to the administrative bodies to do a careful evaluation of these EIA's procedures and to introduce other environmental protection plans, as well as quality environmental management plans during its life operation. Behind all these guidelines, the main recommendation is that the potential benefits of these facilities must be weighed against the potential adverse impacts on the environment.

Recreational ports and marinas should avoid pristine areas as well as vital areas, such as wetlands and estuaries. The presence of a 2 500 boat marina in the middle of the natural park of the Aiguamolls of L'Empordà constitutes a serious environmental mistake. They should not interfere with important natural resources such as seagrass meadows, beaches, dune communities, etc. The future offer of the tourist will depend greatly on these particular natural habitats, as well as public goods. They should know clearly which are the associated changes and impacts that will promote in the marine environment in the vicinity as well as in the neighbouring areas, to be able to include corrective, compensatory, and minimization measures. It is really important to do a careful environmental diagnosis prior to the construction in order to catalogue the organisms and habitats inhabiting the zone, the associated looses by physical destruction, and the effects on the neighboring areas (the enlargement of recreational ports in the vicinity of the Medes Islands Marine Reserve, enhances the pressure on the fragile ecosystems and emphasizes the need for better regulation).

Recreational ports should also be planned within a regional context analysis. It is necessary to analyze what is the correct number of moor sites that are needed in a particular region. Town council managers use to ask the administration for approval and ratification of the development plans on new infrastructures arguing further economic benefits for their own villages and for the entire region. However, sometimes recreational ports are hiding other ludic activities (bars, restaurants, shopping areas, …) or speculative measures about land use, rather than the fleet of boats that they are going to hold. It is also convenient to analyze the possibilities of having inland winter-boat storage for recreational boats that spend a large part of their life static without go to sea, specially for the seasonal recreational fleet. The number of ports need to be adequate to the necessities of the fleet, and should not be excessive. Probably in the Costa Brava we have already obtained this number (the average distance between two ports is actually 9.4 km).

14.4 The Management Framework

The current management of the Spanish littoral is based on different and very heterogeneous initiatives which are hierarchically ordered by three different administrations: national (Spanish), autonomic (different autonomic regions of Spain), and municipal. The Statute of Autonomy of Catalonia defines the distribution of responsibilities between the General Administration of Spain (State) and the institutions of self-government and local Administrations of Catalonia (autonomous country). Within this framework, the state institutions are responsible for basic legislation and general coordination. The parliament of Catalonia has the authority for developing the basic legislation, while local administrations have executive competencies. Since 1991 this executive responsibility has fallen on the Department of the Environment (which acts as a ministry), the first of its kind to be created in the Spanish state. Although the Catalan government has carried out a wide range of active environmental policies throughout its territory, there is not a general plan of coastal zone management and the competencies in the issues are highly fragmented and divided into several administrative offices (environment, territorial policy and public work, agriculture and fisheries, and the different municipalities) (Fig. 14.3).

The coastal zone in Spain is regulated under the "Ley de Costas" Spanish Coastal Law of 1988. The Spanish Coastal Law (1988) was enacted to protect coastal areas from unregulated development. It is commonly accepted however that this law arrived very late in many parts of the Spanish territory. Under the umbrella of the old Coastal Law of 1969 unplanned growth and overdevelopment, abusive building of second houses, many times on sensitive natural areas, unsustainable use of natural resources, and abusive practices of enrichment based on the appropriation of public goods, were carried out everywhere. The new Coastal Law reaffirms the public domain of the coastline and defines the rights of way and limitations on the property. The law also identifies an inner coastal strip of 500 m in which development is subject to strict regulation. The law outlines a transit area of 6 m, a protected area of 100 m that can be extended up to 200 m (20 in areas urbanized previously to 1988), and an area of influence of 500 m, before private property is allowed.

The "Ley de Política Territorial" (Catalan Law of Territorial Policy) of 1983 regulates the development of the territory. Under this law other sector plans have been implemented. As a consequence of this law, the protection of the natural heritage has been one of the key points for several organizations in Catalonia. In 1992, the Spaces of Natural Interest Plan (PEIN) was approved (1997–2000). The plan protects and regulates 21% of the Catalan territory (144 natural spaces) and specific management plans are developed for every one of these spaces. On the Costa Brava, the Cape of Creus, the salt marshes of L'Empordà, and the Medes Islands need yet to be outlined. The Cap of Creus, a peninsula of great geological, floristic, and faunistic interest with abrupt and rocky relief is actually in process of being protected by law. The saltmarshes of L'Empordà, the second most important wetlands in Catalonia after the Ebro Delta, are in part (Alt Empordà) protected by law since 1983, while the others (Baix Empordà) are also protected but still threatened by the surrounding urbanization. Since protection measures were applied in these saltmarshes, a spectacular increase in biodiversity has been observed. The Medes Islands, protected by law since 1990, is a marvelous underwater habitat, and together with a smaller site "Ses Negres" (Cap of Begur) they are the only marine protected reserves in the Costa Brava region. The presence of these islands benefits nearby towns, extending far beyond the reserve itself.

In 1983, the Catalan Government developed the plan of recreational ports. In this plan, the Costa Brava was classified by different categories of protection based on ecological data. The development of new infrastructures should be done having in mind these categories. Other conservation measures and plans have been enacted to protect species and habitats in our territory, such as the Spanish Law of Conservation of the Natural Heritage, Flora, and Fauna (1989), the Catalan Law of Fisheries (1986), or the

Catalan Law of Animal Protection (1989), amongst several orders of protection of particular species such as seagrasses.274

Besides the above considerations, for the territory, the activities which can be a potential factor of degradation of the coastal zone depend of town council managers. In the past, the economic development of many towns has led to several problems of environmental degradation, such as loss of natural habitats by overdevelopment (Fig. 14.9), soil and water pollution, and resource depletion. Local managers were generally more concerned about the benefits of the urbanized process in the short term, than in the protection of the quality of the natural environment for their continued success in the long term. Today, most local managers are much more conscious of the necessity to protect the environment. However, they need to fight stronger than ever because there is still the idea that everybody can get part of the value of a natural public good into a personal cash flow, as it has been occurring in the past following the idea of the "business as usual" kind of management. In addition, the draft of the new "Ley del Suelo" (Land-use Legislation), which is actually under study in Spain, is a potential danger for the environment since it means the reclassification of the land which can open again the free access to speculative activities. This law transforms many of the declared non-urbanized land in urbanized territory, except the spaces specially protected by the PEIN, the Coastal Law, and the municipal ordination plans. In this context, public action to control unacceptable developments would be necessary and the activities of non-governmental agencies can have more importance than ever demonstrating the worries of a significant part of the population to these practices.

14.5 Concluding Remarks: The Need of a More Integrated Approach

The need for sustainable tourism it is now widely recognized. Tourist managers and local administrators will need to face a double challenge in the future, namely the encouragement of tourist activities and the preservation of the environment under the directresses given by documents of supranational authorities such as Agenda 21, the European Community (Tzoanos 1992; CEC 1993), or the United Nations Environmental Program (UNEP; Mediterranean Action Plan, MAP). Local tourist development could not be done without the inclusion of protective measures for the environment. In many cases, even in our "educated" societies, however it will result very difficult to convince local entrepreneurs that certain projects are not friendly to the environment, and that public losses are much more important that private earnings because the economical value of biological resources are difficult to express in monetary terms (pristine beaches such as Castell (Palamós) have more intrinsic values than the urbanized surroundings, delicate vital areas such as the saltmarshes of Pals are necessary to conserve many local resources, beaches such as Fanals (Lloret de Mar) need to preserve its integrity behind spectacular marinas). As several authors have outlined, a number of key elements should be addressed:

a A longer-term perspective on policy making, as sustainable tourism is a goal which cannot be reached immediately;
b A recognition of the interdependence of economic and environmental systems; and
c A concern with biological limits within which human activities need to stay (Stanners and Bordeau 1995).

In this context, the development of effective integrated coastal zone management plans (ICZM) would be essential to achieve the goals for the future. ICZM can serve to integrate public and private interests together with the functioning of the natural environment, and to manage the plan for development process in the future.

To avoid the degradation of the environment, adversely affecting the delicate and valuable coastal ecosystems, aquifers, wetlands, and biodiversity, in general, and the loss of attractiveness for the tourist sector, it would be helpful to design a Coastal Management Plan for the region based on:

a *Integrated management:* Fully integrated management with a clear and observed regulatory framework, coordinating public and private sectors and using serious environmental indicators. Actually, there is a multitude of different authorities with jurisdiction in the Costa Brava, and each day different social groups exert more pressure on its Natural Assets. It is necessary to create an Advisory council to assist in accurately describing environment and management infrastructure, to analyze current pressures, and to identify the various actors and the development of scenarios, by compiling the relevant environmental regulations applicable for tourist activities on the Coast, and the environmental and socio-economical information available from public agencies. The Advisory Council should incorporate all the associated stakeholders: local tourist agencies and managers, representatives of the different administrations, scientists, environmental organizations, and other involved groups.

b *Preserving the natural heritage:* Protection of ecologically vital areas, as well as the cultural Heritage, with mapping and inventories of relevant inshore and offshore resources and Natural Assets. On the Costa Brava, Natural Systems such as salt marshes, wetlands, and seagrass meadows, such as *Posidonia oceanica*, are still suffering severe man-made impacts. These habitats play important ecological roles in nature by having high primary production, maintaining large associated food web, influencing the dynamics of littoral sedimentation and runoff, and giving shelter to a large number of species and recruits. Thus, it is necessary to carry out educational activities to introduce the concepts of ecological sustainability in our society.

c *Mobilization of attitudes:* The desire for the mobilization of better attitudes of the general public based on a broader knowledge and the understanding of sustainable values. There has been a lack of well-founded attitudes in relation to the use and the preservation of the natural environment. Although attitudes can change if people receive new information, a better education based on ecological, utilitarian, and ethical arguments should be incorporated in the population (Hagvar 1994). Ominous behaviour such as the consumption of juvenile fish, or the illegal dumping of personal garbage, amongst others, should be eradicated.

Although the natural environment is the main treasure of the Costa Brava, this coastline has been degraded in the past, and there is still potential danger for more degradation in the future. The Costa Brava is still a beautiful area, moreover it is already attracting visitors, so there is time to preserve its charm and its natural assets. Careful integrated management is advised. To accomplish this, it would be necessary to develop this region under the concept of sustainability, balancing the economic development against the ecosystems preservation. Plans for tourist development based on sustainable principles should be encouraged. It is going to be difficult to readjust tourist activities given what has been done in the past in this region, however, it is completely necessary if we do not want to kill the goose that laid the golden egg.

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Chapter 15

Australian Integrated Coastal Management: A Case Study of the Great Barrier Reef

N. Harvey

15.1 Introduction

The Australian coast is 69 630 km in length with the adjacent continental shelf covering an area of 2.5 million km^2 and varying in width from 15 km to 400 km (State of the Environment Advisory Council 1996). However, definitions of the coastal zone vary between the different governments. The Commonwealth (of Australia) government, for example, has a very broad definition of the coastal zone based on policy rather than any biophysical or cadastral criteria: "*The boundaries of the coastal zone extend as far inland and as far seaward as necessary to achieve the policy objectives, with a primary focus on the land/sea interface*" (Commonwealth of Australia 1992a).

This reflects the dilemma of trying to come up with a workable definition. A major Commonwealth coastal inquiry, conducted by the Resource Assessment Commission (RAC), into the coastal zone adopted the OECD (Organisation for Economic Cooperation and Development) Environment Directorate approach which suggests that the definition of the coastal zone should vary according to the nature of the problem being examined and the objectives of management (Commonwealth of Australia 1993a). The national inquiry took the marine boundary to be the Australian Fishing Zone 200 nautical miles seaward of low water mark. This area (11.1 million km^2) is about two and a half times larger than the entire Australian land mass. The inquiry then used two operational definitions of the coastal zone for identifying and describing the extent of resources and human activities in the coastal zone. It used an administrative definition when describing the extent of human uses and activities (1.318 million km^2) but a definition based on recognisable drainage basins (1.327 million km^2) when describing the extent of physical and biological resources. Both of these definitions account for an area equivalent to about 17% of the Australian land mass (Commonwealth of Australia 1993a).

Before discussing Australian coastal management it is important to note that there is a three tier system of government involving the Commonwealth (national) government, state and territory governments, and local government. The head powers for most coastal management rest with various pieces of legislation at the state and territory level of government, and these reflect a variety of approaches from specific coastal legislation through to a lack of legislation. Much of the coastal legislation is linked to other legislation such as planning or pollution control. However, much of the day to day coastal management and development control is carried out by local government authorities.

Coastal management in Australia has undergone a period of extensive review in the '90s at both the Commonwealth and the State level. At the national level, this culminated in the production of the RAC Coastal Zone Inquiry Final Report, which attempted to examine coastal management responsibilities at the three levels of government (Commonwealth of Australia 1993a). The timing of the RAC report was important for a number of reasons. It was initiated at a time when there was already a Commonwealth government coastal inquiry being conducted by the House of Representatives Standing Committee on Environment, Recreation and the Arts (1991). In preparation for the United Nations Commission on Environment and Development (UNCED) conference in 1992, national strategies on "greenhouse" and Ecologically Sustainable Development (ESD) were being developed by a Greenhouse Working Group (Commonwealth of Australia 1992b) and an Ecologically Sustainable Development Working Group (Commonwealth of Australia 1992c). In the same year the Intergovernmental Agreement on the Environment (Commonwealth of Australia 1992d) was drawn up between the Commonwealth, state and territory governments. The Commonwealth Department of Arts, Sport, Environment and Territories (Commonwealth of Australia 1992b) also produced a document assessing the role of the Commonwealth in the coastal zone. Consequently, the RAC Inquiry had to place its findings within the context of these other national reports and agreements which were being prepared contemporaneously with the RAC Inquiry.

A further problem for the RAC Inquiry, was that there was a plethora of previous inquiries in coastal zone management and related issues in Australia. The RAC even found it necessary to produce its own review of previous inquiries and examined the recommendations of twenty nine previous national and state inquiries, including the reports mentioned above. The need to review previous reviews indicated the dilemma of reinventing the wheel and producing yet another inquiry, particularly when the House of Representatives Standing Committee on Environment and Conservation (HORSCEC) had produced a review of Australian coastal zone management as early as 1980.

At the state level there have also been a number of recent coastal management reviews and changes to coastal legislation. The most relevant of these for this chapter is in Queensland where there has been a *Beach Protection Act* (Queensland State Government 1968) since 1968 and a Beach Protection Authority which has provided strong technical support and advice and conducted its own coastal research, mostly engineering studies. The *Beach Protection Act* allows for separate delineation of coastal management and erosion prone areas, and provides controls on coastal development. Subsequently, the Queensland state government introduced additional legislation, the *Coastal Protection and Management Act* 1995 (Queensland State Government 1995) which has increased consultation and forward planning in Queensland. The new approach is for state determined policy and guidelines with the actual control being at the local level. The Act has linkages with the national ESD policy and provides a framework for protecting, conserving and managing coastal resources and biological diversity while encouraging research into these together with human impact in the coastal zone.

This and other state based legislative reform together with the Australian coastal reviews have to be placed in the context of international responses to coastal management and predictions of potential sea level rise by the Intergovernmental Panel on Climate Change (1991), in particular the Common Methodology for Coastal Vulnerability Assessment. More recently the World Coast Conference 1993, at which Australia was represented, developed agreed coastal management objectives stressing the need for integrated coastal zone management (ICZM) and capacity building for local coastal managers.

It is notable that the HORSCEC report on Australian coastal management commented in 1980 on the need for the development and promulgation of "*national policies and objectives for the conservation and preservation of the Australian coastline*" in consultation with the states (House of Representatives Standing Committee on Environment and Conservation 1980). Thirteen years later the RAC Inquiry recommended a National Coastal Action Plan with adoption by the Council of Australian Governments of *a set of common objectives* (Commonwealth of Australia 1993a). Similarly both the HORSCEC and the RAC reports comment on the lack of integration of coastal management at different government levels. Although very little national integration had been done over the thirteen year period between these two reports, there have been significant advances made since the RAC Inquiry, as shown in the proceedings of the 1996 Australian Coastal Management Conference (Harvey 1996). However, the management of the Great Barrier Reef is a good example of integrated management, based on legislation which predates all of these reports.

This chapter outlines the integrated nature of coastal management for the Great Barrier Reef which began with the *Great Barrier Reef Marine Park Act* of 1975. However, it is first important to consider some of the more recent Commonwealth coastal initiatives and policy directions which provide a context for the current national perspective on integrated coastal management and sustainable resource use.

15.2
Australia's National Coastal Zone Inquiry, 1993

In 1993 a major national coastal zone inquiry was completed after numerous previous coastal inquiries. This inquiry was significant for two reasons. First, the timing of the inquiry was important in that it came when there was a need for greater national cooperation in the early '90s across a number of environmental areas. Second, a key underpinning of the inquiry was the concept of ESD which, as noted above, was being developed into a national strategy while the coastal inquiry was being conducted.

The coastal inquiry conducted by the RAC (Commonwealth of Australia 1993a) was completed in 1993 and is accompanied by a number of separate reports. The final report is split into nineteen chapters covering aspects such as the resources, values and uses of the coastal zone; a national approach; a national coastal action program; institutional arrangements; the role of community and industry; the role of indigenous people; ways of improving management at the local and regional level; approval systems and impact assessment; economic and financial instruments; funding and implementation. In addition one of the three commissioners disagreed so significantly with the other two, that the final report had a special dissenting view section of over one hundred pages in length.

A number of recommendations came out of the report including:

- National Approach;
- Coastal Resource Management Act;
- National Coastal Action Program;
- National Coastal Management Agency;
- National Coastal Consultative Council;
- Coastcare Program.

The inquiry stressed that the term "environment" has to be treated in a holistic sense rather than the traditional way in which governments administer their management practices. These had often treated different elements of the environment separately rather than adopting an integrated approach to management.

The RAC recommended a national approach because of increasing population and development pressure on the coast. It recognized the danger of yet another report sitting on the shelf. The RAC proposed the enactment of a Commonwealth Coastal Resource Management Act to incorporate the objectives and principles for coastal management agreed by the states and the commonwealth. The proposed Act was intended to link funding of activities in the coastal zone to nationally agreed objectives and principles. However, recommendations such as the Coastal Resource Management Act and the National Coastal Management Authority were shelved after opposition from state governments.

Perhaps the most important recommendation to come out of the inquiry was the national Coastal Action Program which had four main elements:

1. Adoption by the Council of Australian Governments of a set of common objectives;
2. Establishment of arrangements for implementing and managing the program;
3. Greater community and industry consultation (such as the proposed Coastcare program);
4. Wider and better use of modern management and economic tools.

The RAC report set the groundwork for the development of a national coastal policy and provided the impetus for getting basic agreement on the Coastal Action Plan from the chief ministers and its adoption by all three tiers of government. The inquiry also emphasized the role played by local government in state based coastal strategies and provided a mechanism for integration between different levels of government and the community through the proposed Coastcare Program.

15.3 Commonwealth (of Australia) Coastal Policy, 1995

After various coastal inquiries over a 15–20 year period, a Commonwealth coastal policy, entitled *Living on the Coast*, was finally produced (Commonwealth of Australia 1995). This policy built upon the RAC inquiry which had the concept of ESD as one of its key aims. It is important to note that the peculiarly Australian concept of ESD equates with what is generally known elsewhere in the world as sustainable development. The Australian definition of ESD is, "*using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased*" (Commonwealth of Australia 1992c).

In addition to the coastal policy's aim of promoting ecologically sustainable use of Australia's coastal zone it also has specific objectives and principles such as sustainable resource use; integrated assessment; the precautionary principle; resource allocation; the user-pays principle; resource conservation; public participation; and, knowledge and understanding.

A key element of the policy was that it had a definable program of action designed to improve community involvement in coastal management, address issues such as coastal development and pollution; increase education and awareness of coastal issues; and, promote coastal management expertize in neighbouring regions. The action program has a number of components:

- Coastcare program;
- Commonwealth Coastal Strategic Planning;
- Local Water Quality Management Plans;
- Ocean Rescue 2000 Program;
- Capacity Building;
- Coast Net and Coastal Atlas;
- National Coastal Advisory Committee and Indigenous Reference Group.

The coastal policy acknowledges that halting development and use of the coastal zone is not an option. It notes that 86% of Australians live near the coast. The objectives and principles were developed in a cooperative approach with the states so that it has general agreement. The flagship of the policy and its coastal action plan is the Coastcare program which is integrative in nature and involves extensive public participation.

In 1997, the action plan was complemented and extended by the Commonwealth government's AU $125 million *Coast and Clean Seas Program* extending over a four year period. An important aspect of this is the need for cooperation between community, local government and state government. This program provides for a number of new activities (taking 65% of the funding): Clean Seas; Coastal and Marine Planning; Marine Species Protection; Fisheries Action; Introduced Marine Pests; Coastal Resource Atlas; and, Oceans Policy. These were in addition to the existing activities of: Coastcare; Marine Protected Areas; Capacity Building; Coastal Monitoring and Vulnerability.

Thus, the Commonwealth has created its own coastal policy which encourages sustainable resource use and integrated coastal management. The action plan associated with the policy earmarks specific funding for integrated coastal management through programs such as Coastcare (Tailby and Lenfer 1996), improved management tools with the Coastal Resource Atlas and the Coastal Monitoring and Vulnerability programs, and increased knowledge base and coastal management expertize through the Capacity Building program (Morvell 1996). Although the legislation for the management of the Great Barrier Reef was in place two decades before the Commonwealth coastal policy, it is within the broader context of the recent coastal initiatives that the current management is carried out. However, it is first useful to illustrate the complexity and diversity of the Reef and its uses in order to appreciate the challenge for integrated management.

15.4 The Great Barrier Reef

The Great Barrier Reef is the largest coral reef system anywhere in the world. The outer perimeter of the reef is about 23 000 km long and the Great Barrier Reef Region cov-

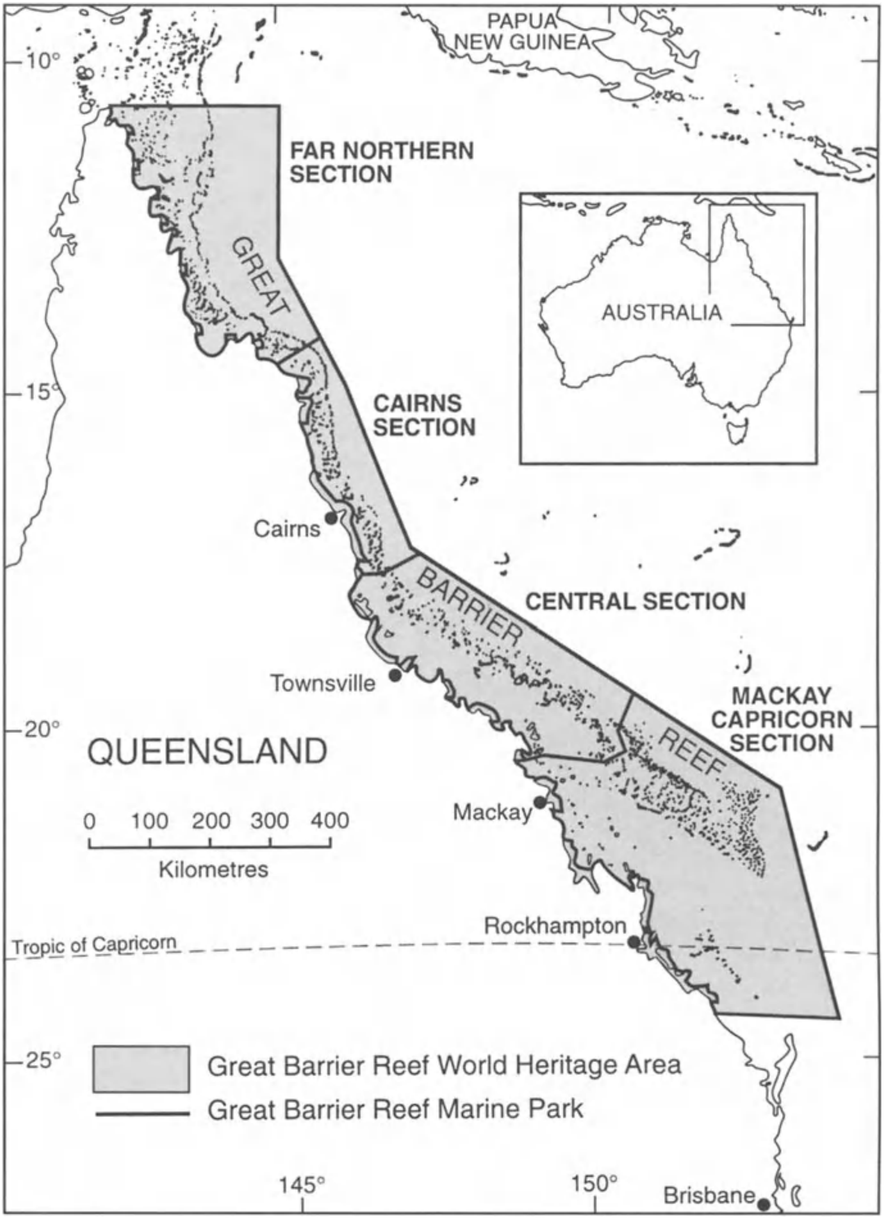

Fig. 15.1. The Great Barrier Reef region, showing the boundaries of the Great Barrier Reef World Heritage Area and the Great Barrier Reef Marine Park (After Commonwealth of Australia 1993a)

ers an area of almost 348 700 km² (Fig. 15.1). The region comprises all of the waters east of Queensland, from low water mark on the mainland to the edge of the continental shelf, and includes a number of Commonwealth owned islands but not the 900 or so islands owned by Queensland. For comparison, the region is larger than the land area of the United Kingdom and Ireland combined and almost the same size as Germany. To call it the Great Barrier Reef is to some extent a misnomer because it is made up of over 2900 individual reefs including about 760 fringing reefs attached to the mainland or numerous islands. In some places these form a semi-continuous barrier such as in the area to the north of Cairns (see Fig. 15.1). The Great Barrier Reef is a continental margin reef which is quite different to the classic "Darwinian" coral atolls where subsidence was a major factor in the evolution of their annular form (Harvey 1982).

Coral reefs in general are complex ecosystems which have high diversity and productivity, together with an interdependence of plants and animals and many symbiotic relationships. The great variety in the corals (about 400 species identified), their life forms and colour give the Great Barrier Reef much of its tourist appeal. Coral reefs have a very efficient system of nutrient recycling and can be almost self sufficient provided there is no oversupply, as can happen with nearby intensive tropical agriculture such as sugar cane. They grow in warm waters down to a depth of 100m but have limited growth at this depth. Their growth is also restricted in a number of areas where there is high runoff, freshwater output and sediment deposition.

The living polyps of the hard coral species lay down the skeletal limestone structure that forms the basis for reef building. The coral polyps has a symbiotic relationship with algae (zoozanthellae) which live within the coral tissue, assist in laying down the skeleton through photosynthesis, taking up polyp wastes and supplying the coral with about 98% of its food requirements. Growth rates of corals in the Great Barrier

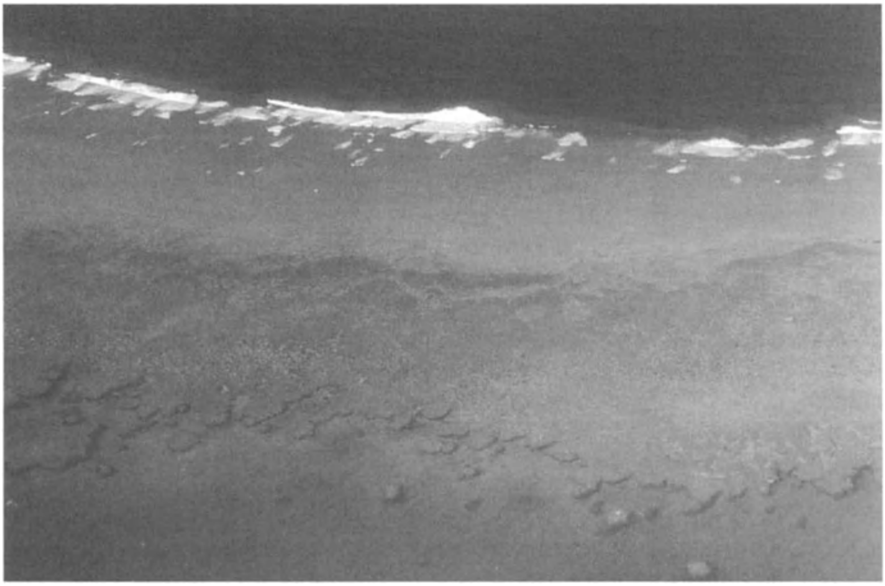

Fig. 15.2. The outer Reef northeast of Cairns. Note the deeper water at the top of the picture near the edge of the continental shelf. Breakers indicate the exposed reef, behind which (*bottom of picture*) there is sheltered water and coral patches (*Photo:* Nick Harvey; *Note:* The coloured version of this figure can be found on the CD, enclosed with this book)

Reef are fastest in shallow well-lit waters and can be up to 20 mm a^{-1} for massive corals and up to 100 mm a^{-1} for branching corals. There are also numerous soft coral species which are not significant in reef building. However, another important reef builder is the crustose coralline algae which in some places on the Great Barrier Reef form up to 80% of reef sediments (Hopley 1982).

The individual reefs within the Great Barrier Reef vary considerably ranging in size from small reef pinnacles up to reefs of 20 to 30 km in length and more than 125 km^2 and in shape from flat platform reefs to the elongate ribbon reefs of the continental shelf margin. In some places the reefs are separated by channels of 200 m elsewhere they may be 20 km apart. The reefs are submerged with some being exposed at very low tides. There are about 300 reef island sand cays, 87 of these are permanently vegetated. There are also about 600 continental or high islands (Hopley 1982).

The Great Barrier Reef varies in its form and complexity. In the north the outer reef is formed by ribbon reefs (Fig. 15.2) up to 27 km long about 500 m wide with narrow restricted passages. Here the continental shelf is very narrow and some of the outer reefs may be 30 to 60 km from the coast. Behind the barrier is what looks like open water which often contains coral patches or "bommies". The water may be 50 m or so deep compared to the steep drop off beyond the shelf edge reefs. There are a series of patch reefs occupying the mid shelf area in addition to a number of high or continental islands usually with fringing reefs (Fig. 15.3). Further towards the land maybe 5–10 km there are a series of reefs with reef deposits and reef islands often associated with mangroves, beach rock, shingle ridges and sand cays. These are called the low

Fig. 15.3. Lizard Island and associate fringing reef in the Cairns section of the Reef. The island is of continental origin and was used by Captain James Cook as a vantage point to find a navigable break in the outer barrier (*Photo:* Nick Harvey; *Note:* The coloured version of this figure can be found on the CD, enclosed with this book)

wooded islands (Fig. 15.4) which exist north of Cairns. Offshore from Cairns is the southernmost of the vegetated coral cays of this section of the Reef.

South of Cairns, in the Central section of the Reef, there are no true reef islands made of reefal deposits (see Fig. 15.1). However, there are plenty of high islands and associated fringing reefs in this area. The continental shelf changes in orientation and widens out to over 125 km and even the inner most reefs can be 40–50 km offshore. In the Central section, there is no outer barrier of reefs although there are numerous large reefs. Often these are fairly low, less exposed and relatively few have permanent sand cays. However, none of these cays have permanent vegetation in the Central section of the Reef.

In the Mackay Capricorn section of the reef there are still many continental islands but the fringing reefs are smaller and patchier. This section contains the first of the permanently vegetated sand cays (Fig. 15.5) south of the Cairns section of the Reef. The outer reefs in the Mackay Capricorn section area may be up to 300 km offshore. It is in this area that some of the largest reefs exist within the Pompey complex (the semi-continuous line of reefs east of Mackay). Here, there are intricate deep channels (Fig. 15.6) and two prominent blue holes (Fig. 15.7) formed during periods of low sea level and sub aerial exposure (Backshall et al. 1979). The Pompey Complex forms a virtual barrier which gives way to the Swains Reefs further south which are much smaller and tightly spaced. These reefs are 200 km from the mainland and separated by the Capricorn Channel.

Finally in the southern part of the Mackay Capricorn section, is an isolated group of reefs (offshore from Rockhampton) referred to as the Capricorn Bunker group. In

Fig. 15.4. Three Isles in the Cairns section of the Great Barrier Reef. This is a low wooded island showing supra reefal deposits of coral shingle around the perimeter, a mangrove island to the left and a vegetated sand cay to the right (*Photo:* Nick Harvey; *Note:* The coloured version of this figure can be found on the CD, enclosed with this book)

Fig. 15.5. Bushy Island on Redbill Reef in the Mackay Capricorn section of the Reef. This is a permanently vegetated sand cay on a reef containing stepped algal terraces caused by a high tidal range in the area (*Photo:* Nick Harvey; *Note:* The coloured version of this figure can be found on the CD, enclosed with this book)

Fig. 15.6. Massive reefs of the Pompey Complex on the outer shelf east of Mackay. Some of these reefs are over 100 km^2 and are separated by deep channels (*Photo:* Nick Harvey; *Note:* The coloured version of this figure can be found on the CD, enclosed with this book)

Fig. 15.7. A blue hole in the Pompey Complex reefs. This feature is a drowned doline related to karst erosion of the reef during successive periods of sub aerial exposure during low sea levels of the Quaternary period (*Photo:* Nick Harvey; *Note:* The coloured version of this figure can be found on the CD, enclosed with this book)

this area there are a number of patch reefs but no outer barrier. Most of the reefs have supra tidal reefal deposits with sand and shingle cays, many with permanent vegetation, and are easily accessible from the mainland.

15.5 Management of the Great Barrier Reef

The Great Barrier Reef became important when discussions about mining and drilling in the '60s resulted in two royal commissions. The first was set up in 1970 to investigate oil drilling on the reef. Then in 1973 the Commonwealth passed its *Seas and Submerged Lands Act* (Commonwealth of Australia 1973) to establish Commonwealth jurisdiction below low water mark. In 1975 the *Great Barrier Reef Marine Park Act* was passed. The key elements of this legislation are:

- A Great Barrier Reef Marine Park Authority consisting of two Commonwealth and one Queensland nominees;
- A Great Barrier Reef consultative committee;
- That the Authority performs its functions in association with the state of Queensland;
- The act prohibits mining and oil drilling;
- The act prevails over conflicting legislation except for navigation;
- The act has one explicit objective;
- The act allows regulation of activities.

An important reason for the success of the legislation is the single overriding goal of the Great Barrier Reef Marine Park Authority which is, "*To provide for the protection, wise use, understanding and enjoyment of the Great Barrier Reef in perpetuity through the development and care of the Great Barrier Reef Marine Park*" (Great Barrier Reef Marine Park Authority 1991). This goal, contains elements of the current national sustainable development objectives, it allows for both protection and enjoyment of the Reef and makes reference to the need for education in doing this.

It should be noted that the Great Barrier Reef Marine Park legislation was produced exactly twenty years before the Commonwealth developed its own coastal policy in 1995. In the case of the Great Barrier Reef, the Queensland state coastal legislation is important since all the islands above low water mark except for a few owned by the Commonwealth fall under state rather than Commonwealth jurisdiction. This necessitated the development of a cooperative working relationship between the Commonwealth and state governments. A compromise was reached where the Commonwealth maintains its over-riding power in the region but Queensland is involved in all aspects of the establishment and management of the marine park. Queensland also carries out the day to day management through the state National Parks and Wildlife Service which is also responsible for most of the islands in the reef region. A major problem is the level of staffing and a relatively low budget for the given area of jurisdiction. For this reason the Great Barrier Reef Marine Park Authority has focused its attention on education rather than law enforcement.

Given the biophysical diversity of the Reef, the multiplicity of resource uses adds to its complexity for management purposes. The major activities are tourism and fishing and the only activities which are prohibited are commercial mining and oil drilling. Tourism is by far the fastest growing activity and is expanding at an estimated 10% per year. In addition to this expansion there has also been a rapid change from the smaller capacity, slow vessels to rapid transit high capacity and high technology vessels moving hundreds of tourists out to the Reef for a complete tourist experience (including underwater diving) often within a single day. The other major reef user is the fishing industry which includes both commercial and recreational fishing. Commercial fishing is mainly for prawns, scallops and line fish such as coral trout and red emperor.

The problem confronting day to day management of the Reef is the competing uses of the area. In addition to tourism and fishing, there are other users or interest groups such as conservationists, scientists, traditional Aboriginal users, or even shell collectors. Some of the options for managing these are:

- *Periodic closure* – short term closure for breeding or stock recovery (such as temporary closure of prawn areas);
- *Yield constraints* – sustainable harvest yields by restrictions on the number of individuals or numbers taken (such as banning the taking of female mud crabs), restrictions on the capacity of boats and commercial fishing licences;
- *Equipment constraints* – protection against explosives, poisons, certain types of anchors, hooks per line, restrictions on spear and scuba fishing;
- *Impact limitations* – restrictions on reef-walkers, number of divers, numbers of campers on reef islands.

However, these options provide only a partial solution to some of the problems and it is more appropriate to incorporate these into comprehensive zoning and management plans. These plans have been designed with the following elements in mind:

- Planning areas should be as large as possible;
- Zones should encompass all acceptable usages;
- There should be a gradation from least through to most heavily protected zones to buffer protected areas;
- Traditional and customary users of the managed area should be consulted and involved in the development and implementation of the management plans;
- Traditional law and management practices (including aboriginal and islander customs) which are consistent with the goals and objectives of modern management should be incorporated to the greatest possible extent.

The zoning plans form an important element in achieving integrated management by providing a mechanism for regulation of activities within the legislation. To this end, zoning plans have been progressively proclaimed for the different sections of the Park as follows:

- 1979: Capricornia section (12 000 km^2) operational 1981;
- 1981: Cairns, Cormorant Pass section (35 000 km^2) operational 1983;
- 1983: Far Northern section (80 000 km^2) operational 1986;
- 1984: Central section (77 000 km^2) operational 1987;
- 1984: Mackay-Capricorn section (137 000 km^2) operational 1988.

Subsequently the Capricornia section has been incorporated into the Mackay-Capricorn section and there is a policy of reviewing each zoning plan after five years, although in practice this has been far less frequent.

The actual process of zoning had the following steps:

1. Compilation of a resource and usage information base for each park section;
2. Public comment on resources and information base and suggestions for what should be in particular zones;
3. Initial draft zoning plan based on natural qualities, location and present and predicted usage patterns;
4. Release of draft plan for public comment;
5. Revision of draft based on public and government department input;
6. Gazetting and implementation of final zoning plan.

The levels of protection vary considerably with:

- *Preservation zones and scientific research zones* – where only controlled scientific research is allowed;
- *Marine-National Park zones* – where most of the major uses permitted are scientific;
- Educational and recreational plus a marine park buffer zone;
- *General use zones* – where uses are held to levels that won't jeopardize the ecosystem. Generally commercial and recreational fishing is allowed but bottom trawling is not permitted in General Use B.

Most of the park is zoned General Use A (80%) and then Use B (15%). The next largest section is the Marine National Park B zone (4.3%). So in reality, most of area in the park is open water and most of that is zoned for General Use and open to trawling and line fishing. Only a small percentage is reserved for preservation (0.12%) or scientific research (0.07%).

In addition to its marine park status, The Great Barrier Reef was given international recognition on 26th October 1981 when it was placed on the World Heritage List. It was considered to fulfil all the requirements of world heritage as set out in Article 2 of the World Heritage Convention:

- An example of a major stage in the earth's evolutionary history;
- An outstanding example of geological processes, biological evolution and people's interaction with their natural environment;
- A place with unique, rare and superlative natural phenomena;
- A place which provides habitats for rare and endangered species of plants and animals.

The Great Barrier Reef World Heritage Area (Fig. 15.1) includes all of the Great Barrier Reef Region comprising the Great Barrier Reef Marine Park (93%) Queensland waters not in the park (2%) and islands (5%). The area meets all of the World Heritage criteria and can maintain those values because it has

- all the interrelated and interdependent elements in their natural relationships,
- all of the elements necessary for the system to be self perpetuating,
- superlative natural phenomena and areas of exceptional natural beauty,
- the habitat requirements for survival of rare and threatened species,
- protected areas for migratory species.

The World Heritage area is protected by the Commonwealth and Queensland governments under legislation and management arrangements. In 1994 a twenty five year strategic plan for the area was released (Great Barrier Reef Marine Park Authority 1994). This plan was prepared over a three year period and included user groups, interest groups, and various agencies. A draft plan was released in 1992 for an eight week period and over fifty separate meetings were held to discuss the plan and more than two hundred and eighty submissions were received. Some submissions such as the conservation sector represented eleven different organisations which had also had wide consultation in their own groups.

The plan examines shared principles, it looks at the impact of the indigenous issues, funding, implementation and also what it terms "continuance". This term refers to difficult issues which are not yet resolved such as mining and aboriginal and Torres Strait islander interests. The plan then divides its objectives and strategies into eight sections:

1. Conservation;
2. Resource management;
3. Education, communication, consultation and commitment;
4. Research and monitoring;
5. Integrated planning;
6. Recognition of Aboriginal and Torres Strait Islander interests;
7. Management processes;
8. Legislation.

For example under the area of conservation there would be a broad twenty five year objective relating to the preservation and maintenance of ecological integrity over that time and then there are a number of separate five year objectives such as "*to pay special attention to conserving rare and endangered species*". The strategies for doing this would be to first identify the species in the area which are endangered and identify the threats to their survival, then to develop and implement appropriate coordinated management actions and then to extend this to species which are globally endangered and are within the area.

While there has been significant management success with the zoning of the Reef and the management strategy for the World Heritage Area, there has been a need for more focused management plans in certain areas where there are specific issues or intensive use. For this reason a number of plans of management have been drawn up to complement the broader zoning for areas with significant sites or intense usage such as important bird rookeries, critical turtle nesting sites, cultural heritage sites, or sites of intense tourism and coastal developments. In the future there is likely to be an increasing use of these plans of management. A further initiative to assist in community participation has been the formation of Regional Marine Resources Advisory Committees. These committees have wide representation from stakeholder groups and function effectively in providing management advice in sensitive areas, providing important formal communication channels with the community and user groups, contributing local expertize, and assisting in local awareness raising of coastal issues. Such initiatives as the plans of management and the advisory committees complement the broader zoning and long term strategies for the Reef.

15.6
How Integrated is the Management of the Great Barrier Reef?

The Great Barrier Reef has previously been quoted as a good example of integrated coastal management (Commonwealth of Australia 1993a; Kelleher 1996). The concept of integrated coastal or coastal zone management (ICM or ICZM) has been around for at least thirty years according to Sorensen (1997) with different interpretations of what is meant by "integration" in ICZM (Kenchington 1994; Kenchington and Crawford 1993). Of the varying definitions of ICZM, a useful one with significant international input comes from the 1993 World Coast Conference which defined it along with the key elements of integration necessary. "*Integrated coastal management involves the comprehensive assessment, setting of objectives, planning and management of coastal systems and resources, taking into account traditional, cultural and historical perspectives and conflicting interests and uses; it is a continuous and evolutionary process for achieving sustainable development.*" (World Coast Conference 1994)

The key elements of integration in order to achieve this are as follows:

- Responsibilities of agencies at different levels of government ("vertical integration");
- The responsibilities of different government sectors ("horizontal integration");
- The responsibilities of government and local groups;
- Policies across sectors of the economy;
- Economic, technical/scientific, and legal approaches to coastal problems(World Coast Conference 1994, p 25).

Some of the goals of integrated coastal zone management include: attaining sustainable development; reducing vulnerability from natural hazards; maintaining ecological processes and biological diversity; being multipurpose-oriented; analysing implications of development, conflicting issues and the interrelations between physical processes and human activities; and, promoting linkages and harmonisation between sectoral coastal and ocean activities.

In a discussion of integrated coastal management Cicin-Sain (1993) refers to different dimensions of integration; among sectors (coastal/marine; coastal/marine and land based); between land and water sides; among government levels; between nations; and, among disciplines. In order to achieve true integration Cicin-Sain suggests it is necessary to have comprehensiveness, aggregation and consistency. In addition, Hollick and Mitchell (1991) characterize integrated management according to five key components of systems, balance, strategic partnerships and jurisdiction.

The Great Barrier Reef example demonstrates many characteristics of the above criteria of integrated coastal management. The foundation for this has been the *Great Barrier Marine Park Act* (Commonwealth of Australia 1975) and the subsequent World Heritage twenty five year strategic plan (Great Barrier Reef Marine Park Authority 1994). One of the prime areas of management (and indicators of integrated management) is the preparation of zoning plans for individual sections of the Great Barrier Reef which aim to balance the needs and aspirations of different user groups by spatial separation of conflicting uses. For example, zoning of national parks reserves and historic shipwreck areas are established to ensure that areas adjacent complement their objectives. In addition, zoning plans are characterized by simplicity, minimal regulation of human activities (such as enabling research without placing unnecessary restrictions on other uses), maintaining consistency with other zoning plans, avoiding sudden transitions between incompatible zones and basing zone boundaries on visible geographic features with single zones surrounding discrete areas.

These factors tend to fall within the realms of Hollick and Mitchell's (1991) partnership approach (with conflict resolution mechanisms, stakeholder involvement and identifying management objectives); their jurisdictional component (by defining the area as a single system, or sub systems, notwithstanding jurisdictional boundaries), their systems component (by addressing interactions between natural processes and humans within a biophysical system) and their strategic approach (by evaluating and prioritising key activities; and by providing flexibility). For example, adaptive management can be achieved via permit systems and special management areas which, by enabling the use of part of a zone to be temporarily changed, aim to manage unforeseen changes in the condition of an area or unexpected activities.

A more specific example of the Hollick and Mitchell's (1991) jurisdictional component (use of intergovernmental agreements and memoranda of understanding) is indicated by the *Emerald Agreement* in 1979 which involved both the Commonwealth and the Queensland Governments, and established a Great Barrier Reef Ministerial Council to further coordinate policy (Commonwealth of Australia 1993b, p 11). Prior to this, both governments had different interpretations of their respective roles (Commonwealth of Australia 1993b). The partnership component of integrated management is also important at this stage, whereby organisation and participation has been established on a cooperative basis with policies of pro-active public participation and facilitation of two way information flows (Commonwealth of Australia 1993b). Similarly, all levels of government are involved, as are Non Government Organisations (NGOs) with interests in tourism, science, fishing, science, conservation and Aboriginal communities, thus enabling continuous interactions and consideration of multiple use activities/conflicts. For example:

- *Ministerial Council* (State and Commonwealth level) – coordinates policy at the ministerial level;
- *GBRMP Authority* (State and Commonwealth level) – principle adviser the Commonwealth regarding the care and development of the Park;
- *Consultative Committee* (all levels of government, including local government, and NGOs) – provides independent advice to the Great Barrier Reef Marine Park Authority;
- *Advisory Committees* (representation of stakeholder groups) – provide advice, creates formal communication linkages, uses local expertize, raises awareness of issues at local level;
- *Queensland Authorities* (Queensland National Parks and Wildlife Service and Boating and Fisheries Patrol) – provide for the daily management of the Reef.

In addition, the establishment of the twenty five year strategic plan for the World Heritage Area (Great Barrier Reef Marine Park Authority 1994) makes direct reference to integrated management and aims to "take into account the ecological relationship between the area and other adjacent areas, particularly the mainland". The eight sections of the plan described earlier, outline the broad objectives and strategies. Of these, the goal of resource management clearly corresponds with the overall definition of integrated coastal management where for example, management aims to facilitate the sustainable multiple uses of the resources of the Great Barrier Reef World Heritage Area through integrated management systems which are complementary with the management of the adjacent regions. This is to be done in a manner consistent with the maintenance of World Heritage, ecological and social and economic values, recognising that the economic viability of many activities relies on the maintenance of the ecosystem (Commonwealth of Australia 1993b, p 20).

Similarly, the direct reference to integrated planning in the twenty five year plan provides aims consistent with integrated coastal management and corresponds with general features of integrated management. In practical terms this means establishing a "regionally based mechanism for integrated planning activities between the following: integrated catchment management strategy; coastal protection strategy; World Heritage Areas: Great Barrier Reef and Wet Tropics; public utilities; local authorities; Cape York Land Use Study;" ... to coordinate ... "planning for the Torres Strait Protected Zone, the Australian Fishing Zone and the GBR World Heritage Area;" ... and ... "to have the integrated catchment management strategy and legislation in place; with pilot projects completed, clear guidelines for the inclusion of additional catchments established and as many catchments affecting the WHA as possible included." (Commonwealth of Australia 1993c).

As such, each dimension of integration needed for the coastal zone (as proposed by Cicin-Sain 1993) has been addressed including interactions among sectors, between regions, among government levels and the wider community, and between disciplines, all of which are essential requirements of integrated management. The recent focus on specific plans of management and the use of Regional Marine Resources Advisory Committees, provides further integration and consolidation of what has essentially been a successful approach in integrated coastal management.

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Chapter 16

Integrated Coastal Zone Management in Venezuela: The Maracaibo System

J.E. Conde · G. Rodríguez

16.1 Introduction

The Maracaibo System (Fig. 16.1) is a remarkable instance of a vast zone that undergoes a gamut of uses, ranging from offshore and coastal oil exploitation and petrochemical industries, to trawl and artisanal fisheries. In this area, urban development, oil tankers transit, maritime trade, oilfields and petrochemical industries, untreated sewage discharges, solid waste disposal, engineering works, pesticide- and fertilizer-laden runoffs, management of conservation units, and fisheries converge and interact in a complex fashion (Table 16.1).

The Maracaibo System, located in the heart of Venezuela's petroleum industry, embeds one of the most important oil fields in South America and also one of the largest in the world. In 1984, there were 8 400 active oil rigs, several hundred flux stations and two refineries, which are connected by 40 000 km of pipelines, mainly underwater (Rodríguez 1984). From 1914 to 1995, roughly 33 000 million barrels (5 238 million m^3) were extracted in this basin. Most of the oil is drawn out from the lake's bottom, the largest in South America and one of the largest in the world. Venezuela's most valuable export is petroleum; the incidence of the oil industry on the national economy is 60% of the Gross National Product. Thus, it might overshadow the importance of other natural resources that do not produce profits as huge as oil benefits, but that nonetheless have hefty social values. That is the case with fisheries in the Maracaibo System. In addition to supporting a substantial population of more than 6 000 artisanal fishermen and a blue crab fishery, the lake also has a marked bearing on the Gulf of Venezuela trawl fisheries, which rank second in landings in the country.

Since the late '60s, concerns were arisen about the impending environmental degradation of Lake Maracaibo. In 1964, following guidelines issued by the Ministry of Mining and Hydrocarbons, oil companies operating in the lake created a committee to prevent water pollution. This committee was formally chartered in 1969 under the name of Intercompany Operational Committee for the Conservation of Lake Maracaibo.

One of the earliest implemental efforts to cope with the environmental concerns arisen by several sectors, was the creation in 1978 of a state-of-the-art laboratory, located in Maracaibo, and affiliated to the Direction of Environmental Research (Ministry of Environment and Natural Resources – MARNR). During a first stage, the laboratory's agenda focused on the Strait of Maracaibo and El Tablazo Bay (Parra Pardi 1979), and comprised studies dealing with water quality, organic and bacterial pollution, and identification of some specific contaminants. Over a second phase, the laboratory widened its efforts to include the lake itself and its eutrophication prospects (Parra Pardi 1979).

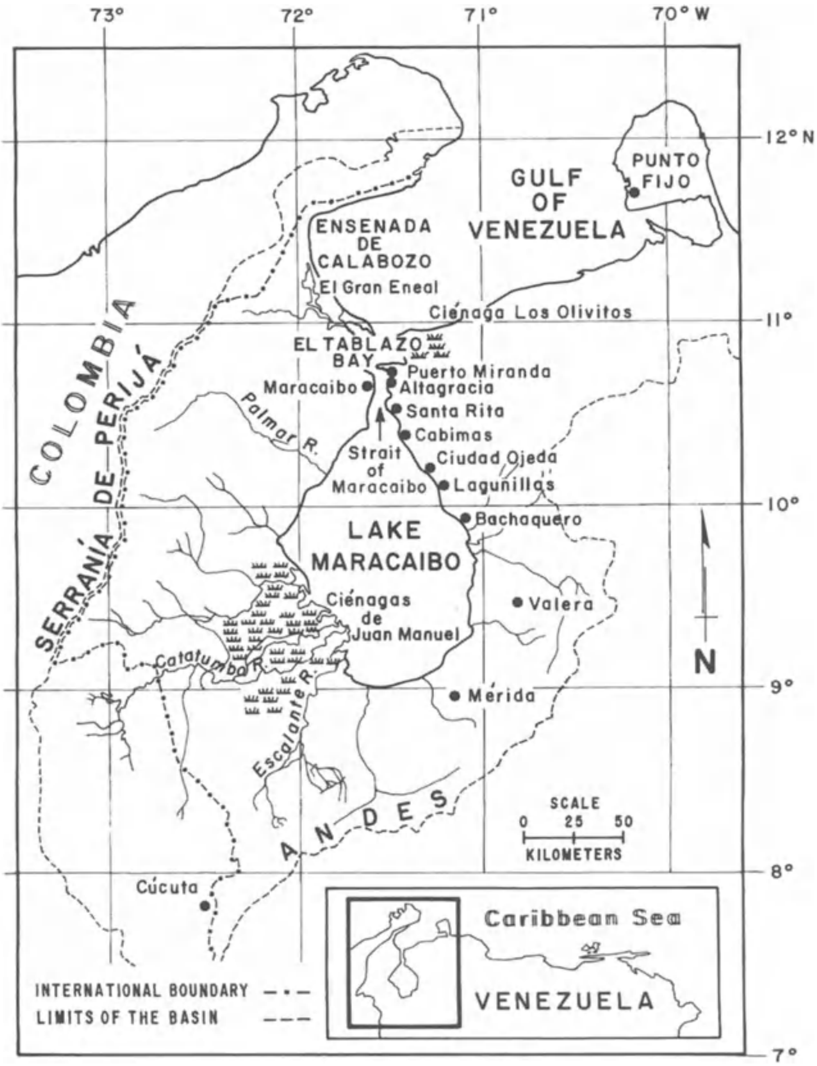

Fig. 16.1. Map of the Maracaibo System, including the drainage basin, showing major features and its relative situation in Venezuela

In 1981, in what might be considered a milestone in environmental management and preservation, the Institute for Monitoring and Conservation of Lake Maracaibo (ICLAM), ascribed to the Ministry of Environment and Natural Resources (MARNR), was enacted. This institution has conducted a variety of studies, including water quality of runoffs that draining into the lake, phytoplankton and water quality in the Strait of Maracaibo, mercury concentrations in fishes and sediments, pollution sources in the strait and in the Chama, Escalante and Motatán watersheds, annual course of the

Table 16.1. Main activities and agents with a high potential to be hazardous or clash among themselves in the Maracaibo System (After Rodríguez, in press)

A	**Activities at the uplands**
1	Water diversion and impoundment (diking, damming, and river bed alterations)
2	Agriculture and livestock rearing in the basin
3	Pesticides and herbicides
4	Fertilizers and soil amendments
5	Slash-and-burn farming
6	Deforestation and land reclamation
7	Erosion
B	**Activities at the lake**
1	Physical processes
1.1	Physiographic changes
1.2	Dredging and spoil disposal
1.3	Salinization
1.4	Thermal pollution
2	Chemical processes
2.1	Industrial effluents discharges
2.2	Heavy metals
2.3	Solid wastes
2.4	Gas and particulate emissions
2.5	Nutrients
2.6	Oil drilling, oil processing and transportation
2.7	Coal mining and transportation
2.8	Sewage discharges
3	Biological processes
3.1	Interference between industrial and artisanal fisheries
3.2	Overfishing
3.3	Trawl fishing

bacteriological quality of water at lake- and seaside resorts, characterization of domestic and industrial effluents at the lake's perimeter, and of sewage discharges from the city of Maracaibo.

Through integrated coastal zone management (ICZM), a process is established whereby government intervention can be organized and made effective through programs that arise from the integration with the various economic sectors and resource conservation programs (Clark 1996). By using a multiple use approach, ICZM provides a framework for broad participation and for resolution of conflicts between a variety of economic development and resource conservation needs (Clark 1996). This way, an ICZM programme has to both manage development and conserve natural resources and thus integrate the concerns of all relevant sectors of society and of the economy. Coastal environmental programs are usually launched in response to a perceived conflict of use, a keen decline in a resource or a devastating experience.

In this paper we survey the menu of interests, actors and conflicts of use in the Maracaibo System. We also address several aspects regarding the possibilities of setting up an integrated coastal zone management programme.

16.2 General Description

The aquatic component of the Maracaibo System and the drainage basin cover approximately 120 000 km^2, that spread through a latitudinal band of approximately six degrees (Fig. 16.1). Located in northern South America, the Maracaibo System comprises two main bodies of water, Lake Maracaibo, the largest in South America and 17th in the world, and the Gulf of Venezuela, interconnected by the Strait of Maracaibo and El Tablazo Bay (Fig. 16.1). The lake, approximately oval in shape and 155 km long, is part of an extensive (89 800 km^2) watershed area located on Colombia and Venezuela. The lake itself occupies 12 000 km^2, and the inlet and bay connecting the lake to the Caribbean Sea cover an additional 1 000 km^2. Depth in the lake averages 25 m, with a maximum of 33 m. The strait and the bay have 39 km in length. The bay, square in shape, opens into the Gulf of Venezuela through two narrow inlets sprinkled by a number of islets and shoals (Rodríguez 1973, 1974, 1984). Overall, the coastline of the Maracaibo System extends through approximately 1 700 km.

The distinct bodies of water form a continuum that includes euhaline waters, in the Gulf of Venezuela; the limnetic waters of the lake proper; and the mixohaline waters of the Strait of Maracaibo and El Tablazo Bay (Rodríguez 1973). The lake's water discharge into the Caribbean Sea at a rate of 49 000 million m^3 a^{-1} (Rodríguez 1974), after spending 5.99 years in the lake (ESCAM 1991). The freshwater volume has been estimated at 50 600 million m^3. The hydraulic balance, even during the dry season, is positive from the lake to the sea.

Due to the large area encompassed by the Maracaibo System, a great variety of climates occurs. Thirteen climates have been recognized, ranging from semiarid tropical (DA' in the Thornthwaite's classification) in the shoreline of the Gulf of Venezuela, to arid mesothermal (EB'), perhumid mesothermal (AB') and semiarid microthermal (DC') at the western and southern watersheds.

The biota and ecosystems of Lake Maracaibo has been thoroughly documented (Rodríguez 1963, 1967, 1973, 1974; Ewald 1967; Taissoun 1969, 1972; Pannier and Pannier 1985; MARNR 1985, 1986, 1990, 1991; Huber and Alarcón 1988; Conde and Alarcón 1993; among others). It is composed of species with quite a variable geographical range, that include pantropical, pantemperate, West Indian, tropical American, and Northern South American distributions, and also several endemisms (Rodríguez 1974). In addition to some endemic species, most of the fishes are typical northern South American forms, while most of the decapod crustacea are West Indian. Most of the crabs from the southeastern coast of the Gulf of Venezuela have a wide distribution (Carmona-Suárez and Conde 1996). Carmona and Conde (1989) have described the principal coastal biotopes and physiographic features of the southeastern and eastern shorelines of the Gulf of Venezuela.

Among the aquatic vertebrates, five species of cetaceans have been confirmed for the Gulf of Venezuela: *Turpsiops truncatus*, *Stenella frontalis*, *Orcinus orca*, *Ziphius cavirostris* and *Balaenoptera edeni*. Another species, *Sotalia fluviatilis*, has been observed at numerous localities, ranging from the southern perimeter of the lake to the Strait of Maracaibo; there are also several sightings in the Gulf of Venezuela (Rodríguez, in press). A subspecies of cayman, *Cayman sclerops fuscus*, has been reported from several rivers of the Serranía de Perijá and from the swamps on the southwestern coast of the lake.

Rodríguez (1963, 1967, 1973) has described in full detail the intertidal estuarine communities of the Maracaibo System and some of the ecological processes and limiting factors in the distribution of species. On the supralittoral zone of newly-formed shores by deposition of sand from dredging, a pioneer community of Graminae and Cyperaceae are arranged in bands, which is believed to prelude mangrove formations.

Several large mangrove expanses are present in the Maracaibo System for a total coverage ranging from 4 337 to 22 566 ha (Conde and Alarcón 1993). It has been estimated that over the last four decades almost 90% of the mangrove coverage in Lake Maracaibo has been lost (Conde and Alarcón 1993). These stands shelter a wealth of bird species, which includes endangered species, non-resident visitors and migratory birds. In Ciénaga Los Olivitos, a coastal lagoon located on the northeastern corner of El Tablazo Bay, 53 species of birds have been reported (MARNR 1986). This wetland is one of the four Caribbean sites where the Caribbean Flamingo *Phoenicopterus ruber* nests (Sociedad Conservacionista Audubon de Venezuela, n.d.). Substantial abundances of this species have been registered since 1983, peaking at 15 000 individuals in 1990; and reaching 6 000–7 000 in 1992 (Figueroa and Seijas 1986; Rodner 1992). A small population of the American crocodile (*Crocodylus acutus*), an endangered species, has also been observed at Ciénaga Los Olivitos (Figueroa and Seijas 1986). In the Maracaibo System mangals, the most common terrestrial mammals are the crab-eating raccoon (*Procyon cancrivorus*), several species of bats, and various visitors of the neighboring zones, including the crab-eating fox (*Cerdocyon thous*) and the cottontail rabbit (*Sylvilagus floridanus*) (Salvatierra 1983); whereas common aquatic mammals include manatees (*Trichechus manatus*) and river otters (*Lutra* sp.) (Figueroa and Seijas 1986). Among the invertebrates, the exceptional presence of the mangrove oyster *Crassostrea virginicum* (MARNR 1991) in Laguna de Cocinetas must be underlined; since *C. rhizophorae* is the species present in most of the Venezuelan coast.

The coastal zone of the Maracaibo System comprises several important areas for biodiversity. Although the lake itself has been rated as a medium priority area from a conservation perspective; El Gran Eneal, a coastal swamp located on the southwestern corner of the Gulf of Venezuela, and Ciénaga Los Olivitos, a coastal lagoon sited on the northeastern shore of El Tablazo Bay, have been ranked as high priority wetlands, based on their biological, scenic, historical and cultural significance (Díaz-Martín et al. 1995). Other important coastal wetlands are Laguna de Cocinetas; and Ciénagas de Juan Manuel, where more than 40 species of birds have been registered and the aquatic and terrestrial mammals *Lutra enudris* and *Leo onca*, respectively, have also been reported (Figueroa and Seijas 1986).

16.3 Population Growth

Since the inception of oil exploitation in the State of Zulia in the '20s, when there were hardly 50 000 dwellers, population increased sharply, reaching 2 235 305 persons in 1990, most of them living on the lacustrine coastal zone (OCEI 1993), particularly (1 401 400) in the city of Maracaibo – the second largest in Venezuela. Also, in the eastern coastal urban stretch (Santa Rita, Cabimas, Ciudad Ojeda, Lagunillas and Bachaquero), almost half a million inhabitants have settled. The population in the basin, as a whole, has been estimated in 3 850 000 inhabitants (Rodríguez, in press). The main reason for this demographic boom was the unveiling of huge oil reserves, which triggered intense migratory influxes towards the State of Zulia. In 1941 more than 20% of the population in the area had arrived from other regions (Vila 1952). Other densely populated areas are the Colombian city of Cúcuta and several towns located on the Norte de Santander Department, where 922 700 persons have taken up residence.

In turn, this spectacular population growth has translated into two important impacts: (a) Land reclamation for urban and agricultural purposes; and (b) alteration of baseline conditions in the basins. At the same time, intervention of basins has bring about changes in the hydrological regime of the tributaries to the lake, due to deforestation, water course diversions for irrigation, and industrial and domestic uses; nutrient enrichment due to fertilizers employed in agriculture and cattle fodder, and because of the increase in domestic discharges carrying human excreta and phosphorous-rich detergents. Presently, the basins with the highest deforestation rates are those in the Serranía de Perijá, where furtive Colombian poppy growers have settled and entrepreneurs are illegally extracting timber.

16.4 Water Diversion and Impoundment

The population boom has also caused an additional demand for water. Diking, damming, river bed diversion, and electric power generation, usually have huge ecological impacts on ecosystems and communities. Another effect of the alterations to uplands hydrology and changes to river's beds and flows due to agriculture, livestock raising and urban development, is the erosion and transportation of particulate material and its ensuing deposition in the coastal hinterlands an into the lake. Although the sedimentation of larger grains is considered a minor hazard to Lake Maracaibo, since they are deposited in the flooded plains, muds and clays do silt in the lake and its impact should be evaluated.

In 1996 there were four reservoirs in the Lake Maracaibo basin. Currently, water for human and industrial consumption for El Tablazo area and the city of Maracaibo comes from the Tule Reservoir, which receives the Cachirí river water and the input of the Socuy river through the Manuelote river. Both reservoirs supply 6 000 l of water per second. On the western shore, the Viejo River Reservoir drains the Grande and Chiquito rivers. Other reservoirs are on the Motatán river and on Onía river, a tributary of the Escalante river. Besides, marginal dikes for flooding control and land reclamation have been built in the Catatumbo, Chama and Escalante rivers.

Electric power generation also taxes heavily on the basin's water budget. For instance, the Central Termoeléctrica Táchira in the basin of the Táchira river, a tributary of the Escalante river, has an output of 25 megawatts, while using 3 million m^3 of water yearly. On the lake's shore, next to the city of Maracaibo, the Central Termoelectrica de Arriaga utilizes 264 million m^3 of water annually to generate 220 MW. The Central Pueblo Viejo, produces 40 MW and uses 48 million $m^3\,a^{-1}$. By consuming 24 million m^3 of water, the Central San Lorenzo, yields 20 MW (COPLANARH 1972).

Cane sugar mills also are large water consumers. The Central Azucarero Mérida, located in the basin of the Chama river, uses 4 000 m^3 of irrigation water to treat cane that is cultivated over 500 ha. The Central Ureña, in the Táchira river watershed, processes 2 000 ha of cane using 6 000 m^3 of irrigation water. The Central Bobures, at the southern littoral of Lake Maracaibo, handles 2 000 ha of cane (COPLANARH 1972). Besides interfering with water cycling *per se*, cane crushing water contains a substantial amount of soil impurities and sugar. Disposal of the solid waste may lead to eutrophication because of high BODs (Biological Oxygen Demand).

16.5
Pesticides and Industrial Wastes

Agriculture can render other deleterious consequences, due to the use of pesticides, fertilizers, soil amendments and herbicides. Timberlands spread throughout 3 898 731 ha in the State of Zulia (MARNR 1984), while croplands cover 83 843 ha bordering the lake (Huber and Alarcón 1988). Organochlorine pesticides have been detected in all the rivers of the Maracaibo System basins. Almost 90% of the pesticides that enter the lake are accounted by the influx of the Catatumbo and Escalante rivers (ESCAM 1991). The Escalante river goes through large rangelands where livestock is raised, while in its uplands, in Venezuela as well as in Colombia, there are expanses exploited by itinerant croppers. The Zulia river, a tributary of the Catatumbo river, traverses, in its medium and upper reaches, extense croplands in Colombian country. The area where the most marked agricultural development has unfolded is the so-called Distrito de Riego Río Zulia – HIMAT (Norte de Santander Departament, Colombia), which spreads throughout 175 km^2.

The origin of industrial contamination (point source pollution) can be pinpointed to the metropolitan areas of Maracaibo, and the Andean cities of Mérida and Valera, in Venezuela, and Cúcuta (Colombia), where industries discharge their waste materials to the sewage systems or directly to the rivers, as well as by the inappropriate disposal of used containers, engendering toxic lixiviated materials. Usually the main contaminants are organic products and heavy metals (e.g. chromium disposed off by chromating metal coating and plating).

The ICLAM has performed evaluations of many of these sources in the shoreward of Lake Maracaibo and in the lowlands. Between 1982 and 1990 the ICLAM drew up reports dealing with the inspections carried out in 44 industrial installations, that included abattoirs, cold-storage plants, dairies, tanneries, hog farms, poultry keeping and packing, food-processing plants, breweries and soft drinks bottling companies, pharmaceutical industries and hydromechanical manufacturing companies. There is no information on the polluting industries sited on the city of Cúcuta (Colombia) that discharge their effluents into Lake Maracaibo through the Catatumbo river; nonetheless, since 24.1% of the population living in the watershed of Lake Maracaibo settles in the Norte de Santander Departament (Colombia), this area probably contributes significantly to the outfall that pollutes the lake.

16.6
Fisheries

Three distinct fisheries can be recognized in the Maracaibo System. Freshwater fisheries, based on several species of catfishes and species of the genera *Anodus* and *Curimata*, are located at the southern segment of Lake Maracaibo (Rodríguez 1984). In the estuarine section of the system, fisheries are based on several sciaenids

(*Cynoscion*) (Rodríguez 1984). This area also functions as a two-compartment system for the large shrimp trawl fishery that unfolds at the Gulf of Venezuela (Ewald 1967), which is based mostly on shrimps (*Penaeus schmitti*, *Penaeus notialis*, *Penaeus subtilis*, *Penaeus brasiliensis* and *Xiphopenaeus kroyeri*) and a few species of demersal fishes. Overall, landings represent roughly one-third of the national yield. In 1984 the fishing sector in this area engaged some 8 500 persons, while the oil industry enrolled 18 000 employees. In 1995, a total of 92 892 t were landed in this zone, which amounted to 18.6% of the national yield. In monetary terms, it represented 24.3% of the overall Venezuelan fisheries production. Approximately 71 600 t correspond to catches in the lake, while 11 500 t were harvested in the Gulf of Venezuela by the trawling fleet. The rest is provided by artisanal fishermen registered in the State of Falcón.

Fishing activities in the lake itself are mainly artisanal, although during the last years a canning industry based on blue crabs has thriven. In 1995 there were 5 581 artisanal fishermen, who used 3 448 boats, in the lacustrine sector of the Maracaibo System. They represented 25% of the country's maritime artisanal fisher community. Also, in 1995 there were 915 artisanal fishermen, based on the western coast of Falcón (SARPA 1996).

In the rivers and creeks that drain into the lake, 116 species and subspecies of fishes have been totallized (Taphorn and Lilyestrom 1984), although just a few have a commercial bearing. These include *Potamorhina laticeps* (5 148 t in 1995), *Prochilodus reticulatus* (3 079 t), *Plecostomus watwata* (390 t), and *Mylossoma acanthogaster* (3 t). Needlefishes, mainly *Farlowella curtirostra*, also represent a substantial staple, reaching 11 t in 1995 (SARPA 1996). Some catfishes probably contribute significantly to the total harvest, but data are not available for these habitats.

Coastal and shelf trawl fisheries in the Gulf of Venezuela started in 1948 with just one Italian-type boat (Cadima et al. 1972). From 1961 on all the boats were converted to the Florida-type standard. In 1971 there were two fleets. One, made up of small boats (15–20 m length), was based on the port of Maracaibo and mostly fished white shrimps in the Ensenada de Calabozo, while the other fleet, with larger boats, was based on Punto Fijo (State of Falcón) and operated offshore at the Gulf of Venezuela (Ginés 1982). Currently, the only fleet left docks at Punto Fijo; its fishing grounds span an area of more than 23 000 km^2, ranging from the Paraguaná Peninsula to the Guajira Peninsula, and from Los Monjes Archipelago to the inlets of Lake Maracaibo. At the beginning of the '80s the trawl fleet peaked at almost 200 ships. From 1956, when 4 000 t were landed, catches increased steadily, reaching 12 000 t during the early '70s. From then on, landings diminished and part of the fleet moved to the eastern region of Venezuela to exploit new fishing grounds, although in 1995, a total of 11 565 t were harvested. Also a shift in the composition of catches has occurred. At the beginning of the '70s, shrimps represented 40% of the catches, while presently the shrimp share is less than 30%. Several species of demersal fishes are harvested, but the most important are *Micropogon furnieri* (2 047 t), *Orthopristis ruber* (1954 t), and *Trichurus lepturus* (1 723 t). Regarding shrimp landings, this fishery is currently being managed at sustainable optimal levels. In 1989 shrimps catches (4 546 t) were very close to the estimated Maximum Sustainable Yield for this fishery (4 478 t) (Giménez et al. 1993). Similarly, the present fishing effort (32 109 days fished) is next to the estimated optimum effort (33 761).

Clashing of artisanal and industrial fisheries is one of the most remarkable conflicts of use in the coastal zone of the Maracaibo System. For years these conflicts have attracted the interest of mass media, environmentalist groups, local politicians and fishermen unions. The main problem, which has important social and economic consequences, is the interference between trawl and artisanal fisheries and the alleged heavy fishing by trawl boats. Antagonism mainly arises from the interference for fishing grounds and destruction or losses of artisanal fishing gears. It is believed that these sectors are not antagonistic in themselves and can flourish side-by-side if some practices are enforced.

In a spatial scale, the conflict can be defused by reserving coastal zones exclusively for artisanal fisheries, whereas in a temporal scale the establishment of closed seasons to the industrial fisheries might be an effective measure. In 1992, a decree was promulgated (N° 2,227; 23.04.1992; "Ecological Technical Norms for Controlling Fishing Activities") banning the activities of trawl boats within a 3-mile limit from the line of meal low water. Closed seasons have also been utilized as a means to placate this particular conflict. In 1989 resolution MAC-DGSPA 215 was enacted, establishing a two-month moratorium (11.05.1989–01.04.1990). The results of this type of action are promising, since the yields obtained after implementing closed seasons have been higher than those observed over the same period in previous years (Dávila et al. 1994).

16.7 Navigation

The Maracaibo Channel has a two-fold importance: as a route for vessels that carry out the trade between several cities located on the perimeter of the lake, and, perhaps a more important role, as a waterway for tankers that carry the main Venezuelan export commodity. This passage is a strategic nautical route, not only for Venezuela, but also for the world economy. In 1996 more than 1 million barrels of crude oil, carried by 1307 tankers, were exported daily through the channel. The total oil transported in 1995 was 53.2 million t (approximately 380 MM bb).

The two main oil terminals are Puerto Miranda, situated by Puertos de Altagracia, and La Salina, located at Cabimas. In 1993, 152 million barrels of crude were exported from Puerto Miranda, while 4.7 MM bb were aimed at cabotage. This loading terminal started its operations in 1960 and over the ensuing 31 years it had supplied 9 000 MM bb of crude to 28 000 tankers. In 1992, La Salina processed 110 MM bb. Both terminals have facilities to discharge ballast waters from tankers. Smaller terminals are La Arriaga on the southern coast of Lake Maracaibo, La Estacada at Puertos de Altagracia; and the lacustrine terminals Lagunillas and San Lorenzo. In addition, since the beginning of the '90s the channel is also the main route for the exportation of coal extracted from the Guasare mines.

During 1996, 732 freighters and merchant ships navigated through the channel; in 1995, 8 504 000 t of cargo were transported – which is 6% of the total for Venezuela (MTC 1997). The traffic of ships to and from the port of Maracaibo is also considerable. In 1996, 432 foreign vessels and 341 cabotage ships docked at this port (MTC 1997).

16.8 Oil Exploitation and Petrochemical Industries

Most of the petroleum-related activities in Venezuela orbits around the state-owned Petróleos de Venezuela, SA (PDVSA), a gigantic holding of three vertically-integrated operating subsidiaries (CORPOVEN, LAGOVEN and MARAVEN) that deal with oil exploration, production, refining and marketing, and a guild of companies with more specialized functions, such as research and development (INTEVEP), maritime transportation (PDV Marina), agroindustry (PALMAVEN), orimulsion marketing (BITOR), training (CIED), petrochemistry (PEQUIVEN) and many others. Currently PDVSA is said to be producing 3.2 million barrels of crude per day and have a refining capacity of 1.8 million barrels per day. The incidence of the oil industry in Venezuela's Gross National Production is nearly 60%. If the Maracaibo System was to be defined with just one word, petroleum should be the most obvious choice. Located in the heart of Venezuela's oil industry, Lake Maracaibo harbours one of the most important oilfields in South America and also one of the largest in the world. In 1984, there were 8 400 active oil rigs, several hundred flux stations and two refineries; all of them connected by 40 000 km of pipelines, mostly running underwater (Rodríguez 1984). From 1914, when the first oil well started its commercial operations, to 1995, roughly 33 000 million barrels (5 238 million m^3) were extracted in this basin. Most of the oil is drawn out from the lake's bottom, and exported by means of oil tankers that go through the Strait of Maracaibo. In 1996, 1 307 oil tankers went through the Maracaibo Channel.

The huge reserves of light crudes an natural gas in this basin have impelled the establishment of a highly diversified conglomerate of petrochemical industries that cluster in an industrial complex situated by Puerto Miranda, on the eastern shore of El Tablazo Bay, under the name "Complejo Petroquímico El Tablazo". Currently, there are more than 20 plants in operation, producing a range of compounds from olefins originating from natural gas fetched from several zones of the Lake, which are processed into plastics, fertilizers and other synthetic organic products. Many of these industries are joint ventures with foreign and national partners. Due to the nature of the substances processed by the petrochemical industries, the potential for environmental incidents is high and, thus, their activities are under the surveillance of governmental agencies, mainly the ICLAM.

In spite of a most extense regulatory umbrella, environmental damages have springed in several opportunities. At the early stages of El Tablazo petrochemical complex, a chlorine-soda plant with mercury cells operated. Mercury disposal and its potential as a contaminant agent for aquatic organisms have drawn the attention of environmental organizations and printed mass media over the last 25 years.

16.9 Engineering Works

Oil exports from Lake Maracaibo through the outer bar and the ever-changing shoals of El Tablazo Bay and the Strait of Maracaibo are critically dependent on the navigational link between the lake itself and the Gulf of Venezuela – the gateway to the Caribbean Sea and thus to the Atlantic Ocean (Fig. 16.1). With the advent of huge oil tankers and an increased world demand for oil and petrochemical products, after World War II, the natural navigation channel that connected all those areas became insufficient. In 1953, a government agency, The National Institute for Canalizations was created to deal systematically with the widening and deepening of the natural channel and its maintenance through continuous dredging. Between 1957 and 1960 both the exterior and interior channels were deepened to a minimum depth of 45 fathoms Rodríguez 1984).

By that time, the main environmental worry pointed towards the increased probability of the saline wedge penetrating into the lake, which, in turn, would translate into more wood-boring species attacks on oil structures (Rodríguez 1984). Concern for other environmental impacts did not arise at that time. However, two problems were faced: high costs of maintenance and hydrodynamic modifications that resulted in crosscurrents and thus in augmented navigation hazards. Two main engineering projects were considered to subdue this situation: to close the lake with a terminal dike or to enclose the channel by means of two parallel dikes.

An early concern with this kind of megaproject was the possibility of salinization of the lake, in one case, or the barring of migratory fluxes of species which use the Maracaibo system in a compartmentalized fashion. These possibilities have been thoroughly studied (Rodríguez 1973, 1974, 1984), and based on the evidence at hand, it has been concluded that dredging the navigation channel had not altered the biotic composition of the estuary and the lake. It has also been pointed out that the construction of parallel dikes, a more economical alternative to dredging, is preferable from either ecological or fisheries perspectives (Rodríguez 1984). Accordingly, in 1972, the construction of terminal dikes was postponed indefinitely, based on the consequences on estuarine ecosystem dynamics and the severe economic repercussion on the low-income fishfolk community (Rodríguez 1984). As well, a possible increase in pollution, already severe in this area, was an element considered in the decision-making process (Rodríguez 1984).

16.10 International Frame

Not all the conflicts that affect the Maracaibo System have a domestic origin. Due to its proximity to the Venezuela-Colombia border, the well-being of the Maracaibo System also depends on the proper management of the basins in Colombian territory, beyond the reach of Venezuelan jurisdiction (Fig. 16.1). The predicament is exacerbated by the fact that Venezuelan watersheds are downstream the Colombian grounds. Currently, the basins with the highest deforestation rates are those in the Serranía de Perija, where furtive Colombian poppy growers and unscrupulous timber entrepreneurs have settled, but the most troubling areas are located in the upper reaches of the Catatumbo river, which account for around 70% of the freshwater that drains into the lake. Additionally, the activities of the Colombian guerrilla in this zone have comprised attacks against Colombian pipelines that run through shared basins. Since 1986, when its operations started, the Caño Limón-Coveñas pipeline, which conducts crude from the oilfields in the Arauca to the Caribbean Sea through 780 km, has been blasted 474 times. In 1996, 47 attacks were infringed on this pipeline, which has a transportation capacity of 300 000 bpd. During 1996 a total of 105 000 barrels of oil were spilled and the damages reached US $9.3 million. Over the first three months of 1997, 13 attacks have been tallied, leading to the spilling of large quantities of crude into the Maracaibo basin. A bilateral contingency program between PDVSA and its Colombian equivalent, Ecopetrol, has been established to try to detect oil spills before they reach Lake Maracaibo.

To these effects, water diversion should be added, as would occur at La Gabarra where a Colombian project of power generation is being considered at the moment; such an intervention probably would unbalance the water budget and hinder migrations of fishes. In Colombia, as well as in Venezuela, the Escalante river goes through extense rangelands where livestock is raised, while in its uplands there are tracts exploited by itinerant croppers. The Zulia river, a tributary of the Catatumbo river, traverses, in its medium and upper reaches, extensive croplands in Colombian country. The area where the more intense agricultural development unfolds is the so-called Distrito de Riego Río Zulia – HIMAT (Norte de Santander Departament, Colombia), which spreads throughout 175 km^2. To the pollution with an agricultural origin, the large input of industrial and domestic wastes from the city of Cúcuta and other nearby populations to the Catatumbo basin should be added.

Based on these facts, it is easy to realize that the success of an ICZM programme for the shorelands of the Maracaibo System will strongly depend on the cooperation of the Colombian government. The Republic of Venezuela has attempted to face this situation by enacting a commission for management of common basins. But trouble would not end at this level. In what might be viewed as a bizarre turn, recently the powerful Colombian guerrilla (ELN) stated its environmental awareness through one of its adherents' declarations to the Venezuelan national press (Zambrano 1997). According to this spokesman, all the military actions (mostly oil pipeline blastings) of the partisans in the basins have been environmentally sound. He also stated a deep concern for deforestations, oil spills and mining concessions to multinationals.

16.11 The Nissos Amorgos Oil Spill

The greatest concern over the oil spill came from artisanal fishermen, who have a high lobbying capacity through a strong union, FETRAPESCA, that has a powerful political leverage. Immediately, the incident found its way to the political agendas of the Governor of Zulia, members of the State Parliament, members of the National Congress, and even of a presidential candidate. Mass media thoroughly covered the incident, but frequently from an emotional, biased angle. Over the next months, most of the Venezuelan newspapers kept on publishing articles on this topic at almost a daily rate.

The situation compounded when more than 10 000 embattled artisanal fishermen organized, with great hoopla, an aquatic parade – intended as a sail-through strike in 3 000 small boats, which was widely covered by national and international mass media (CNN, ECO, among other international TV networks). Outraged fishermen claimed a settlement for their potential losses due to the spillage. They sought legal advise and sued shipowners. The captain of the vessel was detained and an embargo of US $7 million was laid upon the ship. In turn, shipowners, through INTERTANCO, threatened to boycott maritime transportation of Venezuelan oil, alleging the below par maintenance of the channel. LAGOVEN was put in charge of removing the oil from the beaches.

Beach-cleansing was undertaken by more than 600 handymen, hired from the nearby villages and paid a meager weekly wage of little more than US $82. Shoreline clean-up and other related expenses were to be covered by international funds. The usually messy operations involved in the oil collection and clean-up processes posed special technical problems, that lead to the hiring of foreign and domestic experts. The process has been regarded as a total failure by the printed press.

The blame for the damages was put on PDVSA for the purported delay in launching the contingency plan and to a greater degree on the National Institute for Canalizations for alleged under par maintenance of the Maracaibo Channel. Public unrest over this issue lasted several months, and finally it was funnelled into the conclusion that the channel administration and maintenance should be regionalized and a deep-water harbor should be constructed on the Gulf of Venezuela. Coincidentally, these issues were also in the political agenda of the incumbent Governor of Zulia.

The Nissos Amorgos oil spill depicts the superficial minimalism of the domestic conflicts over the aquatic component of the Maracaibo System. The incident, that should have been kept a technical problem, attracted a swarm of opportunistic conducts, which in the final run set up a trite *mise en scène*: artisanal fishermen – the John Does of the Seas – defenceless faced the sly corporations. Meanwhile, politicians and headline seekers grabbed ripe benefits. To avoid a new battle of headlines and reach a fluid state of negotiations, in the probable event of a new incident in the future, the agency designated as the crossroad for conflicts and lobbying groups and organizations, should use a strategy whose backbone should aim at bringing together the actors to define the problem, to derive solutions and to implement them cooperatively.

16.12 Outlook

According to Sorensen and Brandani (1987) all Latin American countries have used sectoral single-purpose planning to manage various coastal resources or activities. The evolution of coastal area management programs in national or subnational units seem to follow a similar track: from initial awareness to program implementation in a five-step progressive course. In 1987, only five countries had progressed beyond the second stage and reached a national concern for coastal management. Venezuela was not one of them. However, the situation has changed slightly. Although Clark (1996), in a thorough review, does not list any coastal zone management programme for Venezuela, he does include a regional program for the State of Nueva Esparta in eastern Venezuela. The Maracaibo System and specially Lake Maracaibo appear to be scenarios in the brink of a full-fledged integrated coastal zone management programme.

Sorensen and Brandini (1987) and Sorensen and McCreary (1990) have discussed the main attributes for a plan of action to be deemed as an ICZM programme (Table 16.2). Items 6 and 7 are considered by Sorensen and Brandini (1987) as the key elements in distinguishing coastal zone management and planning programs from those that are not. The coastal area of the Maracaibo System meets most of the above conditions.

The major matters of contention in the Maracaibo System are oil spills, fisheries and the intervention of the uplands. Clark (1996) sustains that an integrated coastal management program should not include fisheries management. That guideline should show itself appropriate when fisheries do not collide with other sectors. But in the Maracaibo System scenario, the development of artisanal fisheries, and as a matter of fact their sheer survival, is not feasible without controlling two of the other actors: trawl fisheries and the petroleum industries. In the long run, a successful management program should also face the degradation of the uplands; this will require international collaborative efforts since some of those grounds are shared with Colombia.

Table 16.2. Main attributes for a plan of action to be considered an integrated coastal zone management programme (After Sorensen and Brandini 1987; Sorensen and McCreary 1990)

1.	It is initiated by government in response to remarkable resource degradation, exposure to coastal hazards, multiple use conflicts or socioeconomic development needs.
2.	There is a government arrangement to establish the policies for making allocation decisions.
3.	One or more management strategies are employed to rationalize and systematize the allocation decisions.
4.	A specific set of objectives or issues is to be addressed or resolved by the program.
5.	The effort has continuity over time and is usually a response to a legislative or executive mandate. It is distinct from a one-time project.
6.	Its geographical jurisdiction and boundaries are specified. It has an inland limit and an ocean boundary – with the exception of small, unpopulated islands, which often have only an oceanward boundary; because it is not an ocean management program, it must have both shore and landward components.
7.	The management strategies selected are based on a holistic perspective which recognizes the gamut of interconnections among coastal environmental systems, the inland systems as well as the public service systems. Consequently, the design and implementation of management efforts should be characterized by the integration of two or more sectors, based on the recognition of the natural and public service systems that interconnect coastal uses and environments.
8.	It has an institutional identity – it is identifiable as either an independent organization or a coordinated network of organizations linked together by functions and management strategies.

Every ICZM programme should have an institutional identity. Over a 15-year stint the ICLAM has amassed a Leviathan corpus of information dealing with the Maracaibo System, principally Lake Maracaibo. Furthermore, its charter establishes such a lengthened catalogue of responsibilities and functions, that its role as the key institution and full-fledged authority in the orchestration, management and surveillance of Lake Maracaibo is guaranteed. As well, the ICLAM could play a significant part in the arbitration and negotiations in conflicting scenarios.

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Chapter 17

Sustainable Developmental Planning in Ecologically Sensitive Dahanu Region on the West Coast of India

P. Khanna · P. Ram Babu · S.K. Gadkari

17.1 Introduction

India has a coast line of 12700 km with identified maritime areas of 452000 km^2 (shelf to 200 m depth) and 2015000 km^2 (exclusive economic zone). The coast has 357000 ha of mangroves and also coral reefs. The average annual marine catch of fish during 1991–1993 is 2.462 million t and the decadal growth rate is 68%. Marine fish resources support the economic activities of 2–3% of working population in coastal districts of India. There as 11 marine protected areas covering an area of 276042 ha and 4 regional priority sites in the open seas and coastal regions.

Out of 71 coastal districts in India fall under high threat potential as per the coastal area threat ranking by World Resources Institute based on the criteria of existing population, road and pipeline densities. There are 11 cities with a population more than 1 million along the coast line, and the decadal population growth rates of these cities range from 25–75%.

In view of the high anthropogenic pressure on the Indian coastal resource endowment constituting mangroves, coral reefs, estuaries, wetlands and marine biodiversity; and changes in land use in coastal regions threatening the livelihood of fishermen and ecosystem health, the Ministry of Environment and Forests declared in February 1991, coastal stretches as Coastal Regulation Zones (CRZ) for regulation of activities in the CRZ. The CRZ includes coastal stretches of seas, bays, estuaries, creeks, rivers and backwaters which are influenced by tidal action (in the landward side) up to 500 m from the High Tide Line and the land between High and Low Tide Lines. The restrictions on land use in these regions is based on the criteria of eco-sensitivity of the region and the present land use.

During the last 5 years, many developmental proposals including citing of industries (e.g. steel complex in the coast of Ganjam district in the state of Orissa), infrastructure (e.g. development of railways along west coast of the state of Goa), regional plan (e.g. regional plan of Dahanu Taluka along the west coast at a distance of 50 km from Bombay Metropolitan Region) and aquaculture (e.g. intensive aquaculture activity along east and west coasts) met either with resistance from the public or public interest litigations in different courts of India.

In Dahanu region, siting of a thermal power plant and urban development encroached upon wet lands and mangroves threatening the livelihood of fishermen, and ecosystem health of the creek. The state of Maharashtra is mandated, under a declaration by Ministry of Environment and Forests, Government of India (1991), to protect the land cover and land use of Dahanu region, through a regional plan. The perceived inaction of the Government of the state of Maharashtra and unabated industrial and residential growth in the region has been a matter of public interest litigation in the Honourable Supreme Court of India since 1994. The case study delineated below outlines the situation and remedial measures with reference to the matters raised in the public interest litigation.

17.2 Dahanu Region – Pressure, Response and Consequences

Dahanu Taluka, geographically located between 19°15′–20°8′N Lat. and 72°32′–73°7′E Long., is bounded by Palgarh, Jawahar, Talsari and Wada Talukas in the state of Maharashtra in India. The Taluka including 25 km buffer zone has rich land, forest, aquatic and aesthetic resources. The coast line is about 85 km long. The area under wetlands and mudflats constituted 9 546 ha in 1989; the tropical moist teak bearing and mixed deciduous forests and mangroves covered an area of 66 261 ha; and plantations cover an area of 5 189 ha.

The imperatives for the protection of the sensitive aquatic ecosystem, drainage in the coastal zone, land suitable for agriculture/horticulture, rich forest resource endowment, and socio-cultural and economic status of tribals limit the levels and characteristics of the anthropogenic activities in this region. In view of this, the Ministry of Environment and Forests declared the Dahanu Taluka as environmentally sensitive, and delineated restrictions on the industrial activities and land use changes. The coastal regulation zones promulgated in February 1991 regulate the landuse within 500 m buffer zone of high tide line in the face of increasing population pressure in the coastal areas, and on sensitive aquatic ecosystems in respect of urbanization and industrialization.

Despite these regulations, the industrial and settlements development continued unabated resulting in land use/land cover changes and damage to aquatic ecosystem.

17.2.1 Land Use Changes

The following are the critical land use cover changes observed in Dahanu region during 1989–96 (Fig. 17.1) through the analysis of remotely data:

- Dahanu Taluka
  - Wet lands covering an area of 273 ha have been encroached for other landuses.
  - There has been a significant increase in the built-up area by 13% at the expense of wetlands that comprise essentially of mudflats and vegetation.
  - The landmass covered by orchards has increased by 112% at the expense of crop land and fallow land.
  - The landmass covered by dense forest and degraded forest has decreased by 2 590 ha which has resulted in an increase in the area to the same extent of in the forest blanks.
  - Landmass covered by fallow land has decreased by 25% resulting in the development of scrub and land by 19%.

- Dahanu Taluka and 25 km Buffer Zone
  - Wetlands covering an area of 3 793 ha (about 40% of the total wetlands) have been encroached for other landuses
  - Decrease in the cropland and plantations has paved the way for significant increase in orchards (19.6%)
  - The decrease in the forested landmass comprising the dense forest and degraded forest has resulted in proportionate increase in the scrub and grass lands, and fallow lands.

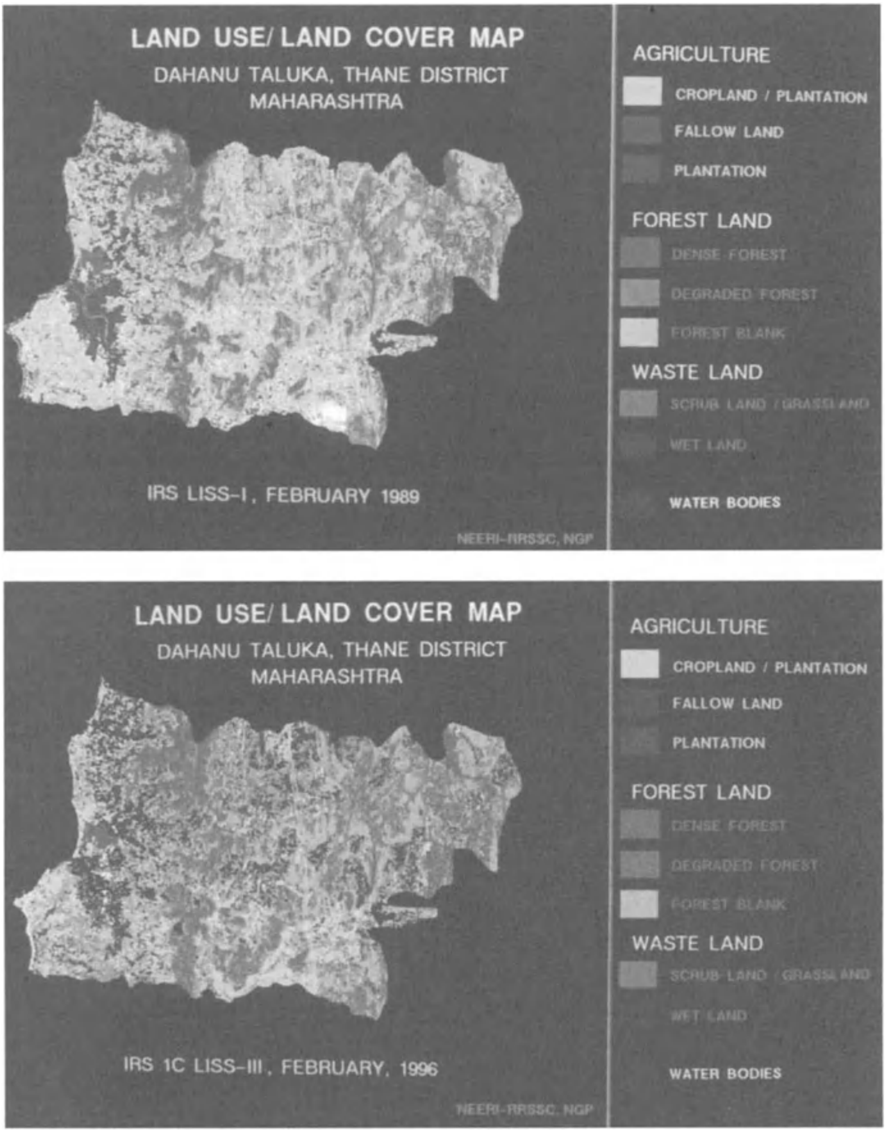

Fig. 17.1. Comparison between the land use/land cover maps of Dahanu Taluka prepared from IRS LISS-I data of February 1989 and IRS LISS-III data of February 1996 respectively. Analysis reveals an increase in orchards by 112% at the expense of crop lands, fallow lands and in scrub and grass lands by 19% at the expense of forested land mass during 1989 and 1996. During the same period, 273 ha of wetlands have been encroached for other landuses (*Note:* The coloured version of this figure can be found on the CD, enclosed with this book)

In addition, the land use does not confirm to land capability especially in locationing of industries and settlements.

Table 17.1. Physico-chemical characteristics of creek waters durings pre-commissioning and post-commissioning phases of Dahanu Thermal Power Station (October 1991 and October 1996)

Sampling point	Parameters pH		Salinity (ppt)		Suspended solids (mg/l)		Chlorides (mg/l)		DO (mg/l)		PO_4 (mg/l)	
	1991	1996	1991	1996	1991	1996	1991	1996	1991	1996	1991	1996
1	8.4	n.s.	36.7	n.s.	270	n.s.	20 400	n.s.	5.4	n.s.	0.02	n.s.
2	8.1	n.s.	37.1	n.s.	236	n.s.	20 580	n.s.	5.5	n.s.	0.02	n.s.
3	8.4	7.3	37.1	2.7	194	20	20 580	1 500	5.3	6.4	0.03	<0.01
4	8.4	n.s.	37.5	n.s.	310	n.s.	20 800	n.s.	5.3	n.s.	0.06	n.s.
5	n.s.	7.6	n.s.	2.4	n.s.	10	n.s.	1 300	n.s.	6.0	n.s.	<0.01
6	8.3	7.6	36.0	2.0	320	30	20 010	1 100	5.3	6.2	0.09	<0.01
7	n.s.	7.5	n.s.	3.6	n.s.	40	n.s.	2 000	n.s.	6.4	n.s.	<0.01

n.s.: not sampled. Remarkable decrease in salinity, suspended solids and chlorides is noticed in 1996 in comparison to 1991. Reduction in phosphate concentration and pH have adverse effects on phytoplankton, affecting the food chain.

17.2.2
Changes in Aquatic Ecosystem

The following changes during 1991–96 have effected the aquatic ecosystem in Dahanu creek:

- Remarkable decrease in salinity, suspended solids and chlorides (Table 17.1);
- Reduction in phosphate concentration and pH levels have adverse effects on biomass of phytoplankton, affecting the food chain;
- Diversity index, indicative of ecological health, has decreased (Table 17.2);
- Number of fish and prawn varieties has decreased;
- The instability of inverted ecological pyramid has become critical due to relatively large decrement of biomass in lower levels and meobenthos (Fig. 17.2).

In addition, the decrease in crown density of forest resources, displacement of tribal population, salinity intrusion into ground water along the coast and sea water intrusion into coastal villages are important consequences of anthropogenic activity in this region.

17.3
Conclusions and Recommendations

The judiciary requested the Institute to examine issues related to:

- Conformity of regional plan in respect of Dahanu area, formulated by the Government of Maharashtra, with the notification (20th June 1991) declaring Dahanu Taluka as an ecologically sensitive area; and notification (19th February 1991) declaring coastal stretches as coastal regulation zone (CRZ) and regulating activities in the CRZ; both under the Environmental (Protection) Act, 1986;
- Environmental viability of the regional plan;
- Delineation of suggestions to protect and preserve ecology in Dahanu region;

Table 17.2. Phytoplankton analysis of surface waters during low tide (day) from Dahanu creek in October 1991 and October 1996

Sampling station	Percent in groups: Dianophyceae		Chrysophyceae		Cyanophyceae		Bacillariophyceae		Chlorophyceae		Total N° per 100 ml		Shannon Weaver diversity index	
	1991	1996	1991	1996	1991	1996	1991	1996	1991	1996	1991	1996	1991	1996
1	–	n.s.	17.00	n.s.	25.00	n.s.	58.00	n.s.	–	n.s.	1600	n.s.	2.99	n.s.
2	7.00	n.s.	10.34	n.s.	48.30	n.s.	38.36	n.s.	–	n.s.	1933	n.s.	2.62	n.s.
3	–	–	23.34	13.00	10.00	26.10	63.33	60.90	3.33	–	1500	966	3.29	2.41
4	–	n.s.	28.57	n.s.	9.53	n.s.	61.90	n.s.	–	n.s.	2100	n.s.	3.05	n.s.
5	3.57	n.s.	7.14	n.s.	10.72	n.s.	78.57	n.s.	–	n.s.	1867	n.s.	2.36	n.s.
6	–	–	23.53	38.40	11.76	23.10	64.71	38.50	–	–	850	1079	2.68	1.92
7	–	n.s.	3.57	n.s.	17.86	n.s.	78.57	n.s.	–	n.s.	2800	n.s.	2.81	n.s.
8	–	n.s.	12.50	n.s.	14.60	n.s.	64.56	n.s.	8.34	n.s.	3200	n.s.	2.95	n.s.
9	–	–	7.50	13.30	5.00	26.70	80.00	60.00	7.50	–	2667	945	3.18	2.26
10	–	n.s.	4.28	n.s.	6.38	n.s.	87.20	n.s.	2.14	n.s.	3133	n.s.	2.43	n.s.
11	n.s.	–	n.s.	161.6	n.s.	33.3	n.s.	50.1	n.s.	–	n.s.	1008	n.s.	2.31

– Absent, *n.s.*: not sampled.
* Diversity index, indicative of ecological health, has decreased in October 1996 compared to October 1991.

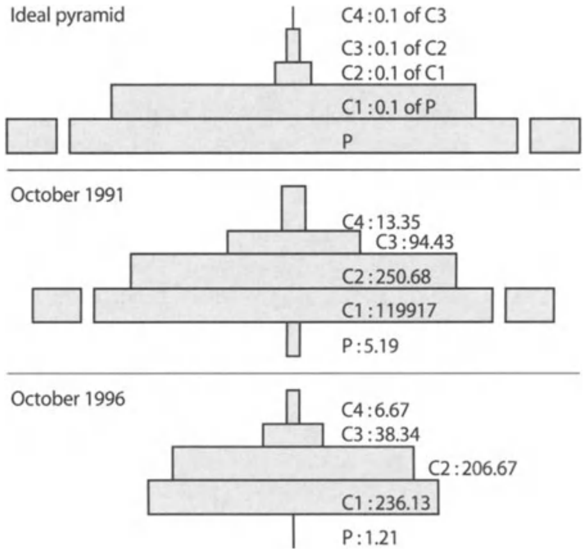

Fig. 17.2. Ecological pyramids for Dahanu creek in October 1991 and October 1996 (based on biomass: kg dry wt km^{-2})

- Typology of industries to be permitted in ecologically fragile Dahanu region;
- Examination of the effect of thermal power plant operating in Dahanu region.

The Institute's report submitted to the judiciary in October 1996 dealt with the afforereferred issues and presented its findings, conclusions and recommendations on each issue as delineated below.

17.3.1
Dahanu Regional Plan

The regional plan violates the MoEF notifications on coastal regulation zone (dated 19th February 1991) and environmentally sensitive Dahanu Taluka (dated 20th June 1991), and is also ecologically and environmentally unviable as the premises in planning are not based on natural resource endowment (supportive capacity) and environmental media quality (assimilative capacity).

The regional plan must have taken cognizance of the ecological fragility of the region, and should be based on following guidelines:

- The planning region should include all micro-watersheds in Dahanu Taluka and the 25 km buffer zone;
- The regional plan should delineate:
  - landuse on 1 : 50 000 scale;
  - ecologically harmonious economic activity typology and levels of each activity;
  - activity zoning;
  - technological and policy interventions to facilitate implementation of the regional plan;
  - implementation and monitoring mechanisms;
- The regional plan should aim at:
  - maximizing equitable quality of life levels;
  - minimizing ecological loading (natural resource usage) in building regional economy;
  - minimizing environmental status degradation.

Such an exercise would require estimation of supportive capacity of resources in the region and assimilative capacity of environmental media to facilitate delineation of preferred scenario for sustainable socio-economic growth:

- The regional plan should also provide operational directives for the preparation of master plans for each urban/semi-urban settlements in Dahanu area
- The satellite imageries of 1996 with six metre resolution should be reckoned as the existing landuse for preparation of the regional plan.

17.3.2
Protection and Preservation of Ecology

The recommended measures for protection and preservation of ecology are:

- Deployment of micro-water sheds as the basis for planning;
- Extensive mangrove plantation along the creeks and on wetlands;
- Protection and rejuvenation of wetlands;
- Protection of natural drainage channels;
- Ensuring free mixing of sea and creek waters;
- Landuse in harmony with land capability;
- Sustainable forest management with focus on protection of forest ecological characteristics, sustainable yields of economically useful forest products and services, and sustenance of forest dependent human institutions;

- Limits to quantitative growth in keeping with the supportive capacity of natural resources, and assimilative capacity of environmental media;
- Control of wastewater discharges in the creeks and wetlands to protect nutrient recycling and breeding functions;
- Control of air pollutant emissions within the assimilative capacity of airshed(s) in the region and restriction on ambient air quality levels of SO_2, NO_2 and SPM to 20, 30 and 100 $\mu g\ m^{-3}$, respectively in Dahanu region to protect the orchards and plantations;
- Preservation of indigenous culture, and ensuring socio-cultural security for tribal population.

17.3.2.1
Industrial Typology

The eco-sensitive nature of Dahanu Taluka and its 25 km buffer zone constrains the industrial typology in keeping with the supportive and assimilative capacities in the region. The criteria for selection of industries in this region should be:

- Use of local resource as industrial raw materials;
- focus on primary and tertiary sectors of economy;
- The preferred economic activity is mariculture, silviculture, agriculture and horticulture eco-tourism should also be promoted;
- Manufacturing of items that aid primary sector activity in the region;
- Focus on employment intensity and low skill requirements;
- Non-polluting, non-chemical and non-hazardous.

The number of units should be limited to the regenerative capacity of resource endowment.

The location of industries should be restricted to the areas outside Dahanu Taluka and the 25 km buffer zone.

17.3.2.2
Environmental Compliance – Thermal Power Plant

Bombay Suburban Electric Supply (BSES) – Thermal Power Plant (TPP). The location of (BSES)-(TPP) is on the wetlands and partly within the coastal regulations zone (CRZ-I), thus violating coastal zone regulations. The measures to be undertaken by BSES-TPP are delineated hereunder:

- BSES-TPP should shift, at the earliest, to the use of natural gas in place of coal. In the interim period, it should use only the washed coal;
- All obstructions to the free flow of sea water into the creek should be removed forthwith by the Bombay Suburban Electric Supply (BSES) – Thermal Power Plant (TPP);
- BSES-TPP should make arrangements for reuse of accumulated flyash. Current practice of disposal of flyash on wetlands should be stopped forthwith;
- The plantation around BSES should be predominantly of mangroves;
- BSES-TPP should install Flue Gas Desulphurization (FGD) system forthwith in view of limited air-environment assimilative capacity;

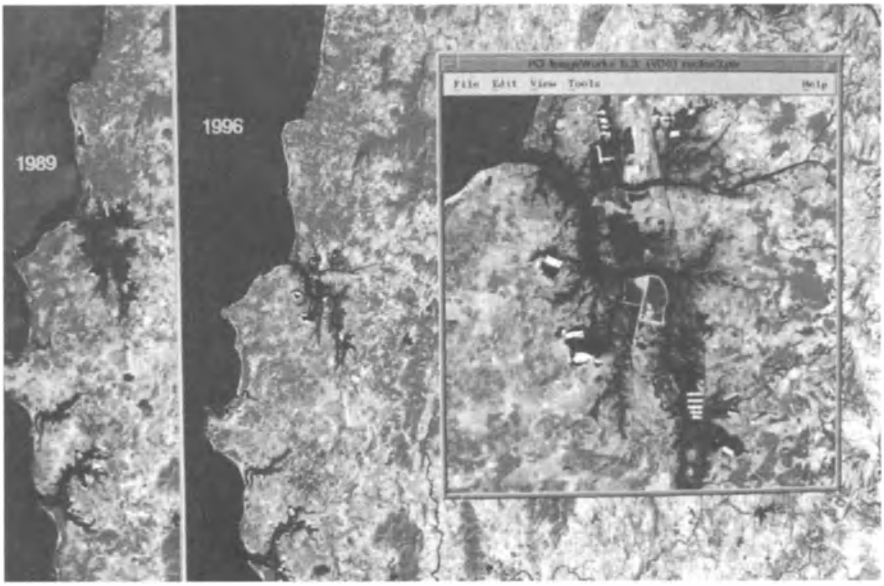

Fig. 17.3. Colour (see note) composites of coastal zone of Dahanu Taluka prepared from IRS LISS-I data of February 1989 and IRS LISS-III data of February 1996 respectively. Inset shows the magnified view of the Dahanu Creek and its surroundings as mapped from LISS-III data of February 1996 (*Note:* The coloured version of this figure can be found on the CD, enclosed with this book)

- The spare fields of electrostatic precipitators be made available at all times of operation;
- BSES-TPP should ensure monitoring of hourly temperature of hot water discharges; monthly variations in ground water quality; weekly variations in creek water quality; and ambient air quality levels and fugitive emissions from TPP every two days in a week at each station; and effective operation of pollution control and environmental monitoring instruments;
- The effect of gaseous emissions on productivity of horticulture plants, viz. chickoo and mango needs to be examined through a scientific study to devise an effective environmental management plan. The study should consider synergistic effects of gaseous and particulate pollutants, humidity, and soil conditions;
- Expansion of BSES-TPP generating capacity should not be permitted in view of its ab initio wrong siting in the intertidal region of an ecological sensitive area.

The location of Thermal Power Plant and ash ponds and consequent shrinking of wetlands is delineated in Fig. 17.3.

17.3.2.3
Institutional Mechanisms

Management of ecologically fragile areas to achieve the overall aspirational goal of sustainable development warrants legal interventions based on the precautionary principle, conservation of natural resources, and environmental protection. These is thus adequate reason to take resource to the Sections 3, 4 and 5 of the Environment (Protection) Act, 1986 for ensuring effective management of ecologically fragile areas in the country.

Authority for management of ecologically fragile areas as per the composition delineated above, with mandate for coordination and implementation of all activities of planning, development, allocation, implementation, research and monitoring in ecologically fragile areas needs to be established to operationalize the precautionary principal in sustainable development. The mandate of the authority needs to include the following:

- To identify ecologically fragile regions and buffer zones in the country, and to delineate and implement appropriate regulations;
- To deploy ecological units as the basis for regional planning in ecologically fragile areas;
- To delineate guidelines for regional planning in ecologically fragile areas;
- To ensure preparation of medium and long term regional and master plans, and their implementation through existing institutions;
- To examine, review and effect modifications in any project/plan/policy envisaged by the Government of India/State Governments/Local Self Governments that has adverse bearing on ecological fragility of the region;
- Monitoring of ecology and environmental media quality for effecting corrective measures;
- Capacity building in existing institutions of management of ecologically fragile regions;
- To ensure community participation in the management of natural resources and protection of ecology.

Chapter 18

Management of Tokyo Bay

K. Takao · B.T. Bower

18.1 Introduction

Tokyo Bay is a relatively small body of water, slightly less than 1 000 km^2 in its inner bay area, and surrounded by the metropolitan area comprised of Metropolitan Tokyo and the prefectures of Kanagawa and Chiba. The bay and the surrounding area are shown in Fig. 18.1. This metropolitan area had a population of 26.5 million residents in 1994 and is the largest urban agglomeration in the world.

The area along the coast of Tokyo Bay is the most highly concentrated industrial area of the world, particularly specialized in so-called heavy industries, e.g., iron and steel, petroleum refining, petrochemicals, rubber, nonferrous metals, shipyards, and power plants. The capacity of iron and steel production of the bay area, for instance, is equivalent to France's capacity of the same industry.

The Japanese model of coastal industrial development, typically seen in Tokyo Bay, is being followed by an increasing number of Asian and other developing countries. Their export oriented industries of manufactured goods typically take advantage of the low cost of marine transport, i.e., raw materials for their manufacturing processes are imported cheaply and their products are exported immediately from adjacent ports.

The result of such urban and industrial development is ever increasing pressures on coastal resources, leading to increasing conflicts among different uses of the water. The case study described herein, done in the mid-1980s, focuses on three facets of the uses of Tokyo Bay:

1. The evolution of the mix of uses of the bay over time;
2. Analysis of alternative futures to shed light on the net benefits to society with alternative management strategies; and
3. Possible institutional arrangements for the decision-making for management of the bay.

The last involves analysis of the existing institutional structure and how it might be changed in order to include:

a a wider range of options and outputs, and
b broader participation in decision processes.

18.1.1 Brief History

Until the end of the 16th century, the Kanto Plain, which consists of a large portion of the catchment of Tokyo Bay, was essentially an underdeveloped area, although the foot-

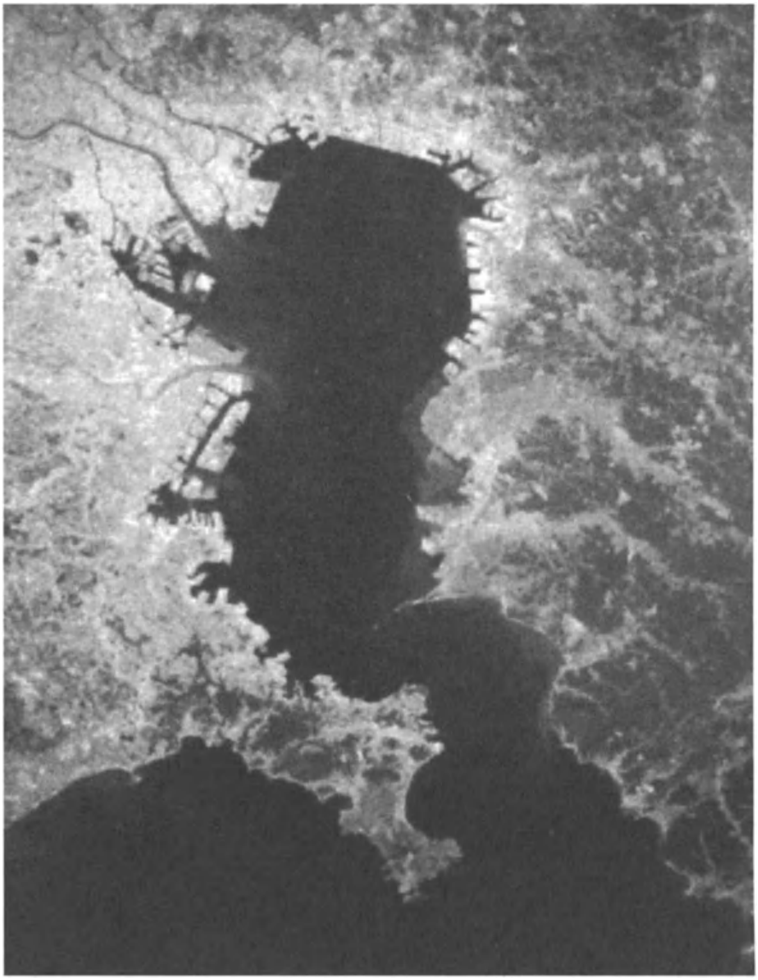

Fig. 18.1. Satellite view of Tokyo Bay and surrounding area

hills beneath the plateau have been inhabited since the Stone Age, as is indicated by a number of shell mounds found in the area. In 1603, Ieyasu Tokugawa founded his shogunate in Edo (now called Tokyo), where residential, official, and commercial areas developed rapidly around his castle. Early expansion of Edo took place mostly in its low-lying areas to the east of the castle, and early land reclamation to expand habitable land began around the estuary of the Sumida river.

An important project in the Edo Era was the diversion of most of the flow of the Tone river outside the drainage basin of Tokyo Bay to join the Kinu river to flow eastbound to Chosi. This project was aimed at mitigating the risk of flooding in Edo. The diversion of the Tone river resulted in shrinkage of the drainage area of Tokyo Bay by almost half, thereby decreasing freshwater inflow to the bay.

In the middle of the 18th century the population of Edo was about 1.3 million, making it probably the largest city in the world at that time. Tokyo Bay was crucially important for the people of Edo, both because large amounts of goods and natural resources were transported on ships from other parts of Japan via the bay and because the fisheries of the bay provided needed protein.

With the Meiji revolution, Edo become the formal capital of Japan and changed its name to Tokyo. The Meiji government was keen to promote industrialization and militarization of the Japanese economy and society. A modern harbor was constructed in Yokohama, and a major naval base was built in Yokosuka near the mouth of the bay. In the beginning of the 20th century, Tokyo, Kawasaki and Yokohama were characterized by high density of heavy industrial operations, which were further developed during the pre-World War II period. Much of the industrial capacity, however, was destroyed by American air raids during the war.

Industrialization adjacent to and in Tokyo Bay began to resume in the early '50s, and accelerated during the decade of the '50s, rising to a peak in the period between 1970 and 1980. The rapid economic growth, principally during the '60s, was driven by the expansion of large industrial factories in the coastal areas, principally in Tokyo Bay but also in the Seto Inland Sea area in western Japan. Many factories along the coast were built on reclaimed land, particularly along the east (Chiba) side of Tokyo Bay. The result of this process was that the total reclaimed area became approximately 20% of the original area of the bay. Reclamation of all available shallow areas along the shore of the bay was largely finished by the end of the '70s.

As a result of urban and industrial development around the bay, very large amounts of wastewater and solid wastes were discharged into the bay. The deterioration of water quality of the bay became more and more visible during the '60s. This deterioration finally culminated in the early '70s when the bay was widely known as the "sea of death". During the '80s, the water quality of the bay began to recover, because of tough measures taken by the central government and local governments around the bay.

18.2 Analysis of Uses of Tokyo Bay and their Conflicts

The demands for uses of Tokyo Bay have been changing over time reflecting dynamically changing economic, social, and technological conditions, domestic and international. This section attempts to characterize the changing conditions, factors, driving forces, and conflicts which have occurred and are likely to occur in the future with respect to management of Tokyo Bay.

Although the types of demands on resources of Tokyo Bay are basically the same as in the Edo era, major change have occurred in terms of intensity and magnitude of demands. Present and future demands for the use of Tokyo Bay can be conceptually identified as:

- Disposal of solid wastes;
- Disposal of liquid wastes;
- Land reclamation for industrial, commercial, and residential sites, and port activities;
- Marine transport;
- Commercial fisheries for finfish, shellfish, and seaweed;
- Water-oriented recreation.

A salient characteristic of the decisions concerning management of Tokyo Bay is that each decision has been made with respect to a single use, without any overall focus and without an institutional mechanism which enables explicit consideration of interactions among proposed uses and the possible tradeoffs between and among those uses. Essentially all decisions about the utilization of the bay in the past had a common feature, i.e., little attention – if any at all – was paid to the ecosystem of the bay.

The present situation can be characterized as one in which there are two general types of attitudes with respect to utilization of Tokyo Bay. One type emphasizes uses of the bay, such as water-oriented recreation, which are basically non-exploitative; the other emphasizes exploitative uses, such as land reclamation and waste disposal. While non-exploitative uses are, and have been, drawing more and more attention of the metropolitan inhabitants than in the 1960–1980 period, there are still strong developmental pressures, i.e., for exploitative uses, as exemplified in current and proposed projects.

In the past, particularly during the years of rapid economic growth in the '50s and '60s, the waters and shores of Tokyo Bay were intensively utilized for industrial development. Shallow water was reclaimed, with the substitution of industrial operations for the traditional commercial fisheries and local water-based recreational activities. The objective was to promote development of the local economies.

By the mid-1980s, it was clear that various factors made unlikely the continuation of the same pattern of development. One, there is little shallow water remaining in Tokyo Bay. Two, almost all types of heavy industries are more or less losing importance in the Japanese economy, or at least are not growing. Three, new types of industrial activities, such as manufacturing of computers and their software, do not require large tracts of land and do not need to be adjacent to navigable waterways. Four, the proportion of the Japanese economy represented by the manufacturing sector has decreased relative to the proportion in the services sector. Thus the demand for space for offices and commercial activities has increased substantially.

Five, the nature of waterborne traffic has changed and continues to change. For example, the average sizes of cargo vessels and tankers have increased, although the era of the supertanker may be over. The proportion of cargo handled in container ships continues to increase. These trends mean that a limited number of piers and wharves with deep water and modern equipment are used intensively, while old-fashioned wharves with shallower water and old equipment are used much less intensively. Six, increasing per capita income and increasing leisure time have resulted in increased demand for recreational opportunities. A significant portion of that demand is for water-oriented recreation.

Given the above trends and the demands for utilization of the bay, a qualitative delineation of some possible conflicts can be made. The following is a list of possible, but not exhaustive, conflicts in the use of Tokyo Bay:

- Land reclamation vs. marine transport;
- Land reclamation vs. fisheries;
- Marine transport vs. recreational boating;
- Water-based recreation vs. commercial fishing;
- Water-based recreation vs. liquid wastes disposal; and
- Among various water-based recreational activities.

The following sections attempt to address the question, what might be the evolution of uses of the bay in the future. More explicitly, what mix of uses, and therefore outputs from Tokyo Bay as a finite resource, would yield maximum net social benefits to the metropolitan inhabitants and businesses.

18.2.1 Land Reclamation

The history of land reclamation of Tokyo Bay starts early in the Edo Era. The first recorded reclamation was in 1603 when Ieyasu Tokugawa reclaimed Hibiya Inlet, now Hibiya Park, by sands and gravels from Kanda Hill. This was intended to dig a moat for the Edo Castle and to prevent flood around the castle. Land reclamation in the bay for residential expansion and solid wastes disposal has continued and has grown since then.

After the Meiji Revolution, much larger reclamation projects began to be carried out to construct the ports of Tokyo and Yokohama and to construct coastal industrial factories in Kawasaki. Conflicts between reclamation and nori cultures or shellfish fishery were seen in relation to the reduction of shallow waters and water pollution caused by wastewater from vessels and from factories.

However, it was after the World War II when land reclamation was done on an enormous scale. The major objective of land reclamation was to create land for industrial expansion for recovery and growth of the Japanese economy. In 1956 a Tokyo Port Plan proposed a large land reclamation project in the Tokyo Port area. This proposal triggered the explosive expansion of land reclamation of the bay. During the '60s and '70s, reclamation was done particularly rapidly and in grand scale in the eastern (Chiba) side of the bay, in which development pressure had previously been less intense, and thus the original coast in that area had been largely left untouched until then, as shown in Fig. 18.2.

By that time, fishermen with fishing rights in Tokyo Bay were increasingly willing, or at least less reluctant, to give up their fishing rights because:

1. compensation for forfeiture of fishing rights had to be paid,
2. more, and in many cases better, alternative employment opportunities became available as the economy developed, and
3. the water of the bay had become increasingly polluted, so that more effort was required than previously to catch a given amount of fish.

In Tokyo Bay, 74 fishermen's cooperative associations existed in 1960, with 15 thousand member fishermen altogether. 64 fishermen's cooperative associations forfeited their fishing rights and were dissolved and 12 thousand member fishermen changed their jobs after they received compensation. Compensation paid over the years for fishing rights in Tokyo Bay totalled some 200 billion yen (approximately 700 billion yen at 1980 price level).

The reclaimed area during the fifteen years after 1960 was four times as large as the total area reclaimed in Tokyo Bay before 1960. The extraordinary rush of land reclamation in the bay was put to an end when the Japanese economic growth slowed down after the oil crisis in 1973. By the mid-1970s there was little shallow sea area left for major land reclamation in Tokyo Bay, and public opinion was keenly against industrial pollution and development after the early '70s.

Fig. 18.2. Land reclamation in Tokyo Bay over time

There are still a number of land reclamation projects in Tokyo Bay after 1980. They include new Haneda Airport, Minato Mirai 21 city development, Kawasaki Civil Port Island, and Sanban-se Reclamation in Chiba. They are typically smaller in physical scale, but greater in monetary scale than the reclamation done in the '60s, because many are aimed at urban development emphasizing concentrated commercial and residential uses, taking advantage of the proximity to the centres of Tokyo or Yokohama.

18.2.2 Disposal of Solid Wastes

Systems for collecting and disposing of solid wastes differ from municipality to municipality in Japan. Some cities require separation of certain types of post-consumer wastes for collection while other cities collect unsorted, mixed wastes. Tokyo and many other cities are asking citizens to separate solid wastes into two classes, combustibles and noncombustibles. The former materials are incinerated; the latter are transported directly to landfills along with residual ash from incineration. Other municipalities ask for further separation of noncombustibles, i.e., into recyclable glass, metals, and plastics. The national Solid Waste Disposal and Sanitation Act requires each prefectural governor to have a plan for solid wastes disposal.

Table 18.1 shows the quantities of solid wastes generated and landfilled in 1980 in the Tokyo Bay region, by locality. About 126 million t were generated in the region, of

Table 18.1. Quantities of solid wastegenerated and landfilled in 1980, Tokyo Bay region, by locality

Locality		Municipal wastes	Industrial wastes	Redidual soil	Sanitation residuals[a]	Total[b]
Tokyo	Generated	4919	6817	21116	1118	34.0
	Landfilled	2164	3550	21116	513	27.3
Chiba	Generated	1303	17755	9782	427	29.3
	Landfilled	409	2993	9782	92	13.3
Saitama	Generated	1418	12674	8077	115	22.3
	Landfilled	433	3434	8077	56	12.0
Kanagawa[c]	Generated	923	8114	11428[d]	119	40.4[d]
	Landfilled	355	3776	11428[d]	51	22.6[d]
Yokohama	Generated	973	9680		144	
	Landfilled	328	4667		61	
Kawasaki	Generated	371	8568		128	
	Landfilled	69	1807		63	
Total[b]	Generated	9.9	63.6	50.4	2.1	126.0
	Landfilled	3.8	20.2	50.4	0.8	75.2

All values in 10^3 t, except totals.
[a] Sanitation residuals consist of residual ash from incineration of municipal wastes and water and wastewater treatment sludge.
[b] Values are rounded and in 10^6 t.
[c] Kanagawa means all municipalities other than Yokohoma and Kawasaki Cities.
[d] Includes Yokohama and Kawasaki Cities.

Table 18.2. Estimated quantities of solid wastes (*Source:* Professor Yuzuru Hanayama, personal communication, based on data from each prefectural governments)

Types of wastes	Total landfill	Tokyo Bay
Municipal wastes	48	35
Industrial wastes	294	198
Residual soils	1798	269
Sanitation residuals	23	19
Total	2163	512

which about 60% was landfilled. The difference between quantities generated and landfilled represents the amount recycled and reduced by incineration.

Table 18.2 shows the estimates of the quantities of solid wastes to be landfilled in the region and estimated demand on Tokyo Bay for solid wastes disposal, for the 1980–2000 period.

Municipalities and prefectures adjacent to Tokyo Bay typically have sites in their respective port areas for disposal of solid wastes. For example, Tokyo disposed of some solid wastes in a site outside the central breakwater and a landfill site for the new Haneda Airport. However, as the Tokyo Port area is relatively small and most of the surface area other than active waterways has been already reclaimed, it will be very difficult to find new sites after current sites are filled.

Assuming the volumetric capacity of existing sites allocated by the local governments for solid waste disposal to be 182 million m^3 and the average specific gravity of wastes to be 2.0, then the total capacity of these sites could accommodate about 364 million t of solid wastes, about 150 million t less than the estimated total volume available for landfill in Tokyo Bay, as indicated in Table 18.2.

Various proposals have been made for projects to accommodate the indicated shortfall, as well as expected quantities beyond ca. 2000 requiring disposal. One project is a very large man-made island, termed the Phoenix Island, proposed by the Ministry of Health and Welfare of the central government. The new island is envisioned to be located in the centre of Tokyo Bay outside of any nearby port areas, thus involving an area which has been left untouched up to the present. Ironically, the Phoenix project represents one of the first efforts to tackle a problem common to all the jurisdictions surrounding Tokyo Bay. The Multi-prefectural Solid Waste Disposal Act of 1981 enables governors of prefectures and mayors of municipalities to cooperate to establish an administrative district to construct and operate large landfill projects in port areas. Although this type of district has been established in the Osaka Bay area, such a district has not yet been created in the Tokyo Bay area.

Nevertheless, given the recognition of the problem by the various governmental jurisdictions and the increased concern for preventing further adverse effects on the Tokyo Bay ecosystem, it seemed reasonable to conclude that provisions would be made to dispose of solid wastes through and beyond 2000 so as not to result in adverse impacts on the bay. Some combination of reduction in generation of wastes, increased recycling, reduction via incineration and compaction, and small additions to landfills should enable this result.

18.2.3 Living Marine Resources

In its natural state, Tokyo Bay was noted for its high productivity and rich biological diversity. For a long time, the bay provided the highest yield of cultured nori (laver, *Porphyra* sp.) in Japan. Native species of the bay included:

- *Shellfish:* asari (short-neck clam), hamaguri (clam);
- *Crustaceans:* kurumaebi (prawn), gazami (crab), shako (mantis shrimp);
- *Ichthyofauna:* kurodai (black sea-bream), suzuki (sea bass), bora (mullet), ishigarei (flatfish), anago (conger eel), mahaze (common goby); and
- *Offshore migrant species:* kamasu (pike), inada (yellowtail).

An investigation of fisheries carried out at the beginning of this century showed that the entire area up to the innermost part of the bay was utilized as fishing grounds. Fishing activity in Tokyo Bay reached a peak around 1960, when between 16 thousand and 17 thousand households produced total catches of about 140 000 t a^{-1}. The total in 1960 consisted of: finfish 5 600 t; shellfish 109 000 t; crustaceans and others 2 500 t; and seaweed 2 500 t. In addition, about 45 000 t of nori were produced in 1960. The culture of nori was done all along the shoreline of the bay, except for small areas of the ports of Yokohama and Chiba.

The increasing rate of land reclamation in the '60s, combined with deterioration of the water quality of the bay, resulted in major declines in the catch of some important fish species. Nori culture was among the species with the sharpest declines, because of the major reduction by land reclamation of areas available for nori culture. By around 1980, only three small areas of nori culture remained, i.e., those adjacent to Ichikawa, Kisarazu, and Futtsu.

With respect to recreational fishing, mahaze angling was long a popular sport for people in the metropolitan area. Mahaze is quite voracious, and is easy to catch. Until about 1958, about 500 thousand people took part in this type of recreation each year. After 1960 the number of anglers began to decrease to between 300 thousand and 400 thousand, and the average catch per angler decreased even faster. After the decline of mahaze, recreational fishers have moved out of Tokyo Bay and turned to alternative species. By the early '70s, the number of anglers had decreased to between 50 000 and 100 000.

A summary of fishery activities in Tokyo Bay over the 1965–1980 period is presented in Table 18.3. Total fish catch in the bay reached bottom in the early '70s, and the catch has stabilized at a level about half the level in the '50s. The number of fishery households has declined to about one fifth of the number in the '50s. The major decline has been in shellfish; finfish catch has actually increased slowly since the mid-1960s.

These data, together with data on ambient water quality and rate of land reclamation, suggest qualitatively that a new aquatic ecosystem may have been established. The new equilibrium is associated with fewer shallow areas for species habitat and somewhat better ambient water quality than in the early '70s. This new system probably involves a lower species diversity and lower mean annual yield of fish than in the early '50s. One might hypothesize that if habitat decreases no further and if ambient water quality remains at least as good as in the mid '80s, then the new dynamic ecosystem for the bay could be maintained, or even strengthened to some extent. The recovery in finfish catch since the late '70s may offer a good prospect for recreational fishing, taking account of steadily and visibly growing demand for such fishing.

Table 18.3. Number of fishery households and catch, Tokyo Bay, by principal species, 1965–1980

	N° of fishery households (10^3)	Fish (1)	Flatfish	Sea bass	Shellfish (2)	Shortnecked clam	Crustacean and others[a] (3)	Seaweed (4)	Total harvest[b]	Laver culture	Shellfish collecting
1965	10.1	5.8	1.2	0.8	87.2	64.6	1.0	2.8	96.8	11.8	81.8
1966	9.9	5.6	1.2	0.7	91.8	78.9	1.7	1.7	100.8	16.6	85.6
1967	9.5	6.1	1.5	0.9	58.7	50.3	1.2	1.8	67.8	19.4	55.3
1968	10.0	11.6	1.4	0.9	59.0	51.8	1.2	0.4	72.2	19.6	55.2
1969	9.1	6.9	1.3	0.7	66.9	55.5	0.6	0.1	74.5	12.4	59.5
1970	8.5	4.8	1.0	0.5	90.6	64.0	0.3	0.1	95.8	20.7	85.9
1971	8.0	4.3	0.8	0.4	67.5	57.2	0.2	0.3	72.3	22.5	65.4
1972	6.8	4.4	0.3	0.7	37.0	34.2	0.1	1.6	43.1	16.4	34.4
1973	5.5	3.5	1.0	0.3	36.2	31.3	0.2	1.4	41.3	16.3	32.2
1974	4.3	4.4	1.5	0.9	36.9	32.3	0.5	1.1	42.9	21.5	34.8
1975	3.8	6.0	1.3	1.5	40.7	34.9	0.4	0.3	47.4	20.3	38.7
1976	3.8	9.2	1.5	1.7	30.3	22.2	0.6	1.6	41.7	18.2	23.7
1977	3.8	10.1	1.5	2.3	40.6	26.1	0.7	3.2	54.6	14.7	32.9
1978	3.5	9.9	1.5	2.0	33.6	23.0	1.2	0.4	45.1	15.1	28.3
1979	3.2	6.4	0.8	1.2	25.8	17.7	1.0	1.1	34.3	15.1	21.3
1980	3.1	12.3	1.2	1.1	29.0	18.4	1.3	1.8	44.4	15.4	24.0

All values in 10^3 t, except fishery households.
[a] Including Kuruna prawn, Portunus crab, cuttlefish.
[b] (1) + (2) + (3) + (4).

18.2.4 Marine Transport

The amount of cargo handled in the six ports of Tokyo Bay, namely, Tokyo, Yokohama, Kawasaki, Chiba, Kisarazu and Yokosuka, grew sharply from 78 million t in 1960 to about 500 million t in 1980. Items which showed large increases were crude oil, iron ore, and coal with respect to international movements and petroleum products, metals, and sand and gravel with respect to domestic trade.

The number of vessels entering the six ports in Tokyo Bay grew substantially from 1960 to 1970. However, the number began to decline beginning in the early '70s, mainly because of a decline in the number of coastwise vessels, which include the intrabay movements, and because of increasing size of vessels.

Although the number of vessels entering the bay decreased, the gross tonnage associated with vessels entering the six ports continued to increase. This is attributable to the continuing increase in average tonnage of ocean-going vessels, whereas the tonnage of coastwise vessels remained about the same.

The tonnage handled in the six ports in container form represented a substantially increasing proportion of the total tonnage exported. Container cargo requires facilities such as cranes and large storage areas, rather than small warehouses. Older piers typically do not have room for the larger facilities required to handle container cargoes. This trend in form of cargo is important with respect to the inefficiency of utilization of piers in the ports and therefore in relation to the potential mix of uses of Tokyo Bay.

Another notable trend is that the majority of cargo in the bay is being handled at private piers, such as piers built on individual factory sites for handling cars for export. Private piers include highly efficient offshore sea-berths at which crude oil and oil products are handled, both of which are major items transported in Tokyo Bay. On the other hand, public piers handle less and less of the total cargo moved, e.g., in 1986 only 26.5% in Tokyo Port, 10.3% in Yokohama, 8.7% in Chiba.

The fact that some piers are not used efficiently in terms of cargo handled per unit length of pier, plus the trend of increasing containerization of cargoes and the increasing proportion of private piers, suggest that less mooring length will be needed in the future, even if total demand for marine transport in the six ports continues to grow. Therefore, it seems logical to transform the inefficiently used piers and wharves to other uses, such as civic, business, and recreational. The criterion used to identify efficiency in pier utilization in the study was 1 000 t m^{-1} of pier.

Total length of piers where the efficiency was less than 1 000 t m^{-1} in 1980 was about 21 km, or 14% of the total length of piers in the six ports of Tokyo Bay. However, the total tonnage of cargo handled at these piers was only 3% of the total tonnage in the six ports. Based on this analysis, shifting the use of piers from marine transport to water-based recreation was a logical option for consideration.

18.2.5 Liquid Waste Disposal and Water Quality

The analysis relating to water quality focused on Chemical Oxygen Demand (COD) and Dissolved Inorganic Nitrogen (DIN). COD is an indicator of organic pollution which is directly linked to such problems as low oxygen levels in water (thereby threatening survival of finfish, shellfish, and other marine species), offensive odour, poor transparency, and blackish colours. COD is used as the criterion for some of the governmental pollution reduction programs in Japan.

Among nutrients, nitrogen and phosphorus are particularly important as substances of concern in metabolism of algae, and should therefore be considered as limiting factors to primary production. In comparing these two, nitrogen is less abundant than phosphorus in Tokyo Bay in light of the amount needed for algal growth. This means that additional inputs of nitrogen would combine with already available phosphorus to stimulate algal growth. Thus, nitrogen is selected as the focus of the analysis.

In order to analyze the loads of COD and DIN to Tokyo Bay, the classification of residential and commercial activities according to the methods of handling liquid wastes is essential. Currently there are four methods of handling nightwaste in the Tokyo Bay area, as indicated in Fig. 18.3. These are:

1. Discharge into municipal sewerage systems and hence into municipal sewage treatment plants;
2. Store nightwaste in a tank, for subsequent removal to nightwaste treatment plants, with other wastewaters being discharged directly to adjacent gutters or rivers;
3. Treat nightwaste with digestion chamber ("independent" septic tank) on-site, and discharge other wastewaters directly;
4. Treat both nightwaste and other wastewaters with digestion chamber ("combined" septic tank, or community plant).

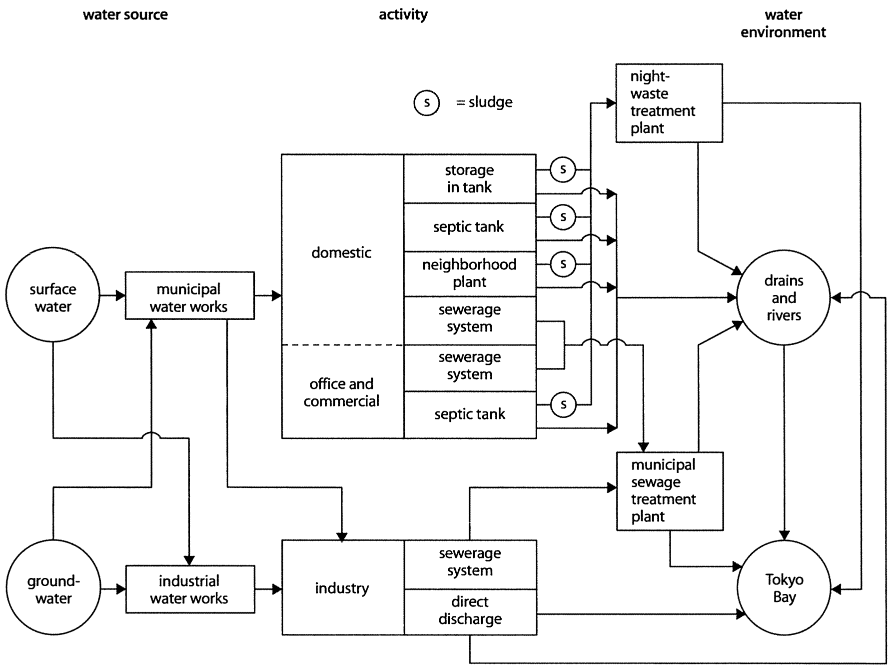

Fig. 18.3. Schematic of water intake and wastewater discharges for domestic, office, commercial, and industrial activities, Tokyo Bay region

Installation of, and connection to, a sewerage system have occurred only recently, except for the central areas of Tokyo and Yokohama. In 1980 about 42% of the population in the Tokyo Bay watershed was estimated to be connected to a municipal sewerage system. There were 60 municipal sewage treatment plants in the Tokyo Bay watershed; 25 of them discharged directly to the bay and the reminder discharged upstream into rivers tributary to the bay. Storage of nightwaste for subsequent collection is seen only in rural areas, as this method is associated with traditional non-water toilets.

The Water Pollution Control Law of 1970 established a set of the world's toughest emission standards applicable to wastewaters from manufacturing industries; the standards have been further strengthened since then. Factories equipped with certain water-related facilities are required to register them with the prefectural governments and to monitor the quantity and quality of their effluents periodically. Wastewater discharges from industrial activities in 1980 were estimated, based on their industrial water intakes, to be about 2.6 million $m^3 d^{-1}$, down from 4.2 million $m^3 d^{-1}$ in 1970. This decline in industrial water intake was mainly associated with increased water reuse, which comprised approximately 85% of total industrial water use in 1980.

Estimated COD and DIN loads to Tokyo Bay are shown in Table 18.4. The table shows the loads in terms of the four categories of sources identified, i.e.:

- *River inputs:* loads carried via 20 major rivers tributary to Tokyo Bay;
- *Industrial activities:* loads from coastal industrial factories and plants;

Table 18.4. Estimated total COD and DIN loads to Tokyo Bay, 1980

Source	COD (t/day)	(% of total)	DIN (t/day)	(% of total)
River inputs	177	47	96	42
Industrial activities	74	20	53	24
Domestic dischargers	64	17	13	6
STPs and NTPs[a]	58	16	64	28
Total	373	100	226	100

[a] Sewage treatment plants and nightwaste treatment plants.

- *Domestic dischargers:* loads from households, based on the four categories of discharges of nightwaste and other wastewaters;
- *STPs and NTPs:* loads from sewage treatment plants and nightwaste treatment plants along the bay.

Loads are predominantly from the northern part of the Tokyo side of the bay. River inputs were estimated to comprise almost half of the COD load and a little over 40% of the DIN load.

18.2.6 Water-based Recreation

Water and waterfronts of Tokyo Bay had long provided good opportunities for bathing, shell-gathering, fishing, pleasure boating, and outings to scenic seaside areas. Locations for these popular outdoor recreational activities were very convenient for many people living in the Tokyo Bay area.

The number of recreational beaches in Tokyo Bay began to decrease in the '50s because of land reclamation and/or because of water pollution. For example, the beaches of Daiba, Omori-Heiwajima and Haneda had disappeared by the middle of the '50s. Kasai beach, which had been very popular for bathing, shell gathering and fishing, fell into disuse after 1958, when water pollution by wastewater from the Edogawa Plant of Honshu Paper Manufacturing occurred.

During the '60s, the availability of nearby recreation areas decreased even more rapidly than during the '50s. For example, bathing beaches at Sankeien and Isogo disappeared after the completion of Negishi Bay reclamation in 1970. In Kanagawa prefecture, the 18 ha of bathing beaches and 1.8 million of bathers in 1960 shrank to 5 ha of beaches and 0.2 million of bathers in 1970. These declines in availability occurred at the same time demand for such opportunities was increasing as a function of increasing incomes and a slight increase in leisure time.

The extent of the disappearance of water-based recreational opportunities over time is shown in Fig. 18.4. The figure shows the locations of bathing beaches in the bay in 1950 and 1980. By 1980, people who wanted to go bathing were compelled to go either to the few remaining beaches, which had become crowded, or to beaches outside of Tokyo Bay.

With respect to shell-gathering recreationists, losing the nearby beaches meant abandoning the activity altogether, because a long-distance trip made it difficult to bring shells

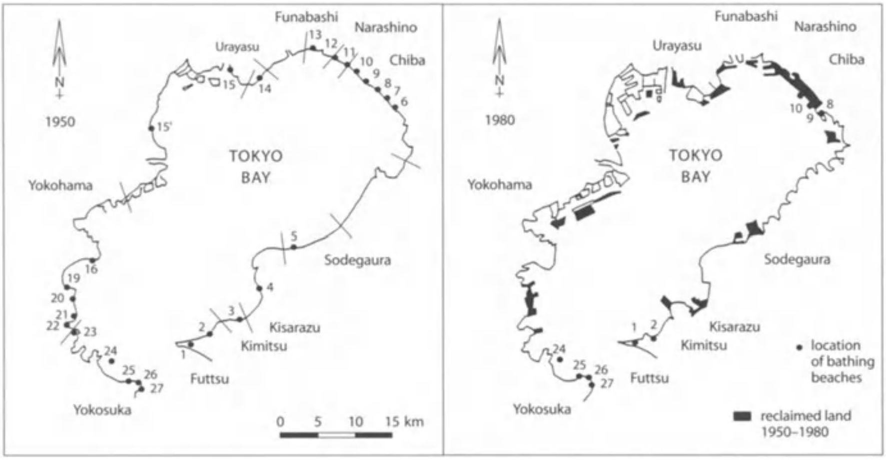

Fig. 18.4. Locations of coastal bathing beaches, Tokyo Bay, 1950 and 1980

home fresh, which was an essential factor of the activity. As a result, the demand for shell-gathering activity from residents in the Tokyo Bay area began to disappear after the '60s.

In contrast, the demand for yachting and boating increased rapidly, although the absolute magnitude of this demand was not as large as the demands for bathing and shell-gathering. The number of marinas increased from none in 1950 to 2 in 1960 to 13 in 1970. However, because areas for yachting and boating in the bay were not specifically designated, the available area for such activities became even smaller as the bay became more crowded with commercial vessels.

By the end of the '70s, the local governments surrounding Tokyo Bay began to recognize that land reclamation on their coasts had become critically unpopular among their residents. They began to make plans and to implement projects for restoring water and waterfront recreation areas which had been largely lost, particularly in the previous two decades. Reclamation of an artificial beach at Kasai was completed in 1976, which brought a revival of a shell-gathering beach park in that location. 29 parks of 102 ha were opened by 1980. Other prefectures have moved in a similar direction.

18.3 Analysis of Costs and Benefits of Alternative Policies

Alternative mixes of uses of Tokyo Bay can be achieved by different combinations of governmental actions or "policies". These actions include the construction and operation of facilities to produce desired outputs, and various incentives, e.g., regulations, charges, imposed on various actors to induce behaviour such that the desired mix of outputs is achieved. Any given combination of policies can be considered a management strategy, in this context a strategy for management of Tokyo Bay.

Given that many combinations of policies are possible, only a finite number can be analyzed. The objective is to select those which appear to have the most influence on the major outputs (uses) of interest. Other policies and relevant factors are assumed to be constant or to have little effect on the results. To evaluate combinations of policies, benefits and costs that would be achieved if each strategy were applied and enforced were estimated.

18.3.1
Formulation of the Analysis

In this study the following specific condition were used for the analysis.

- The year 1980 was selected as the base year, and ca. 2000 as the target year;
- Costs and benefits were estimated in terms of constant prices as of 1980;
- Investment (capital) costs were converted to annualized costs using a Capital Recovery Factor (CRF) of 0.1, corresponding to an interest rate of 7.75% for 20 years. Costs and benefits were thus calculated as annual figures, and the only criterion used in evaluation was net annual benefits, i.e., benefits minus costs;
- Certain major projects already underway were assumed to have been completed by ca. 2000. These are a coastal highway between Kisarazu and Yokosuka along the Tokyo Bay shoreline, a coastal railroad between Chiba and Tokyo, and the expansion of Haneda Airport.

In order to explore the implications of alternative mixes of uses, a number of cases were defined. A case was defined as a combination of values of scenario variables (*S*) and policy variables (*P*). Scenario variables refer to the variation resulting from overall social/economic conditions and related uncertainty in the future and are composed of two major elements, i.e., population and level of industrial activities. Three scenarios were defined and were characterized as:

- S-0: No change from base year of 1980 (also referred to as the base case);
- S-1: Moderate growth in both population and industrial activity; and
- S-2: Rapid growth in both population and industrial activity.

Estimated levels of the two variables in ca. 2000, based on various government studies, for each of the scenarios are shown in Table 18.5 for the four prefectures involved.

Policy variables refer to actions of the central and local governments which directly affect specific uses of Tokyo Bay. The values of these variables used in the analysis are described in the following sections.

Land reclamation for industrial sites and solid waste disposal. As indicated previously, almost all of the shallow waters in Tokyo Bay have been reclaimed and the demand for reclaimed land for sites for heavy industries has decreased to zero, if not to negative. Therefore, except for the ongoing projects enumerated previously, no additional governmental actions which would result in significant land reclamation in the bay were assumed to take place by ca. 2000. Thus, land reclamation is assumed to have negligible impacts on ambient water quality, fisheries, and marine transport, over the time period of the analysis.

Fisheries. Fisheries used to be a major commercial activity in Tokyo Bay. However, much of the fishing activity was eliminated with the purchase of fishing rights in the '60s and

Table 18.5. Values of scenario variables for ca. 2000

Prefecture	Item	Base (S-O)[a]	S-1	S-2
Tokyo	Population[b]	11.5	11.5	11.6
	Industrial output[c]	14.5	17.0	20.4
Kanagawa	Population	6.9	7.2	7.4
	Industrial output	16.0	22.4	25.1
Chiba	Population	4.7	5.4	5.6
	Industrial output	7.7	14.0	14.3
Saitama	Population	5.4	5.8	6.1
	Industrial output	7.2	9.0	11.4
Total	Population	28.5	29.9	30.7
	Industrial output	45.5	62.4	71.2

[a] Base case represents 1980 conditions.
[b] Unit for population is million people.
[c] Unit for industrial output is billion yen.

'70s. The trends in the catch of various species suggest that the fisheries in the bay may have stabilized in the early '80s, at a new equilibrium level based on the available habitat and ambient water quality existing in that period. There appear to be no explicit actions which the government plans to undertake which would increase fishery productivity under these circumstances. As long as habitat and ambient water quality as of the mid-1980s are maintained, the mean annual fisheries yield should be maintained.

Disposal of liquid wastes. Two elements of policy were defined in relation to the use of Tokyo Bay on the disposal of Liquid Wastes (LW). These are:

a The extent of coverage of the sewerage network in the Tokyo Bay watershed;
b The degree of removal of wastes in the liquid effluents discharged from the municipal STPs and from directly discharging industrial activities.

With respect to (a), only 42% of the population living in the Tokyo Bay region was connected to sewerage systems in 1980. Many municipalities were proposing expansion of sewerage networks and increasing the capacity of STPs to remove certain wastes. However, the dates when these proposed projects will be completed depends on the financial conditions of the municipalities. Three levels of proportion connected to sewerage systems were selected for this element of the liquid waste disposal (LW) policy. These were:

1. No change from 1980 level, i.e., 42%;
2. Connected, as authorized by the long-term sewerage construction program of the Ministry of Construction;
3. Connected, which is equivalent to the share of the population of the region living in what are termed "densely populated districts" as defined by the 1980 census.

With respect to (b), i.e., removal of wastes from discharges, three levels were also selected. These were:

Table 18.6. Values of elements of liquid waste disposal policy, ca. 2000

Elements of policy		**Liquid waste disposal policy**		
		LW-0	**LW-1**	**LW-2**
Extent of connection to sewerage systems (%)		42	75	82
Reduction in discharges				
Additional reduction in discharges from municipal STPs (%)[a]	COD[b]	0	0	50
	DIN[c]	0	0	70
Additional reduction in discharges from direct discharging industrial activities	COD	0	20	50
	DIN	0	0	50

[a] STP = Sewage treatment plant. Secondary treatment is assumed to be in place as basic government policy.
[b] COD = Chemical oxygen demand, as measured by potassium permanganate method.
[c] DIN = Dissolved inorganic nitrogen (nitrite + nitrate + ammonium).

1. No change in percentage removal from 1980;
2. The same percentage removal from municipal STP discharges as in 1980; and 20% reduction in COD discharges from directly-discharging industrial activities; and
3. 50% reduction in COD discharges and 70% reduction in DIN discharges from STPs and 50% reduction in COD and DIN discharges from industrial activities.

These elements are shown in Table 18.6.

Water-oriented recreation. Demands for various types of water-oriented recreational activities were estimated to increase substantially over the period of the analysis. However, meeting those demands depends on:

1. maintaining ambient water quality, and
2. providing access to recreational facilities.

Given the increase in demand for water-oriented recreation, possible government actions to respond to that demand involve conversion of old fashioned and economically obsolete port facilities from marine transport use to recreational use, and the development of specific recreational facilities associated therewith. This possible governmental policy is based on the earlier discussion of the efficiency of piers and wharves in Tokyo Bay. The policy variable in relation to water-oriented recreation, designated R, is therefore the level of conversion and additional development of recreational facilities undertaken by the government. Three levels of this policy variable were defined:

- R-0: No change from level of facilities in 1980;
- R-1: Convert all old-fashioned port facilities to recreational use to the extent authorized by current port plans and develop all man-made beaches proposed as of 1980;
- R-2: As in R-1, but in addition convert all piers and wharves where annual handling is less than 1 000 t m^{-1} to recreational use, and develop recreational facilities at all locations where no explicit plan for such use has been made, such as the old Haneda Airport area after the shift to the new offshore Haneda Airport.

Marine transport. Governmental action taken into account with respect to marine transport is related to water-oriented recreation, as noted above, in relation to shifting use of older piers and wharves. No other actions were identified which would affect benefits for marine transport directly.

Combinations of scenario variables and the two policy variables, discussed above, yield the cases for analysis, i.e., 2 scenarios, 3 liquid waste policies, and 3 recreational policies yield a total of 18 cases.

18.3.2 The Model for Analyzing Benefits

As indicated previously, within the adopted time horizon no explicit measures were proposed to enhance fisheries and marine transport, and solid wastes disposal in the bay over the period was estimated to have no adverse effects on the bay. Therefore, benefits from management of Tokyo Bay devolved into benefits associated with water-based recreation. This section describes the procedure for estimating those benefits.

The estimation of benefits associated with water-oriented recreation is based on the concept of consumer's surplus. Applied in the context of Tokyo Bay, consumer's surplus can be explained as follows.

The extent to which individuals visit, V, a given recreation site for day recreation in a year is a function of the time-distance t, between the residential zone and the recreational site, and the quality of the site Q. This relationship is expressed as $V=f(t,Q)$.

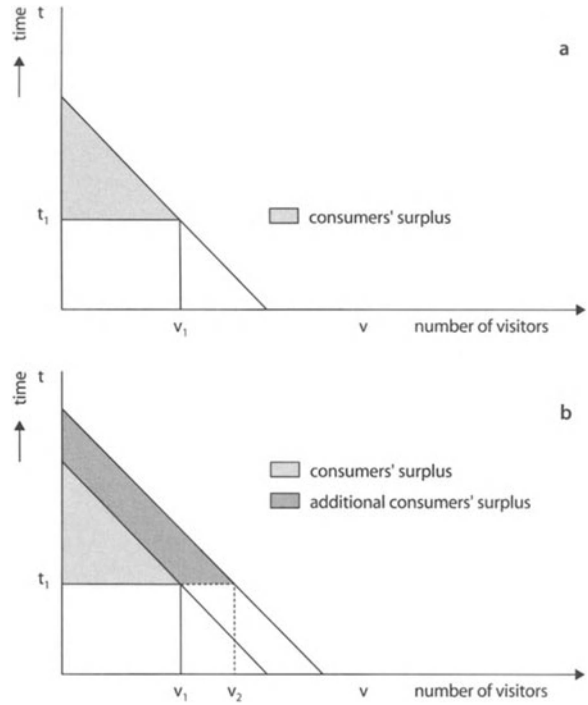

Fig. 18.5. Relationship between time-distance to recreation site and number of visitors: **a** for given quality at site; **b** for improved quality at site

For a zone which is farther from the site, the assumption is that fewer individuals are likely to visit, all other factors being the same.

The relationship between number of visitors and the time-distance to the site can be plotted, as shown in Fig. 18.5a. Suppose the distance from the given zone is t1, and the number of visitors to the site is V_1. What the diagram indicates is that all visitors up to V_1 visitors would actually be willing to spend more time travelling to the site. If t is now translated into cost of travel (travel expenditures plus opportunity cost), then the ordinate represents the willingness of the individuals to pay for the recreational experience. However, all individuals to the left of V_1 have to pay less than they are really willing to pay, so that there is, in real terms, a "consumer's surplus". The total amount of that surplus is represented by the hatched area in Fig. 18.5a.

Figure 18.5b illustrates the effect of improving the quality of the site. If the distance remains the same, i.e., t_1, the improved quality will induce more visitors to the site, as reflected by V_2. This increases the consumer's surplus, the additional consumer's surplus being represented by the trapezoidal area in the figure. The increment in consumer's surplus represents the benefits of the actions taken to improve quality. However, the increase in consumer's surplus may or may not be larger than the costs to improve the quality of the site.

A monetary estimate of Potential Consumer's Surplus (*PCS*) is hence derived from the physical demand function of a recreational activity combined with an estimate of unit travel cost and the population of the area from which recreationists come. Thus,

$$PCS_{ijk} = 2mp\int_{t_{ij}}^{t_0} f_k(t, Q_j)dt \ ,$$

where

- PCS_{ijk} = potential consumer's surplus associated with visitors from i residential zone to j recreational area for k recreational activity;
- m = cost per hour of travel;
- t_o = longest possible time distance for a day recreation trip, assumed as four hours.

The unit demand function for activity k at site j, i.e., potential visits per 100 000 population of residential zone i to recreational area j, is $V_{ijk} = f_k(t_{ij}, Q_j)$. A coefficient, 2, reflects the fact that each recreational visit requires a round trip consisting of two trips, i.e., one each way.

The expression after the integral is the number of visits in a year to zone j, for activity k, per 100 000 persons of population in residential zone i. This rate, multiplied by the population, p_i, yields the estimated number of visits to zone j for activity k. The number of visits multiplied by the cost of a round trip yields the potential consumer's surplus in monetary terms. The integral with respect to time indicates that all zones with $t_0 \leq 4$ hours each way are included in the estimate of *PCS*. Summing up *PCS* with respect to all i's yields total *PCS* expected in zone j for activity k.

$$PCS_{jk} = 2m\sum_i p_i \int_{t_{ij}}^{t_0} f_k(t, Q_j)dt \ .$$

The *PCS*, however, may not be achieved in a given case because the physical capacity for activity k in area j is limited. If the demand is greater than the capacity, not all potential visitors could be accommodated and therefore not all potential consumer's surplus could be realized. Thus the gross benefit for a given case is the Realized Consumer's Surplus (*RCS*), which will be equal to or less than the *PCS*. The total potential visits to site j to pursue activity k is

$$V_{jk} = p_i \sum_i V_{ijk} \ .$$

If the potential visits to site j to pursue activity k is equal to or smaller than the capacity, i.e., $V_{jk} \leq C_{jk}$, then the realized consumer's surplus, RCS_{jk}, is equal to the potential consumer's surplus, PCS_{jk}. Conversely, if $V_{jk} \geq C_{jk}$, then the potential visits beyond the capacity will never be realized, and thus the total number of visits to site j to pursue activity k must be kept at $V_{jk} = C_{jk}$. This is done by adjusting the visits per person, V_{ijk}, by the ratio, C_{jk} / V_{jk}, such that

$$V^*_{ijk} = Vi_{ij} C_{jk} / V_{jk} \ ,$$

in which V^*_{ijk} represents adjusted realized visits per 100 000 persons of residential zone i to site j to pursue activity k. The realized consumer's surplus, RCS_{jk}, is then estimated by the following equation:

$$RCS_{jk} = PCS_{jk} - 2m \sum_i p_i \int_{t_{ij}}^{t^*} \{ f_k(t, Q_j) - V^*_{ijk} \} dt \ ,$$

where t^* represents imputed time distance corresponding to V^*_{ijk}, so that:

$$V^*_{ijk} = f_k(t^*, Q_{jk}) \ .$$

The foregoing procedure yields the estimate of the increment in consumer's surplus for a given activity for a given case. This increment is the difference between the estimated *RCS* for the given case and the *RCS* for the same activity for the base case. Summing over all activities for that case yields the total realized consumer's surplus, that is, the estimated gross benefits for the combination of management policies of case n.

$$(\text{Gross benefit})_n = \{ \sum_j \sum_k RCS_{jk} \}_n - \{ \sum_j \sum_k RCS_{jk} \}_{base} \ .$$

18.3.3 Recreational Demand Functions

In estimating specific demand functions for different types of water-oriented recreational activities, data on recreational sites and facilities, ambient water quality, number of visitors from different zones participating in different types of activities, and population in different zones were obtained. The dependent variable of each demand function was the number of recreation visits v_{ij}, from a given residential zone i, to each destination zone j ($V_{ij} = v_{ij} / p_j$) Using the v_{ij} as the dependent variable, multiple regression analysis was done with the following factors as independent variables: the population of each residential zone p_i; the time distance from residential zone to destination zone t_{ij}; the indicator of environmental quality, COD concentration of the destination zone Q_i; and, in the case of sea-bathing, length of beach L_j.

The regression analysis using the empirical data yielded the following demand functions for bathing, shell-gathering, and on-shore fishing.

- *Bathing:* $v_{ij} / p_i = 0.049\, t_{ij}^{-2.13}\, Q_j^{-1.07}\, L_j^{0.50}$
  $n = 26, R^2 = 0.56, F = 12.9^{**}$
  t: $t_{ij}\,(-6.07)^{**}, Q_j\,(2.07)^{*}, L_j\,(-2.09)^{*}$
- *Shell-gathering:* $v_{ij} / p_i = 7.59\, t_{ij}^{-1.58}\, Q_j^{-3.03}$
  $n = 11, R^2 = 0.91, F = 49.1^{**}$
  t: $t_{ij}\,(-9.69)^{**}, Q_j\,(-4.87)^{**}$
- *Onshore-fishing:* $v_{ij} / p_i = 3.89 - 1.11\, t_{ij} - 0.48\, Q_j$
  $n = 9, R^2 = 0.91, F = 41.5^{**}$
  t: $t_{ij}\,(-7.95)^{**}, Q_j\,(-5.58)^{**}$

For the activities of on-boat fishing and boating/yachting/wind-surfing, developing demand functions as for the above three activities was not possible, because identification of destinations was difficult and because the number of observations was insufficient. Given that most of the recreation benefits would accrue to the first three activities, no further consideration was given to on-boat fishing and boating/yachting/wind-surfing in estimating benefits and costs.

18.3.4 Water Quality Model

In order to evaluate the effects of alternative management strategies for Tokyo Bay, it is necessary to have a model of the aquatic ecosystem which enables estimating changes in Ambient Water Quality (AWQ) for changes in loads resulting from alternative policies. The development of a simulation model for Tokyo Bay was based on: water quality data from 85 sampling points, representing upper and lower levels of the bay, each sampled once a month; the hydraulic characteristics of the bay; and estimated loads for conditions existing in 1980. The characteristics of the model are summarized as follows.

1. Basic water quality variables included were COD and DIN, with recreational behaviour being identified as dependent on the COD level (concentration).
2. A steady-state, two-layer, two-dimensional model was selected, incorporating primary production, decomposition, external inputs of COD and DIN, release of DIN from bottom sediments, tidal convection and dispersion.

The basic structure of the model developed and used is shown in Table 18.7. Numerical simulation was executed with a 4 × 4 km-grid cell system for Tokyo Bay's inner bay area (north of the Futtsu-Kannonzaki line). The model was calibrated

Table 18.7. Equations comprising the water quality model

Upper COD

$$0 = -\frac{\partial C_1 u_1 h_1}{\partial x} - \frac{\partial C_1 v_1 h_1}{\partial y} + wC_* + \frac{\partial}{\partial x}\left[K_1 h_1 \frac{\partial C_1}{\partial x}\right] + \frac{\partial}{\partial y}\left[K_1 h_1 \frac{\partial C_1}{\partial y}\right] - K_s C_1 + \alpha D_1 h - kC_1 h + L_C$$

Upper DIN

$$0 = -\frac{\partial D_1 u_1 h_1}{\partial x} - \frac{\partial D_1 v_1 h_1}{\partial y} + wD_* + \frac{\partial}{\partial x}\left[K_1 h_1 \frac{\partial D_1}{\partial x}\right] + \frac{\partial}{\partial y}\left[K_1 h_1 \frac{\partial D_1}{\partial y}\right] - K_z(D_1 - D_2) - \alpha\, r_D D_1 h + kr_p C_1 h + L_D$$

Lower COD

$$0 = -\frac{\partial C_2 u_2 h_2}{\partial x} - \frac{\partial C_2 v_2 h_2}{\partial y} + wC_* + \frac{\partial}{\partial x}\left[K_2 h_2 \frac{\partial C_2}{\partial x}\right] + \frac{\partial}{\partial y}\left[K_2 h_2 \frac{\partial C_2}{\partial y}\right] - K_s(C_2 - C_1) + kC_2 h_2 + B_C$$

Lower DIN

$$0 = -\frac{\partial D_2 u_2 h_2}{\partial x} - \frac{\partial D_2 v_2 h_2}{\partial y} + wD_* + \frac{\partial}{\partial x}\left[K_2 h_2 \frac{\partial D_2}{\partial x}\right] + \frac{\partial}{\partial y}\left[K_2 h_2 \frac{\partial D_2}{\partial y}\right] - K_z(D_1 - D_2) + kr_D C_2 h_2 + B_D$$

where subscripts 1 and 2 indicate upper and lower layers respectively, and the asterisk* indicates either layer depending on direction of flow; C, D = COD and DIN respectively; h = depth; u, v, w = flow velocity; K = horizontal dispersion coefficient; K_z = vertical dispersion coefficient; K_s = sedimentation velocity; α = rate of promary production; k = rate of decomposition; r_D = nitrogen consumption for COD assimilation; r_p = nitrogen release with COD decomposition; B_C, B_D = rate of COD and DIN release, respectively; and L_C, L_D = external loads of COD and DIN, respectively.

using data for the 1978–82 period for summer and winter conditions. The resulting model was then used to analyze different cases under different scenario/policy combinations.

18.3.5 Estimating Costs

Two categories of costs had to be estimated, i.e., liquid waste disposal costs for LW policies and water-oriented recreation costs for R policies. All costs were estimated in terms of 1980 yen.

With respect to the liquid waste disposal costs at Sewage Treatment Plants (STPs), capital costs and operation/maintenance costs were estimated from the cost functions in the "1984 Sewerage System Planning Guide" of the Ministry of Construction, applicable to secondary wastewater treatment plants, and data from Konan Chubu Sewage Treatment Facility in Shiga Prefecture, applicable for additional treatment with nitrogen removal processes. Because the government has adopted the requirement that all municipal STPs install secondary treatment, the costs attributable to the LW policy variable consist of costs of increased capacity for secondary treatment beyond the base case and the incremental costs beyond secondary treatment.

With respect to the costs of liquid waste disposal from industrial activities, reduction of discharges was assumed to be by treatment using the activated sludge process. To achieve an additional 20 % reduction in COD discharges with the LW-1 policy required the addition of a flocculation-filtration system to the activated sludge process. The cost of this system was estimated to be 20% of the cost of the activated sludge system.

The LW-2 policy requires industrial operations to achieve a 50% reduction in discharge of COD and a 50% reduction in discharge of DIN. The incremental cost to achieve an additional 30% reduction in COD discharge was estimated to be 1.5 times the LW-1 increment. It was estimated, based on a study by Tokyo Metropolitan government, that capital and operation/maintenance costs for reduction of DIN discharge for the industrial discharges would be 25 billion yen and 1.2 billion yen, respectively. The costs to STPs and industrial activities to meet the various scenario-policy combinations are shown in Table 18.8.

Table 18.8. Estimated incremental costs to meet scenario-LW policy combinations, ca. 2000

LW policy	Scenario S-1		Scenario S-2	
	LW-1	LW-2	LW-1	LW-2
Capital costs				
STPs	0	265	0	272
Industrial activities	107	292	107	292
Total capital costs	107	557	107	564
Annualized capital costs[a]	11	56	11	56
Operation and maintance costs				
STPs	0	7	0	7
Industrial activities	5	14	5	14
Total operation and maintance costs	5	21	5	21
Total annualized costs	16	77	16	77

All values in 10^9 1980 yen.
[a] At capital recovery factor of 0.1, representing approximately 7.75% at 20 years.

Table 18.9. Estimated costs for development and maintenance of beaches, piers, and related facilities for water-based recreation, under R-1 and R-2 policies, ca. 2000

Item	Recreation policy	
	R-1	R-2
Lenght of shore (km)	2.2	8.6
Lenght of piers (km)	2	99
Total length (km)[a]	4.2	107.6
Capital costs (10^9 yen)	9	74
Annualized capital costs (10^9 yen)[b]	0.9	7.4
Operation and maintance costs (10^9 yen)[c]	0.4	10.8
Total annualized costs (10^9 yen)	1.3	18.2

All costs in 10^9 1980 yen.
[a] Total lenght = increment to R-0 conditions.
[b] At capital recovery factor of 0.1, representing approximately 7.75% at 20 years.
[c] Based on 0.1×10^9 yen per km/year.

Costs with respect to recreation policy involve the capital costs of:

a converting the old-fashioned and inefficient port facilities to recreation uses,
b developing man-made beaches,
c installing recreational facilities, plus annual operation and maintenance costs associated with these investments.

Table 18.9 shows the estimated costs for development and maintenance of beaches, piers, and related facilities for water-oriented recreation under policies R-1 and R-2.

18.3.6 Estimating Net Benefits

The results of estimating gross benefits and estimating costs, as described in the previous sections, are combined to provide the estimated net benefits. The estimated net benefits are shown in Table 18.10 for all cases relating to S-1 and S-2. The values for the base case, the combination of S-0/R-0/LW-0, is also shown to provide the estimate of realized consumer's surplus in the absence of any directed recreational policy.

Table 18.10. Costs and benefits for selected cases, management of Tokyo Bay, ca. 2000

Scenario	Policy		Gross benefits[a]	Costs[b] Liquid wastes disposal	Recreational facilities	Total	Net benefits[c]
S-1	LW-0	R-0	1.8	0	0	0	1.8
		R-1	2.8	0	1.3	1.3	1.5
		R-2	14.6	0	18.2	18.2	-3.6
	LW-1	R-0	-0.2	16	0	16	-15.8
		R-1	1.0	16	1.3	17.3	-16.3
		R-2	11.3	16	18.2	34.2	-22.9
	LW-2	R-0	44.2	77	0	77.0	-32.8
		R-1	47.7	77	1.3	78.3	-30.6
		R-2	90.5	77	18.2	95.2	-4.7
S-2	LW-0	R-0	1.8	0	0	0	1.8
		R-1	2.8	0	1.3	1.3	1.5
		R-2	12.9	0	18.2	18.2	-5.3
	LW-1	R-0	-0.2	16	0	16	-16.2
		R-1	1.0	16	1.3	17.3	-16.3
		R-2	10.9	16	18.2	34.2	-23.2
	LW-2	R-0	52.5	77	0	77.0	-24.5
		R-1	56.4	77	1.3	78.3	-21.9
		R-2	98.5	77	18.2	95.2	3.3

[a] Benefits relate only to water-based recreation and represent increment in consumers' surplus.
[b] Costs represent capital costs × capital recovery factor of 0.1 + operation and maintance costs.
[c] Benefits and costs relate to conditions in the terminal year of the period, i.e., ca. 2000. The net benefits do not represent the value of the time streams of costs and benefits.

In almost all cases, the monetary value of the potential recreation demand, *PCS*, is larger than that of the realized demand, *RCS*. This is because of the limits of the operational capacities of the recreational facilities. Additional net benefits could be obtained by developing more recreational facilities, up to the level where the marginal annualized cost of the facilities is equal to the marginal benefit, assuming the same LW policies and assuming that the recreational activities themselves do not result in deterioration of ambient water quality.

Positive net benefits are achieved for LW-0/R-0 and LW-0/R-1 combinations for scenarios S-1 and S-2. This reflects the increased demand as a result of increased population, increased household income, and increased leisure time, even with ambient water quality at the 1980 level. Except for these cases, the only case achieving positive net benefits is the S-2/LW-2/R-2 combination. This reinforces the conclusion that, once adequate water quality has been achieved, which requires at least LW-2, additional recreational benefits can be achieved only by more investments to provide recreational opportunities.

Except for the LW-0 policy cases, the estimated gross benefits from recreation exceed the estimated costs of the recreational facilities alone only for the S-1/LW-2 and S-2/LW-2 cases. Substantial gross benefits from recreation are achieved only with policy LW-2, irrespective of the recreation policy. This suggests that reduction in DIN discharges more than reduction in COD discharges is critical in achieving ambient water quality sufficient to induce more recreational activity.

Clearly the results indicate that two conditions are required for achieving significant net benefits from management of Tokyo Bay:

1. improved and maintained ambient water quality; and
2. increased provision of recreational facilities.

18.4 Discussion of the Institutional Structure for Management

In order to manage Tokyo Bay effectively, the institutional structure (mechanism) for management should deal with all activities that have potential repercussions on the ecosystem of Tokyo Bay. Theoretically, major aspects (elements) to be incorporated should include:

1. regulations relating to land reclamation and development,
2. prevention of water pollution,
3. the conservation and restoration of remaining wetlands and natural shores,
4. landfilling for solid waste disposal,
5. fisheries and protection of marine resources,
6. marine transportation and its safety,
7. the safety of chemical and petroleum operations along the bay, and
8. access of residents to the waterfront and to water-based recreation opportunities.

However, the present institutional structure for decisions with respect to uses of Tokyo Bay, and for the implementation of those decisions, is characterized by a complex network of ad hoc measures taken by, and legislation passed by, central and local

Table 18.11. Decision-makers and laws relevant to management of Tokyo Bay

Subject matters	Local governments[a]	National government	Related laws[b]
Reclamation			
1 Port area	Port Manager	Minister of Transport	Port law
2 Port area in river estuary	Port Manager	Minister of Transport	Port law
	Prefectural Governor	Minister of Construction	
3 Fishing port	Prefectural Governor	Minister of Agriculture, Forestry, Fisheries	Fishing port law
4 Other public waters	Prefectural Governor	Minister of Construction	Public waters reclamation law
Construction of port facilities			
1 Port area	Port Manager	Minister of Transport	Port law
2 Fishing port area	Prefectural Governor	Minister of Agriculture, Forestry, Fisheries	Fishing port law
3 River estuary	Prefectural Governor	Minister of Construction	River law
4 Coast protection area	Prefectural Governor	Minister of Construction	Coast law
		Minister of Transport	
		Minister of Agriculture, Forestry, Fisheries	
5 Navigational aids		Minister of Transport	Navigational aids law
Maintance and management of port facilities			
1 Port facilities	Port Manager	Minister of Transport	Port law
		Ministry of Treasury	National assets law
2 Fishing port facilities	Port Manager	Minister of Agriculture, Forestry, Fisheries	Fishing port law
3 Navigational aids		Minister of Transport	Navigational aids law
4 Facilities related to river	Local Governor	Minister of Construction	River law
5 Facilities related to coastal protection	Coast Manager	Minister of Transport	Coast law
	Port Manager		
6 Facilities related to customs area		Ministry of Treasury	Customs duties law
Prevention of marine pollution			
1 Control of discharge of oil and wastes		Commandant of the Maritime Safety Agency	Marine pollution prevention law
2 Construction of waste oil disposal facilities	Port Manager	Minister of Transport	Marine pollution prevention law
	Fishing Port Manager		
Control of total pollutant load	Prefectural Governor	Environmental Agency	Water pollution control law

[a] Includes prefectures, municipalities, and inter-local government entities.
[b] At central (national) government level.

governments with respect to different uses of the bay. Most measures taken deal only with one specific use. Multiple agencies at different levels of government have varying, and sometimes overlapping, responsibilities for aspects of the bay's development and management, such as land reclamation, fisheries, navigation, recreation, and pollutant discharges. Table 18.11 lists decision-makers in relation to various uses of the bay and national laws relevant to management of Tokyo Bay. There is no overall, effective, co-ordinating mechanism: at the national level, i.e., among ministries; at the prefectural level, i.e., among prefectures and designated cities (i.e., cities endowed with virtually the same level of administrative authority as prefectures); and among the national, prefectural, and municipal levels.

The ministries and agencies of the central government and of the prefectural and municipal governments have formulated and implemented single-purpose projects for development of the resources of Tokyo Bay with little or no regard for the essential unity of Tokyo Bay, i.e., the Tokyo Bay ecosystem. It is no exaggeration to say that unilateral and fragmented actions, whether public or private, national prefectural or municipal, dominate the decision-making process in planning and implementation of coastal management activities, especially land reclamation.

The fact is that decision-makers have never regarded the whole of Tokyo Bay and the various uses made of it as a system. The bay has been divided by harbor limit lines within which governors and mayors, as port mangers, have enjoyed almost complete discretionary powers with respect to certain activities. The central governments has failed to deal with Tokyo Bay as a single body of water, and prefectural and municipal governments and private developers have been interested only in short-term gains. These entities and interests: have pursued short-term economic interests at the cost of long-term interests of protecting the natural heritage and maintaining the ecological balance of the bay; have neglected the simple fact that the bay is a single physical-biological mechanism in which actions affecting one part very often affect other parts; and have ignored the tradeoffs among the various possible outputs which could be taken into consideration under integrated management.

In the Tokyo Bay area, no area-wide management mechanism exists for evaluating individual projects with respect to their effects on the entire bay. The absence of such a mechanism has left the ministries and agencies, and the prefectural and municipal governments, free to act in their own self-interests, without the constraints of any broader responsibility for environmental protection, public access to and along the shoreline, and navigational safely.

The past and present uncoordinated and haphazard developmental activities have threatened the existence of the bay itself and have been inimical to the welfare of both present and future residents of the region. Poorly planned development policies have caused many serious environmental problems. Water quality has deteriorated as a result of waste discharges from multiple sources. Red tides are occurring with increasing frequency. The aesthetic values of the coast of Tokyo Bay have been increasingly undermined by careless reclamation, marine pollution, and eutrophication. Marine transport is increasingly being done with larger vessels, which are inherently less maneuverable than medium-size vessels. Any accident in the bay involving an oil tanker, an LNG tanker, or a vessel transporting any dangerous/hazardous substances could cause major, and possibly irreversible, damages to the marine ecosystem of the bay. Another serious concern is the concentration of processing and storage facilities for inflammable, explosive and toxic substances in coastal areas of the bay. Such facilities as petroleum refineries, chemical plants, LNG and LPG tank farms, are potential hazards to life and property, especially during earthquakes.

In addition, limited public access to the shorelines and water of Tokyo Bay, and reduction of amenities, are critical concerns of citizens. Although large concentrations of people now live close to the water, they are predominantly shut off from it. Heavy industries still dominate most of the shoreline of Tokyo Bay. Yet, with the continuing increase in per capita income and increase in leisure time, residents of the region are seeking more opportunities for various types of water-based recreation. The bay and its shoreline offer particularly important opportunities for recreation developments in, and near to, densely populated urban areas. Demands for new recreation opportunities such as shoreline parks, fishing piers and beaches, hiking and bicycling pathways, are expected to increase at an increasing rate.

Clearly, it is not an easy task to ensure that the public shoreline recreational space desired for the projected increase in population and recreational demand will in fact be available. The present trend is toward further development in the bay. Ministries and agencies of the central government and prefectural and municipal governments contemplate, and are implementing, more land reclamation projects. Thus, it is clear that the above objective, and the objective of rational use of the bay, will not be achieved unless there is a new institutional arrangement for management of the bay.

18.4.1 New Institutional Arrangements for Management of Tokyo Bay

The existing institutional milieu has led to a general lack of ability to deal effectively with new problems arising from rapid economic and technological developments and from changing concerns of society. Therefore, in order to:

1. recover and maintain the health of the marine environment, especially the living marine resources of Tokyo Bay,
2. be able to decide among competing demands about the mix of uses to be made of the bay, and
3. be able to integrate the various tasks of management, both a new philosophy and some new or modified institutional arrangements must be devised for management of Tokyo Bay.

The new philosophy must be introduced and adopted to implement a comprehensive and an integrated approach to management of Tokyo Bay. Following are three suggested institutional arrangements for moving in this direction.

One option would be for the Japanese Diet to establish an overall, comprehensive agency to direct the diverse functions involved in managing the marine environment and the resources of the bay, in relation to the competing demands on the bay. That agency might be given responsibility to:

1. develop, and continually update, a comprehensive plan for managing the marine environment and resources,

2. make and enforce rules and regulations to achieve the management purposes,
3. establish water quality standards, discharge standards, input standards, performance standards,
4. impose effluent charges,
5. monitor activities and impose sanctions for non-compliance,
6. conduct and/or organize research activities, with public and private entities,
7. collect, interpret, and analyze data,
8. disseminate information, including results of research activities, and
9. provide a continual evaluation of various elements of the plan, of the activities of users of the bay, and of the performance of the agency itself.

It should be emphasized that the overall agency need not, and should not, perform all of the tasks required to manage Tokyo Bay. Existing agencies have expertize, for example with respect to marine shipping and fisheries, so that there is no need to duplicate carrying out of tasks. What is essential for integrated management, which the overall agency could provide are:

1. the development and continual updating of a comprehensive management action program,
2. the mechanism for integrating activities of public and private entities with respect to, for example, developing standard procedures for measuring ambient water quality, measuring discharges, monitoring activities of commercial and recreational fishers, developing coherent research programs with respect to various management problems,
3. a focus for public participation in the decision process, and
4. a review and veto function to ensure that any project proposed by public or private entities is consistent with the comprehensive plan adopted by all parties at interest.

However, under the present situation, the establishment of a single comprehensive agency may not be politically feasible. A second option, which is more feasible politically, would be to establish an inter-prefectural agency to integrate the policies and programs of prefectural and municipal governments. The agency would be empowered to recommend individual or joint measures to be undertaken by prefectural and/or municipal governments. Such measures should be based on the results of integrated research and data collection activities about, and analysis of, the marine environment and resources of Tokyo Bay. Joint task forces consisting of staff of the agency and staff from the agencies of the prefectural and municipal governments and from the private sector could be established to work on particular problems and to develop and maintain the overall plan.

Such an inter-prefectural agency has been established in an embryonic form with respect to one specific problem. In 1979, the "Liaison Meeting for Secondary Pollution Problems in Tokyo Bay" was established by Tokyo, Kanagawa, Chiba and Saitama Prefectures and Yokohama and Kawasaki Cities. A related entity, the "Liaison Meeting for Measures against Eutrophication in Tokyo Bay" was established in the following year. This latter entity initiated exchange of information about the degradation of water quality by eutrophication and stimulated joint research activities on the mechanisms of the occurrence of eutrophication in Tokyo Bay. The group of four prefectures and two cities promulgated the "Guidelines for controlling eutrophication in Tokyo Bay" on 1st July 1982.

A major deficiency of such an inter-prefectural forum is that it is ad-hoc, and depends on voluntary cooperation among the major players involved in the management of Tokyo Bay. Therefore it lacks the necessary authority to approve or veto individual developments and activities which have potentially significant repercussions on the ecosystem and other human activities involved in Tokyo Bay. As seen earlier, given the complex and fragmented system of authority regarding the management of Tokyo Bay, such a mechanism is unlikely to be powerful enough to have a significant influence on the activities undertaken in Tokyo Bay.

Another possible deficiency of the inter-prefectural agency is that it is missing important entities, namely the ministries and agencies of the national government, which have major responsibilities relating to management of Tokyo Bay. Therefore a third option is to establish an entity based on a compact among national, regional, and local governments. The entity would in essence be an interprefectural-national agency, with at least the following signatories: Tokyo Metropolitan Government; Kanagawa Prefecture; Chiba Prefecture; Yokohama City; Kawasaki City; and Ministries of Transportation and Construction, and the Environment Agency of the central government. Membership of the board of the agency might be composed of one member from each of the five local government signatories, appointed by the respective governors and mayors (who themselves could be the members), and five members appointed by the Prime Minister to represent the national government.

The question is, how much power and which functions should be given to the agency. If the powers and functions vested in the agency are similar to those in the first option suggested above, the agency is limited to coordination and services, then the agency will only be able to facilitate decision-making by national and local governments. It would amount to being an interprefectural-national forum to exchange views and information, with no power to implement actions, allocate resources, and veto actions of other entities.

If comprehensive and integrated management of Tokyo Bay is to be achieved, in both the short-run and the long-run, special legislation must be passed establishing a Tokyo Bay Management Agency (TBMA). The legislation should be backed by the national government, the prefectural governments, and the municipal governments. There are two critical requisites for the TBMA to be effective.

- The agency must have authority to reject any proposal which is considered not to be consistent with the comprehensive plan, regardless of what entity – public or private, municipal, prefectural or national – puts forth the proposal. If the TBMA were established by interprefectural-national compact legislation, the signatories would have to agree that the executive board of the agency – with representation from each of the signatories – should have that power.
- The agency must be staffed with individuals competent to develop, put forth, defend, modify and continually update, a comprehensive plan (action program) for management of Tokyo Bay. Only by having a dynamic action program which is economically, technologically, ecologically, and institutionally feasible, is it likely to be possible to implement the veto authority.

18.5 Epilogue

The analysis involved in this study was done in the mid-1980s. Since then Tokyo Bay has seen a major rise and fall of mega-projects. These include Minato Mirai 21 in Yokohama, Makuhari Messe in Chiba, Kawasaki Civil Port, and Tokyo Teleport. Salient characteristics of these proposals were: they were planned to be located on parts of reclaimed areas close to the centres of big cities; most of them were aimed at development of new office, commercial, and residential spaces rather than for heavy industries; and the financial scale of the projects, in terms of the expected market value of the newly-developed land, was much greater than the value of land reclaimed for industrial development in the '60s and '70s.

A typical example is the Tokyo Teleport Project, planned for Ariake and Aomi areas of Tokyo Port during the late '80s under the auspices of the Tokyo Metropolitan government. The plan intended to turn reclaimed land existing in the port area into a new business centre for Tokyo, in which an high standard of infrastructure with enhanced telecommunication capacity was expected to attract new demand for office space. The business district was planned to allow for 110 thousand business employees; the residential district was to allow for 60 thousand inhabitants. Surprisingly, the entire project, including the construction of roads, railroads, and facilities for disposal of wastes, was to be financed exclusively by the rent revenues from the tenants, i.e., private companies, and thus no public expenditures were envisioned.

However, as the Japanese "bubble economy" collapsed in the early '90s, such optimistic calculations, based on assumed large increases in rent revenue, began to face jeopardy. A committee of the Tokyo Metropolitan government found, for example, that the current market price has fallen to 1.16 million yen m^{-2}, whereas Tokyo's subsidiary development corporation had already spent 1.30 million yen m^{-2} to construct infrastructural facilities. If current conditions continue, the debt burden would eventually be borne by tax payers. A study estimated that the tax bill for Tokyo's residents would be increased by a total of 100 thousand yen (approximately US $800) per person.

This miscalculation may be primarily due to the unexpected fall in the rent of office space. However, newly-created office space in the Tokyo Teleport, Minato Mirai 21 in Yokohama, and the Makurari Messe area in Chiba would add up to an huge supply that could never be matched by any reasonably projected demand.

The boom and bust of mega-developments are not the only instances of mismanagement of Tokyo Bay. A 1997 spill of crude oil from a big tanker, "Diamond Grace", which was considered to be one of the most advanced and safest tankers available under today's technology, drew attention to essential safety issues of marine transport in Tokyo Bay. An outrageous proposed toll, i.e., 5 500 yen (approximately US $50) one way, for use of the new bay bridge, "Tokyo Aqualine", connecting Kawasaki and Kisarazu, revealed a poor analysis of the demand for cross-bay automobile and truck traffic. A plan for land reclamation in the Sanban-se area in Funabashi emphasizes the basic question of whether or not reclamation of the remaining natural shore of Tokyo Bay would really contribute to the net benefit of the citizens in the metropolitan area. The management of Tokyo Bay is therefore an issue of ever growing concern, including the need for competent, objective analysis of management options.

Chapter 19

Integrated Coastal Zone Management in Sweden: Assessing Conflicts to Attain Sustainability

B. Glaeser

The Swedish coastal zone suffers from environmental degradation, loss of biodiversity, overexploitation of fish stock and habitat destruction. Moreover, the coastal zone is an area of conflicts between many users, representing different types of fishery, aquaculture, tourism and nature conservation, among others. On the other hand, Sweden has taken measures to regulate coastal problems. Recently, efforts have been devoted to "Sustainable Coastal Zone Management" (SUCOZOMA). They are directed towards promoting a management of marine and coastal ecosystems that approaches the requirements of sustainability. The SUCOZOMA research program was launched in 1997 and is funded by the Swedish Foundation for Strategic Environmental Research (MISTRA) for the period 1997–2000.

19.1 Context and Problems

Following an international trend, this research program involves researchers with different scientific backgrounds, combining life science, social science and planning and development expertize. The program combines 12 different projects, covering not only technical issues – as traditionally done – but matching them with questions concerning:

- Which user groups can be identified in coastal zones?
- What are their perceptions and values as relating to the coastal zone?
- How do they interact with each other?
- Which conflicts result from this interaction, and how can they be resolved?
- What is the economic basis for these conflicts, and how does it relate to ecological constraints?
- What are the consequences for society's use of scarce resources?
- Who owns these resources and who has access to them?
- Which national and international regimes manage this access in order to avoid overexploitation and resource depletion?
- Which institutional arrangements are known and necessary to cope with access and property rights?
- What are the planning tools and who participates in the planning processes?
- How can the planning processes be applied to achieve the overall goal: an economically and environmentally sustainable use of resources for human needs in a just and equitable way?

Roughly 60% of the human population live or will live in coastal zones and use it. In Sweden it is approximately 50% of the population that lives within a 30 km wide coastline (Bernes and Grundsten 1991). The "coastal zone" is a concept rather than a strictly defined area, involving visions and ideas, perceptions, values and intentions how to use it.

One of the aims of this program is to increase the dialogue between the various users of coastal zones and to enhance the conditions for a (more) sustainable coastal management. In particular, a better understanding and balance between coastal fishery, mariculture and environmental groups are to be promoted. Other user groups, as identified in the sites selected, include tourism (among other forms, ecotourism), energy use (wind power), offshore fishery and coast based industry and shipping.

Problems can be resolved or minimized by means of institutional arrangements, improved planning tools, participation of the people affected, or by negotiation and mediation devices. Management of coastal areas has to be done in an integrated way if the different users are to be satisfied and if a sustainable approach is to be followed. Awareness has increased nationally and internationally as to the need for an integrated coastal management, for socioeconomic as for environmental reasons. At the local, regional and national levels the complex range of activities necessary to arrive at compromising vested interests need to be integrated. Internationally, arrangements and regimes are needed as in the case of the Baltic Sea where institutional cooperation with the Baltic Republics and other Baltic countries are necessary to manage the access to areas and resources.

In order to achieve a (more) sustainable coastal development social, economic and environmental aspects of development need to be integrated. It is essential that a broad, if not holistic perspective is taken concerning the various user interactions. Coastal zone development and planning has to take into account

- the sociocultural equity and acceptability,
- the economic feasibility, and
- the environmental compatibility of integrated development and planning measures.

Need orientation, including participation, economic self-reliance and environmental compatibility have long since been basic elements of the ecodevelopment concept as it was first propagated and supported by the United Nations Environment Programme (UNEP) after the United Nations Conference on the Human Environment (UNCHE I) 1972 in Stockholm. These elements are embedded in the sectors of society and culture, economy and ecology within the human ecological or politico-ecological concept. They were originally applied to rural development, specifically to the ecofarming technology (Glaeser 1984, 1995).

More recently, and specifically after the United Nations Conference on the Environment and Development (UNCED) in Rio de Janeiro 1992, the above mentioned elements appeared again under the heading of a "triangular framework". The World Bank, more precisely its Environmentally Sustainable Development (ESD) vice presidency, defined the idea of ESD by a triangular framework that is composed of the economic, the environmental and the social elements. The economic includes sustainable growth and capital efficiency. The social component deals with equity, social mobility, participation and empowerment. The ecological element comprises ecosystem integrity, natural resources, biodiversity and carrying capacity (Serageldin 1996). The triangular framework is offered as "multicriteria analysis" (M. Munasinghe) to policymakers as an alternative instrument when progress toward multiple objectives cannot be measured by a single criterion, monetary value (Serageldin and Steer 1994). This was precisely the ecodevelopment objective, as carried through by an array of case studies. A shift may be observed as the economic criterion moved away from self-reliance towards efficiency: a tribute to globalization. A framework for improving the management of water resources, based on international examples, is offered on World Bank policy grounds (Serageldin 1995).

From the perspective of human ecology, a holistic view and a holistic approach are necessary to deal not only with natural resource use, but also with the users in society (Folke and Jansson 1992). Such a socioenvironmental perspective crosses the boundaries of various academic disciplines. It involves and combines disciplines adhering to the natural, the social and the planning and management sciences. Such an "integrative approach" is perceived in this program as the scientific prerequisite and basis for coastal management which, in a multifaceted way, deals with people (users, stakeholders) and their natural environments. Human ecology addresses the social component in addition to ecological considerations: its explicit subject is the interface between society and the environment. This implies that, in addition to technical problems, the applied life sciences deal with successfully when it comes to, say, production or output increases, other issues are at least equally important.

19.2 Multiple Use and Conflicts

Coastal zones are highly dynamic and diverse. This stimulates the development of a great variety of human activities (professional and recreational fisheries, mariculture, industries, tourism, transport, energy, defense, nature conservation, etc.) and involves a large number of stakeholders. These are those who affect and are affected by policies, decisions and actions taken in relation to the coastal environment and resources by any one concerned. A stakeholder could be an individual or a community, a social group or an official institution and they are at risk because coastal management may hazard their interests (stakes) in one or another way. In the following, competing ways of using the coastal zone are identified (Ackefors and Grip 1995: see the following quotations).

19.2.1 Fishing

Modern fishing has an adverse impact on marine ecosystems by over-fishing and use of certain fishing gear e.g. different bottom trawls, which have a detrimental impact on bottom fauna (ICES 1993; Anonymous 1995). Another problem is the large amount of fish accidentally caught and thrown overboard when target species are fished. Current fishing practices also result in incidental catches of mammalian and avian species and favour scavenging seabirds.

At the same time, fishing depends on a healthy environment, above all in spawning and nursery areas. Commercial fishing suffers from pollution by various sources. Marinas for leisure craft in spawning grounds and nursery areas for wild populations of fish present a long term problem. Spawning grounds, nursery and fishing areas are not suitable places for aquaculture. Aquaculture may in return influence the natural ecosystem in that wild stocks of salmon or other fish species may be harmed (Ackefors et al. 1991). Contagious diseases may spread from aquaculture to natural fish populations and vice versa.

There is an ongoing conflict between wild animals such as bird and mammals and the fishing industry. an increasing problem is that of cormorants. The cormorant (*Phalacrocorax carbo sinensis*), has received protected status, and has a worldwide distribution. The north European population, including the non-protected *Phalacrocorax carbo carbo*, has increased from about 20 000 in 1978 to 160 000 in 1992 (EIFAC 1994) and may have an impact on fish populations and aquaculture farms.

Seals are another problem for fishermen as well as for fish farmers. All hunting of seal is currently prohibited, which has also been recommended by the Helsinki convention. At present there are 5 000 gray seals (in the Baltic Sea), 4 000 ringed seals (in the Gulf of Bothnia) and 370 harbor seals in the Baltic area. At the beginning of the century there were 100 000 gray seals in the Baltic area. Fishermen have now requested that hunting be reintroduced. However, the attitude of authorities, based on facts presented by scientists, is that it is too early to agree on this. In 1993 Swedish authorities paid SEK 6.3 million in compensation to fishermen whose gear was damaged by seals.

19.2.2 Mariculture

"Modern aquaculture started to develop Sweden in the late '70s. At that time much of the coastal zone was already used for other purposes" (Ackefors et al. 1982). Conflicts have arisen as a result of farmers wishing to establish aquaculture in areas particularly worthy of conservation. Rare plant and animal species may be on obstacle, unique terrestrial or aquatic habitats another. The main problem, however, is usually the discharge of nutrients and organic matter. The preservation of historical monuments is another reason for preventing the establishment of aquaculture. The introduction of genetically modified species presents a new problem. Escapes from cage farming may lead to genetic changes of natural salmon populations.

Mussel farming was established on the Swedish west coast in the late '70s (Haamer 1977; Ackefors and Haamer 1987; Haamer 1995). Birds protected under the Nature Conservation Act are a problem: It has been estimated that an adult eider consumes 2.5 kg of mussels daily. A flock of ducks can easily consume an entire mussel harvest.

Conflicts arose with people who have built holiday cottages. This is very common along the coast of Sweden close to urban areas. Industrial operating permits, including aquaculture, have often been appealed by owners of such cottages. In those cases it is the Government that makes the final decision (Anonymous 1993) In addition, concern has been expressed by people bathing on beaches close to aquaculture operations; they are afraid of bathing in the vicinity of farms. Outdoor leisure activities and tourism conflict with aquaculture. Leisure boats and water skiing disturb aquaculture. The disturbance includes effects on cage farming and discharges of waste from boats and urban settlements.

19.2.3
Tourism and Recreation

Outdoor leisure and activities require clean water, free space and harbours. The development of land versus non-exploitation involves careful planning in the coastal zone to create areas suitable for all types of outdoor leisure activities. Conflicts arise with those who establish urban settlements, build holiday cottages, carry on commercial fishing, build marinas or establish aquaculture.

In Scandinavian countries people spend much of their free time in the countryside pursuing various outdoor leisure activities. The right to spend leisure time in the countryside and walk in forests and other natural areas to pick mushrooms, berries and flowers is called "the right of public access" in Sweden. This right is also coupled with a "public duty of consideration". Outdoor leisure activities along the shores are governed by the Nature Conservation Act. People may bathe and use small leisure craft everywhere except in the vicinity of private sites and specially protected areas. In many areas people are free to fish. Two million Swedes fish for fun (Anonymous 1992). "While most types of fishing with rod and line in coastal and marine waters are allowed, fixed gears and traps are much more strictly controlled and require sometimes licenses."

Many Swedes own holiday homes at the coast. The growth in holiday homes is one of the main reasons for the incorporation of shore protection in the Nature Conservation Act. "There is so little undeveloped land in the archipelagos close to urban areas nowadays that strict management is necessary to keep remaining areas free of holiday homes."

19.2.4
Nature Conservation

Marine protected areas are crucial tools in any strategy for preserving living resources and biodiversity. The European Commission Habitat Directive, adopted in 1992, aims at protecting the North Sea.

"The most well developed and complex marine ecosystems are found in coastal waters." Here the threats to the marine environment and deterioration of marine ecosystems are most severe (including wetlands: Gren et al. 1994; cf. also Costanza et al. 1993; Günther and Folke 1994). Marine nature conservation preserves and protects "vulnerable marine species and their genetic diversity, as well as habitats such as the benthos of the soft and hard bottoms, algal belts, eelgrass meadows, fjords and lagoons".

The signatories of the Helsinki Convention committed themselves to protect natural habitats, biological diversity and ecological processes in the Baltic Sea. The list of Baltic Sea Protected Areas proposes 62 marine areas and includes 13 such areas in Swedish coastal waters, west and east coast.

19.2.5
Industry

Coastal zones offer favourable sites for industries. They are well suited to ship raw materials and finished products. There is ready access to groundwater, process water, cooling water and to recipients for the discharge of waste water.

The pulp and paper industry is one of the most important Swedish industries. The environmental impact of bleaching effluents are such that large amounts of chlorinated organic substances will remain in the Baltic Sea for long. Ecological and biological effects include reduced biomass and morphological changes. Biochemical and physiological effects an fish have been observed (Södergren 1993).

Swedish nuclear power plants are located at four coastal sites. "The twelve reactors have a total capacity of 10 000 MWe (megawatt electric), covering about half of the electricity consumption." Brackish or marine water is used for cooling.

Oil refineries apply air cooling. They require a harbor with a depth of at least 27 m and around 1 km² of land per unit. Petrochemical and chemical plants require both fresh and cooling water as well as a harbor. Pulp and paper mills require land and water. Metal processing plants and engineering works require cooling water (brackish or salt water), a harbor and roads. All of this amounts to the need for coastal space and resources.

The coast acts also as a receiving body (sink). Industrial plants discharge polluted air and water. The effect on the environment depends on type, concentration and quantity of pollutants as well as on the composition of the ground, soil, water, flora and fauna. The use of coastal water as a recipient demands consideration of other water use interests.

19.2.6
Shipping and Navigation

Shipping requires space for lanes, anchorage, quays and harbor reception facilities for pollutants. Shore erosion, sewage discharges, oil spills, litter have an impact on fishing, outdoor leisure activities and aquaculture. (On trade and environmental sustainability, see Ekins et al. 1994.)

An increasing problem is posed by air pollution from ships adding significantly to the nitrogen and sulfur load to air and the marine environment (high speed catamaran ferries). Another growing problem, particularly in the Baltic, is the introduction of alien species via ballast water: they may have a detrimental effect on native marine species and ecosystems (Jansson 1994).

Beach users are concerned about the waste and trash washed ashore, carried out to sea by rivers and municipal drainage systems and dropped by beach users.

19.2.7
Energy Use

Increasing energy needs will demand new techniques including regenerative energy from wind and waves to be developed. These involve large constructions with impact on coastal activities and environments. The goverment's Wind Power Survey has investigated extensive coastal areas and proposed offshore sites for wind power farms using large-scale wind power plants. Examples can be seen and conflicting interests can be observed on the west coast, in Halland (cf. Böhler 1998). The press reported in early 1998 about 22 sea based wind power plants, between 60 and 70 m high, to be installed by the utility company Bohus Energi in the vicinity of Göteborg harbor. Some concern was expressed as to how this activity would influence sea traffic. Tremendous unrest, however, was created among the local eel fishers who were afraid that their catches might drop considerably (Andrée 1998).

19.3
Policy and Planning

19.3.1
Conceptual Framework

The coastal zone conveys the notion of a land-sea interface. This interface has two axes – one axis is parallel to the shore (longshore), and the other axis is perpendicular to the shore (on/off-shore). There is relatively little controversy concerning the definition of the longshore axis since it does not typically cross environmental systems boundaries, with the exception of watersheds and major headlands. There is, in contrast, considerable discussion about the on/off-shore axis. Coastal zone management should be based upon an ecosystem approach. Such an approach implies that the on/off-shore axis should cover part of the hinterland and include the associated aquatic ecosystems, spawning migratory fish or the economic impacts of coastal activities on inland areas (OECD 1993b).

There are quite a number of countries that are presently adopting ICZM programs. There are very few, however, that have had programs in full operation. Among the latter is the USA where programs have started around 1972 and continuously grown and expanded so that evaluations can be done. An example is provided by NOAA (National Oceanic and Atmospheric Administration) which evaluated a total of 235 state Coastal Zone Management Programs (CZMPs) that were issued in the twenty year period between 1977 and 1996 (OCRM 1997). Some earlier reviews focus on integrative frameworks and methods for coastal management and include the research needs of the academic disciplines involved (Chua and Scura 1992; Clark 1992).

There has been some confusion or at least diverging opinions as to what ICZM really means. We can follow Jens Sorensen who took on the task of defining ICZM and its components (Sorensen 1997). First of all, there is a difference between a "coastal area" and a "coastal zone". There are six types of coastal areas:

1. Coastal waters, the area measured oceanward from a tidal mark;
2. The coastline or shoreline, the area between high tide and low tide;
3. The coastlands and shorelands, the area extending inland from a tidal mark.

These first three types can overlap. Their combination results in

4. Coastal waters and coastline;
5. Coastline and coastlands;
6. Coastal waters, coastline and coastlands.

A coastal zone, by contrast, includes offshore waters, a coastline and shorelands. An ICM program can thus be directed at any one of the six areas whereas a CZM program has to include all three geographic components.

The term management must be distinguished from planning. Planning is a process to analyze coastal systems, including their environments and natural resource use, in order to provide a framework that guides decision makers to allocate scarce resources (such as capital investments, land, water, fish) among stakeholders. The framework is called a plan. CM institutions must have a plan for land use and water use to guide the decision-making process.

Planning is often integrated into the management process but management is not a part of planning. Integrated coastal zone management (ICZM) (following Sorensen 1997) is based on the physical, socioeconomic and political interconnections among dynamic coastal systems and integrates the planning and management of coastal resources and environments. Integration is understood horizontally and vertically. It requires to coordinate those stakeholders whose actions have a significant impact on the quantity or quality of coastal resources and environments. The coordination process is done in a cross sectoral way (horizontal approach) and involves different government levels and non-government organizations (vertical approach). ICZM usually includes, in addition to the planning component, applied research and public outreach and education.

John Clark's handbook "Coastal Zone Management" (Clark 1996) is no doubt the most comprehensive source on the theme. It was influenced by the author's international consulting activities and has its main merits in its accumulated applied knowledge and case studies. The book divides between management strategies, methods and information. According to Clark, the main purpose of ICZM is not to directly manage coastal resource use. ICZM manages the development process for the coast "to assist in conserving environmental resources by serving a multi-sectoral and multi-agency coordinative purpose" (Clark 1996).

Integration describes the effort to coordinate the separate economic and governmental sectors to reduce fragmentation and duplication. ICZM is divided into a planning and an implementation mode. In planning, the consequences of development actions are examined; safeguards and development alternatives are proposed to guarantee the sustainable use of coastal natural resources, at the most productive levels possible. This aspect of the definition (cf. GESAMP 1996) actually qualifies ICZM as SCZM, sustainable coastal zone development which is the name of the Swedish research program: SUCOZOMA.

19.3.2
Guidelines for Implementation

There are various ways to implement and operate an ICZM program. A rather clear example was provided by the World Bank (Post and Lundin 1996; cf. Serageldin and Steer 1994; Serageldin 1995, 1996). The authors differentiate between plan formulation, program implementation, monitoring, evaluation and enforcement.

Plan formulation consists of four steps. Step 1 initiates the effort. The needs for improved management are recognized by consulting stakeholders and key agencies. A concept paper is prepared, an ICZM program is approved. A team is formed to review institutional capacities. In step 2 the ICZM plan is formulated. Information and data on coastal characteristics, including physical, economic and social aspects, are assembled. Public participation is included. Management problems and economic opportunities are assessed. Policies, goals and projects are recommended. Monitoring and evaluation systems are designed, a time table is set up. Step 3 involves the government to formally adopt the program. An interagency coordination is established, staffing is included. The legal framework is enacted, funds are allocated. The ICZM program becomes operational in step 4. Management programs come into effect, projects are designed, a monitoring and evaluation program is initiated.

The information to be collected includes the coastal resource base (fishing, recreation, mining, assessment of water, soil and air ecosystems), the social organization in the coastal zone (villages, towns and their economic base, indigenous people and social issues), already existing resource related programs (fisheries management programs, environmental regulatory programs, as related to protected areas, erosion management, pollution control) the institutional, legal and financial capacity available.

A key decision is the size of the area to be managed ideally extending inland to the upper reaches of the coastal watersheds and seaward to the 12 nautical mile limit of the territorial sea. The non-governmental sector may play a role, including the private sector and local communities. Long term development objectives can be secured by creating incentives for sustainable management. They include property right protection, fiscal measures and coastal tenure systems. Possibilities for economic development are to be explored.

Program formulation is followed by program implementation. The following measures and conditions improve the chances for effective implementation. High visibility improvements are achieved at an early program stage. The program policy is clearly spelled out. The program goals and its elements are quantitatively measurable. The institutions involved are clearly responsible and held accountable. Sufficient human and financial resources are allotted. The public is aware of the program and supportive.

Monitoring, evaluation and enforcement activities, finally, are instrumental to continuously improve the process. The monitoring and evaluating procedure includes the following elements. The expected performance is identified and compared with the actual performance. Variances between the two need to be communicated. The enforcement of rules and regulations depends on public knowledge and governmental program credibility. Strong enforcement capacities are needed if breaking the rules results in economic benefits for certain groups of stakeholders.

19.3.3 The Commons

When Garrett Hardin, professor of biology at Santa Barbara, University of California, introduced his ideas about the tragedy of the commons 30 years ago on not more than six pages (Hardin 1968) – what exactly did he have in mind? Hardin was one of the early limits to growth prophets and fed right into the Forrester and Meadows world models. He was a strict Malthusianist, advocating for birth control "... by relinquishing the freedom to breed" (op. cit., 1248).

A secondary thesis developed out of his conviction to limit population growth: the tragedy of the commons. Commons of whatever type cannot be maintained under conditions of population density. He referred to farm land just as to fishing areas. The term tragedy was used in the classical Greek sense of an inevitable destiny. The inevitable destiny of the commons was, according to Hardin, that all gains are private whereas the losses are public, they are shared. The commons can only be managed if we abandon the freedom to breed.

Twenty-two years later, a group of anthropologists and human ecologists, most of them specifically interested in fisheries, published a critical review and update of

Hardin's theses in 1990 in the journal "Human Ecology". They called it "The tragedy of the commons: twenty-two years later." (Feeny et al. 1990; cf. Berkes 1989) Their main assessment was: "Hardin's model is insightful but incomplete" (op. cit., 12). The model should be amended in that the herdsmen or fishermen firstly control the access to the commons, secondly agree on rules of conduct. In other words: Hardin missed institutional arrangements on the one hand and cultural factors on the other. Instead, viable options according to the authors are shared governance or state regulation, including user self-management.

These solutions apply to the global problems of the commons as well, to ozone depletion as well as to ocean depletion. The authors conclude: "A new and more comprehensive theory for common property resources must be able to account for sustainable resource management under communal-property regimes" (op. cit., 14).

Presently, two strategies to manage the commons have been newly emerging themes: fisheries co-management and participation in fisheries management (Jentoft et al. 1998; Wilson and McCay 1997). Co-management is a tool in fisheries management that has received much attention (Jentoft et al. 1998). A recent perspective is how institutions are embedded in human communities. Co-management "is a set of principles for institutional design that can assume various organizational forms" (op. cit., 5), depending on circumstances. Co-management is related to communities: it is true, of course, that fishermen fish from individual boats but they also fish from communities (op. cit., 6).

Property rights constitute an important set of institutions, influencing the nature of a resource regime in fishing communities. Fisheries management and co-management are influenced by the prevailing property rights regime. "In the original 'Tragedy of the Commons' model, open access is the root problem" (op. cit., 8). The conclusion is that co-management is an alternative management strategy to deal with controversial regulatory decisions and conflicts (op. cit., 10). It involves participation (for the participants' view, see Wilson and McCay 1997) and it may involve institution building.

One thing seems to be undoubted if comparative international experience is reviewed: While co-management and participation "imbue the regulatory process with legitimacy" there is "no single model for implementing such management principles" (Jentoft 1989). Cooperative management regimes depend on the context of its introduction, and this context varies from country to country as well as from fishery to fishery; whereas others advocate individual property rights to areas or species (cf. de Alessi 1998).

19.3.4 Governance

A model of and approach to governance for integrated coastal zone management was assembled and introduced by McGlade (in McGlade et al. n.d.; cf. also Ostrom 1990). According to McGlade, two approaches to coastal governance are commonly followed, and may be termed (1) communicative and consensual action and (2) instrumental action. Both facilitate to allocate resources equitably. Within the first approach, moral rules or norms are established and form consensual actions. The importance of moral values is recognized as a critical factor in governance. Within the second approach, a technical rule leads to an instrumental action. An example from fisheries is the desirability of an exploitation level that will not harm the parent stock; the instrumental action is to adopt net mesh sizes or to enforce quotas. The two approaches treat communication in radically different ways. But it is clear that its effectiveness depends on good communication, coordination and integration between the various institutions and coastal users. The importance of this is underestimated, leading to dissatisfaction with the more traditional public intervention in social affairs.

The type of governance most likely to succeed is one in which the complexity and dynamics of the biophysical and social processes are a part of the problem definition and potential solution. This can be achieved through three interdependent ways. One is by starting from the reality of the world as a complex situation. The second is to start from an integrated point of view. If internalized social rules are the basic instrument, then these rules should be at the centre of policies and other instruments should integrate and support them. Third is to formulate governance approach in terms of interaction levels. "The governance approach stresses that prevention, implementation, steering and control in such areas demand continuous interactions between participants on different levels with different responsibilities and different, but interdependent tasks" (McGlade n.d.).

An analytical framework for governance of common pool resources includes three aspects: How is successful governance achieved and measured? How complex are the issues? What tools are available for dealing with the issue? Governance of the environment covers the coastal zone resources themselves, their sustainable development and the economic and sociocultural spheres of influence. The complexity of each determines the degree of complexity that governance will have to cope with. Once the goals and complexity of the problem have been assessed, the possible solutions are constrained by the institutional structures and tools available. The structures range from individuals to international bodies.

The success of a governance framework can be assessed in terms of goals, systematic structures and institutional constraints. In many regions the degradation of coastal resources has been the result of poor governance. Coastal management regimes based solely on a partnership between government and sector specific groups may eventually cause environmental degradation. It is therefore appropriate to involve the community and include also the non-specific sectors. In this way conflicts and over-extension of influence can be avoided, a more open system of communication may emerge. Participatory management in coastal regions will create a better understanding of the role that communities play. And it will generate information on the resource base itself (McGlade n.d.).

19.3.5 Integrated Management Process

Effective and sustainable coastal management, a contradictory notion possibly, depends on integrating relevant information, agencies and decision-making processes. The process of integrated management (OECD 1993b) involves a detailed inventory and assessment (information and analysis) to produce the data to assist policy development and implementation, coordinated analysis to identify the criteria established for decision-making, and then the modification of plans necessary, coordination of policy formulation to eliminate conflicting policies, implementation, monitoring and evaluation mechanisms and allocating responsibilities. To work this out in detail involves administrative and political coordination processes and the creation of the institutional mechanisms, information (analysis and planning), a reassessment of present policies, legislation, and the allocation of administrative responsibilities, the preparation of alternative options and analysis of their implications (environmental, social and economic), including risk and uncertainty, the selection of the final plan, involving public participation, implementation as well as monitoring and evaluation to feedback into subsequent planning.

Given the complexity of natural systems in coastal zones, information constraints and the broad nature of the objectives, it will often be necessary to be cautious in defining and adopting the policies to be used in coastal zone management. Systematic analysis of the natural and economic systems, and policy implementation through the use of regulatory and economic instruments is an essential part of the management strategy proposed in this conceptual framework. But neither analysis can be carried out properly, nor the various integrating instruments efficiently applied, unless the necessary institutional mechanism exists and operates successfully (OECD 1993a).

19.4 Institutions and Environmental Legislation in Sweden

Legislation for coastal zone management is often piecemeal, placing administrative and enforcement responsibility for various resource sectors amongst a number of agencies at different levels of government, and overlapping in content. These shortcomings usually become readily apparent when a comprehensive review of the relevant legislation and exemptions granted is undertaken. Policy conflict and contradiction can also be identified. One of the most difficult problems concerns determining when and for what reasons should national priorities over-ride local considerations, and vice versa (OECD 1993b).

19.4.1 The Institutional Mechanism

Linking sectoral agencies and all levels of government with responsibility for the coast is a prerequisite for an improved institutional mechanism. This does not necessarily imply the creation of new agencies, but involves a re-evaluation of the objectives and operation of existing bodies. "Of primary importance is a consistent national or regional government policy for the coast that provides clear direction and support for integration in general and the creation of an appropriate institutional mechanism in particular" (OECD 1993b). The coordinating body could consist of a management council and various sub-groups. It should fit as far as possible the boundaries of the coastal zone area concerned to cover the linkages between water and land resources in that zone. Responsibilities of the management council include:

- to meet regularly,
- to make major decisions,
- to define the functions of participating agencies and the methods used to involve the public in policy development and decision making,
- to delegate authority to competent sub-groups,
- to distribute the funds necessary for the functioning of the management mechanism, and
- to review the performance of the management mechanism and coordinate any necessary modifications (OECD 1993b).

Regulatory instruments (OECD 1993b) include administrative, political and legal approaches. Administrative approaches are the following. Agencies responsible for coastal management are coordinated (linking national level departments or interdepartmental committees). Integrative mechanisms to cross sectoral boundaries at all levels of government are promoted (environmental assessment, public participation and education, collection of comparable information). A broad coastal policy and strategic planning are prepared at the national and regional government level, with detailed implementation taking place at the local level. Bargaining and other methods of conflict resolution are adopted as appropriate, to supplement regulation setting.

Political and legal approaches include national governments to provide guidance on standards setting, policy development and conflict resolution (rights of appeal, rights of participation in impact assessment and decision-making processes), and to specify clear responsibilities and links between legislation and regulations. The latter covers coastal resources, a clear definition of responsibilities for each level of government and reviews of the functioning of coastal resource management systems (state of the environment reporting).

Economic instruments may create new markets for coastal resources by auctioning sites, or by issuing discharge permits and transferable permits for resource use. A system of royalties, resource rentals and taxes may be established to use and extract resources and to occupy land and water space. The application of the Polluter-Pays-Principle may be promoted to regulate discharges into rivers, streams, lakes and coastal waters. Resource pricing may be introduced to establish the real cost of resource use and waste disposal.

In short: Integrated coastal management is an "overlay program": it does not replace existing institutional arrangements but strengthens them. In most cases, this holds true. It may, however, be desirable to create a new agency for full-scale, comprehensive programs, in the sense of a joint authority. As to where the authority be lodged or whether a coordinating unit would be sufficient, there is no single answer. Most countries fit their coastal program into the existing government structure where it causes the least disruption, institutionally. This may be within an agency that has regulatory power, already, such as the environmental ministry, natural resources or fisheries. Wherever the ICZM office is located, it should be mandated, staffed and budgeted to accomplish the following tasks:

- to coordinate coastal development and resource conservation in an inter-institutional mode,
- to do environmental assessment and issue permits for all major coastal developments,
- to gain compliance of all sectors with coastal rules and decisions,
- to build a full-service ICZM operation (Clark 1996).

19.4.2 Coastal Regulations in Sweden

Sweden is administratively divided into municipalities. These are responsible for planning land and water use within their borders. They have their own administration including a planning and building department, an environment and public health department and a recreation department. Each municipality is obliged to have an overall plan for land and water use within its territory: management of coastal zone includes the interaction between coastal land and offshore waters (cf. Ackefors and Grip 1995).

National interests are handled by the county administrative boards, which are regional government agencies. They employ experts on environmental protection, fisheries, aquaculture, physical planning and regional finance in their departments. On the national level, sector authorities supply advice and guidelines to the Government. Areas of national interest are to be specified and presented to the municipalities. Coastal management is a multi-sectoral issue. Management has to be implemented by various sectoral agencies, but different sector plans compete for the same space in the coastal zone.

Sweden follows "the public review principle", which means that all planning documents are accessible for the public for a period of at least two months for comment. This planning process is a top-down process, complemented by the work on local Agenda 21 in Swedish municipalities as a bottom-up process. This process also includes local coastal management problems.

To start an activity permission to use the land or water for that purpose must be obtained. The following are the most important laws in the permit process (Ackefors and Grip, 1995):

- *The Natural Resources Management Act* (NRMA) contains general rules on the use of land and water and the environment designed to encourage good long-term management in ecological, social and economic terms. It is an umbrella act, with basic requirements for natural resources management. Permit applications are considered by the Government.
- *The Environment Protection Act* governs non-mobile hazardous activities, many of which require a permit. A control programme often includes monitoring and inspections.
- *The Water Act* requires a Water Court permit for industrial development and construction in the water. Permit applications are handled by the Water Court, while inspection is the task of the County Administrative Board.
- *The Planning and Building Act* requires a planning permission for most activities on land. It includes details about siting, the size of buildings and protection zones. Applications for permission are handled by the municipality.
- *The Fisheries Act* governs fisheries management, including fish diseases. The rules have been harmonized with European Union regulations. The National Board of Fisheries has overall responsibility; surveillance is done by the Coast Guard.
- *The Nature Conservation Act* regulates nature conservation and shore protection. The shore protection zone extends 100 m from the shoreline and may be extended by up to 300 m. The aim is to ensure public access to the shore. Activities preventing public access require a permit which is the responsibility of the county administrative board, sometimes of the municipality.
- *The Water Pollution Act* regulates discharge from ships and floating constructions. Permit applications are done by the National Maritime Administration.

Applications under most of these acts must include an environmental impact assessment (EIA). Environmental impact assessments are a fairly new tool in Swedish environmental policy. They are not followed by an Environmental Impact Statement but are related to different laws. EIAs examine forms of impact and effects on soil, air, fresh water, coastal waters, flora and fauna, recreation, infrastructure and natural recourses.

Environmental monitoring programs cover air quality, the terrestrial environment fresh water, sea water and toxic organic pollutants. Three types of environmental monitoring are performed in Sweden: the National and Regional Monitoring Programme, monitoring of receiving bodies of water and the control of discharges. The National Monitoring Programme, NMP, aims at environmental changes to survey the state of the environment. Similarly, the Regional Monitoring Programme meets regional needs. The marine program under NMP includes hydrological, biological and toxicological sub-programs. Environmental quality control in receiving bodies of water consists of individual monitoring programs. To inspect these programs is the responsibility of the county administrative board and the Swedish EPA. Control of discharged sewage water is managed by the county administrative board or the municipality (Ackefors and Grip 1995; cf. also SWEDMAR 1995).

19.5 Coastal Fisheries and Eutrophication: Sustainable Management Issues

After one year of the SUCOZOMA program, a few perhaps small but important experimental steps have been taken to integrate the program and to find common denominators for its various activities. An attempt was made to identify the management of the commons, as related to fisheries, as a unifying theoretical issue.

19.5.1 Coastal Fisheries[1]

Sustainability has been stated as an explicit goal of fisheries management within the EU. Most current approaches to sustainability revolve around attempts to define and subsequently police some form of "sustainability limits". In European fisheries, the maximum sustainable yield plays a central role in policy formulation. The lack of progress towards sustainable development within fisheries testifies, however, that such approaches may be inadequate. To understand non-sustainability in realist terms beyond the level of policy formulation involves identifying which mechanisms are significant in causing unsustainable events. Modernization is linked to the integration of the industry within a regional and global food system in which processors and retailers exert an increasing, and often detrimental, influence on the practices of the harvesting sector. The treadmill effects of technological innovation is exacerbated by the conditions of open access in which overcapitalization is a product of the race to fish. Alienation amongst resource users is resulting from a sense of exclusion from policy-making processes and allows certain practices to be socially legitimated. Falling unit values for the harvested resource are certainly an outcome of market globalization, product substitution and low elasticity of demand (Drummond and Synes 1996).

[1] The comments under this heading are owed to Erik Neuman, SUCOZOMA program.

A critical study issued by the Swedish Ministry of Finances reveals a lack of efficiency and perhaps even fraud in Swedish fisheries. Subsidies work towards stock depletion, according to the authors, and are thus counterproductive from the sustainability, i.e. resource conservation, perspective. In addition, the authors claim that Swedish fishery policy is shaped by a small number of people who mainly represent interest groups, specifically by Fiskeriverket, the Swedish National Board of Fisheries (Hultkranz et al. 1997).

The interest in coastal management, not least coastal fisheries, has increased in the '90s among politicians and administrators, both at the national and at the European Union (EU) level. Sustainable development is a political issue for Swedish archipelago areas as the government report "Hållbar utveckling i Sveriges skärgårdsområden" (Sustainable development in Sweden's archipelagos) (Miljövårdsberedningen 1996) clearly points out. The problematic pertaining to fish and fisheries as addressed by the SUCOZOMA program were emphasized in the report. As a result, the Swedish government ordered seven provinces to implement the recommendations given. This decision has provided the SUCOZOMA program with the excellent opportunity to study and, perhaps, influence this strategic process at precisely the right time. This chance is being used by means of meetings and seminars with communal planners who showed specific interest for the improvement of recruitment areas of predatory fish which is a SUCOZOMA project theme.

For the first program year (1997), scientific results were neither expected nor planned. Two surprising observations can be reported, however. The project "Enhancement of sea trout in the Baltic" had released trout fry in 1995 in the area near the island of Gotland soon after hatching. This was done in an attempt to eliminate the severe limitations to recruitment posed by the small size of the local spawning brooks and by the risk that these brooks dry up during the summer. In the fall of 1997, the first spawners emanating from these releases returned. This fortunate incident happened one year earlier than expected and indicates an already successfully functioning solution for sea trout improvement.

A second, yet less fortunate observation was made in the sound of Kalmar (Baltic Sea), in one of the model areas for the "Improvement of recruitment areas of predatory fish". A fry survey indicated an almost total lack of recruitment of pike and perch, two of the target species, along a considerable part of the coastline.[2] The absence of fish caused not only great distress among the fishermen but attention by the press media, and it alarmed the provincial government. The latter suggested to support additional documentation and analysis of the problem with the aim to arrive at a solution as soon as possible.

19.5.2 Eutrophication[3]

Eutrophication is a change towards a more nutrient-rich state. Eutrophication of marine areas accompanied by pronounced mass growth of algae has been recorded over

[2] This was confirmed by personal communications with Jan Andersson, Fiskeriverket, and local fishermen on 9th April 1998.

[3] The comments under this heading are owed to Ragnar Elmgren, SUCOZOMA program.

the past few decades in many coastal waters around the world. Some of these species of algae produce toxins. Toxic algae blooms as such are nothing new. However, the problem has been exacerbated and is now giving rise to serious concern (ICES 1992; cf. Folke et al. 1994; Gren 1993; Folke and Kautsky 1992).

The occurrence of exceptional cyanobacterial blooms in the Baltic during the summer of 1997 and the unusually severe oxygen deficiency along much of the Swedish west coast during the winter of 1997/98 indicate the importance of the eutrophication issue for Sweden. The media attention was considerable in both cases. The governmental report "Nitrogen from land to sea" (Swedish Environmental Protection Agency 1997) emphasized the necessity to reduce the nitrogen load: to improve the marine environment around Sweden and to fulfil Sweden's international obligations. According to the estimate presented in the report, the nitrogen load on the seas can be reduced to 50% as compared with the 1985 loads. This outcome would cost the Swedish society an annual 500–600 million Swedish Crowns (SEK) (op. cit., 10). The European Union has, in fact, tightened the criteria for nitrogen in sewage effluents from treatment plants, and within HELCOM Sweden has been under pressure to implement nitrogen reduction measures along the coast of the Gulf of Bothnia, as well.

At the same time, representatives of the sewage treatment industry (VAV) and some scientists remain unconvinced of the usefulness of nitrogen reduction. The debate on the effects of nitrogen in the marine environment and about the pros and cons concerning the Swedish and EU nitrogen removal policy is ongoing. A specific issue is the municipal sewage treatment plants' discharge to the Åland Sea and further south. The Swedish EPA arranged a meeting under the auspices of "scientific mediation". Its most notable result was an agreement on the fact that the spring phytoplankton bloom in the Baltic is limited by nitrogen availability. A thematically related international seminar, organized by the National Committee for Water Protection Research (Royal Swedish Academy of Science), underlines the national and international interest in the eutrophication issue.

The Himmerfjärden Sewage Treatment south of Stockholm applied a new nitrogen reduction technology which removes 90–95% of the incoming nitrogen. As a result, the N/P-ratios were very low during the fall and early winter of 1997, in late autumn the lowest ever recorded since 1978. The outcome indicates that the treatment effects are measurable in the recipient water.

19.5.3 Coastal Management

To integrate the different coastal activities and actors' interest and to articulate them in planning and management presents a true challenge to policy makers, planners and managers, especially if the aim is to reach solutions which are environmentally sustainable, economically feasible and equitable (cf. French 1997: specifically Chapter 7). A SUCOZOMA goal is to understand and compare different stakeholders' interests and positions in relation to the sustainable use of the coast. A first stakeholder analysis with respect to mussel culture was done. The result was an identification of stakeholders synthesized in an evaluation matrix which indicates the capability to influence mussel culture in Sweden or to be influenced by it. The groups considered were regulating bodies, resource users, industries, local inhabitants and political actors. A combined ranking list shows the provincial government (länsstyrelsen), land/water right owners, part-time residents, neighbourhood associations and mussel farmers on top and the Nordic Council and the International Council for the Exploration of the Sea (ICES) at the bottom (Ellegård 1998a).

A related media survey explored the press coverage of mussel culture with respect to different aspects. In the view on mussels, as presented by selected Swedish print media, the "food connection" is by far the strongest. It represents 52% of the articles identified. As a comparison, environmental issues were mentioned in 19% of the cases, poetry/archeology in 12% and tourism in 5%. The positive or at least neutral view on mussels is overwhelming in relation to negative connotations. The environmental message is mixed: Close to 50% of the texts deal with environmental degradation, warnings and alerts (Ellegård 1998b).

All aquaculture in Sweden, independent of size, requires a permit under the Fisheries Act, which governs the risk of fish diseases being introduced and the transfer of fish and shellfish. The act falls under the authority of the county administrative board. If the operation is to produce more than 10 t the farmer submits an application to the county administrative board for regulation under the Natural Resources Management Act and for consideration of a permit application under the Fisheries Act, the Environment Protection Act and the Nature Conservation Act. A permit from the county administrative board will include detailed conditions regarding the development. A decision under the Environment Protection Act must be compatible with existing local plans. The operator must pay a fee for the application, currently SEK 100 per tonne. If the operation will be producing less than 10 t, it is merely necessary to notify the municipality. Aquaculture operations other than fish farms (e.g. mussel farms) follow the same application procedure but the Environment Protection Act is not involved. The county administrative board informs the municipality of the application (Ackefors and Grip 1995).

The investigation of institutional conditions for coastal zone management and decision making capacity have not yet produced concrete results. The same holds true for the development of participatory tools in physical planning, its implementation and enforcement. Bio-economic models for Swedish fisheries are to provide an economic base for policy decisions.

19.6 Conclusions

Interdisciplinarity and integration is the major thrust of the SUCOZOMA program. The 12 projects represent three major areas of research: coastal management, eutrophication and fisheries. The projects were originally assembled as scientifically promising and socially relevant research fields, represented by individually outstanding researchers, with coastal fisheries and eutrophication as the core. The social science, human ecology, and management oriented projects were included to provide the program with an integrative principle. It was agreed and it is necessary that all projects work toward a common goal, a socially and environmentally sustainable coast (cf. Glaeser and Grahm 1998).

It is foreseeable that with mounting population pressures and increasing competition for sites for development and access to resources in coastal regions throughout the world there will be an increasing incidence of conflicts between different forms of economic activity. In the terminology of economists, demand exceeding supply is a potential source of conflicts. This applies equally to the use of natural resources as to all other factors of production. The normal supply of and demand for environmental services engenders an ambient background level of conflicts under any resource use scheme. This level of conflict associated with "normal" use may be modified if additional environmental, economic or social variables change. We distinguish between

- changes in natural conditions,
- changes induced by planning and management, and
- changes induced by social change.

"Changed natural conditions" includes highly variable, catastrophic or even "chaotic" changes in the environmental conditions in coastal areas. Examples are changes in the geomorphology, as through landslides or changes in sediment deposition areas along a coast line. These changes affect the supply of environmental services. It does not matter whether the changes are man induced or the result of the natural evolution of coastal geomorphology. What matters is that it affects the supply of environmental services and consequently the potential for conflict between resource users.

Inappropriate planning and management, including other forms of regulation can have an adverse impact on both, the supply and the demand side of environmental services. Examples are subsidies, taxation policies or land use planning measures that act as incentives in favor of certain types of resource exploitation. Such incentive are often also direct contributors to the over exploitation of those resources and exacerbate existing conflicts over scarce resources.

Changes in socially accepted values and norms of behaviour can also affect the mix of resource exploitation in the near-shore environment. The societal debate over what is a desirable lifestyle, is in part responsible for changing perception of the value of nature among various subgroups in our societies. Such changes affect the demand for environmental resources of the coastal environment.

The changes that are required to protect the ecological and economic assets of the coastal zone in the long term will entail a very substantial cost to society, and every effort must therefore be made to develop methods and systems which are effective. At present there are few economic or legal incentives to take account of the value of functioning ecosystems and the products and services they provide. An important objective is to develop practicable methods of harnessing the value of these assets.

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