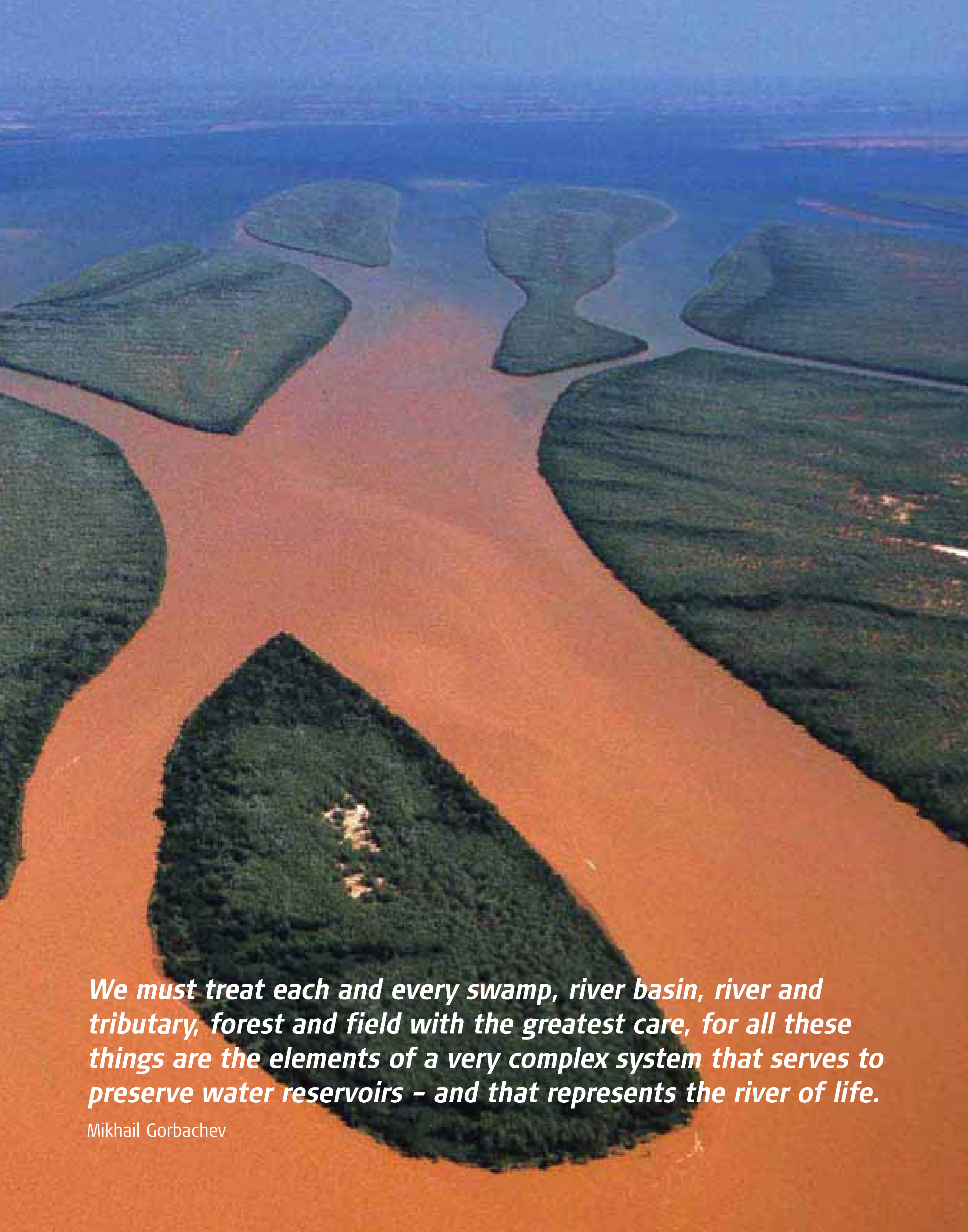


We must treat each and every swamp, river basin, river and tributary, forest and field with the greatest care, for all these things are the elements of a very complex system that serves to preserve water reservoirs – and that represents the river of life.

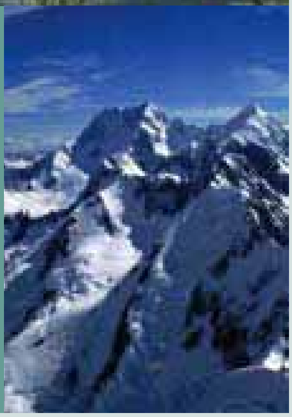
Mikhail Gorbachev

CHAPTER 5

Coastal and Freshwater Ecosystems

By
UNEP
(United Nations Environment Programme)

Betsiboka River, Madagascar



Top to bottom:
Ticti reservoir, Mexico

Franz Joseph Glacier, New Zealand

Heavy rains in the province of Misiones, Argentina, carry off significant quantities of ferruginous earth into the River Uruguay

Key messages:

Coastal and freshwater ecosystems are deteriorating in many areas and at a faster rate than any other ecosystem. Such changes are caused by intertwined factors, making it difficult to identify the problems early on. While progress in integrating these various factors in managing water and ecosystems has been made in some places, the majority of the world and its inhabitants increasingly suffers from a lack of priority given to environmental protection.

- Humans depend upon healthy aquatic ecosystems for drinking water, food security and a wide range of environmental goods and services. Aquatic biodiversity is also extremely rich, with high levels of endemic species, and is very sensitive to environmental degradation and overexploitation.

- Aquatic ecosystems and species are deteriorating rapidly in many areas. This is having an immediate impact on the livelihoods of some of the world's most vulnerable human communities by reducing protein sources for food, availability of clean water, and potential for income generation.

- People in regions with highly variable climatic conditions are particularly vulnerable to droughts and floods and the resulting deteriorating condition of freshwater ecosystems. Coastal lowland areas, where population densities are usually very high and coastal habitats are fragile, are most likely to be affected by sea level rise in future.

- The conservation of biodiversity (species, habitats and ecosystem functions) must become an integral part of all water resource management programmes. This will assist poverty reduction strategies by ensuring the sustainability of aquatic ecosystems for future generations.

- Ecosystem approaches constitute a fundamental element of Integrated Water Resource Management (IWRM) and are essential for safeguarding and balancing the needs and requirements of water resources among different stakeholder groups and ecosystems. Ecosystem approaches are the subject of global and regional targets and policy initiatives, but they have yet to be implemented in practice. This requires awareness raising, tools and methodologies to monitor and negotiate the trade-offs involved in such broad-scale approaches.

- Our understanding of the properties and functions of many aquatic ecosystems is seriously hampered by inadequate data. Enhanced monitoring efforts are required to provide a better assessment of the status, conditions and trends of global water ecosystems, habitats and species.

Human population growth and the expansion of economic activities are collectively placing huge demands on coastal and freshwater ecosystems

Part 1. Ecosystems and their Capacity to Provide Goods and Services

The majority of us live in temperate and subtropical regions centred around the coast or inland water systems. Coastal waters, rivers, lakes, wetlands, aquifers and other inland water systems such as swamps and fens have in consequnce been subjected to disproportionate human-induced pressures. These include construction along coastlines for harbours and urban expansion, alteration of river systems for navigation and water storage, drainage of wetlands to increase farmland, overexploitation of fisheries, and multiple sources of pollution. Human population growth and the expansion of economic activities are collectively placing huge demands on coastal and freshwater ecosystems. Water withdrawals, for instance, have increased sixfold since the 1900s, which is twice the rate of population growth (WMO, 1997). In addition, the quality of many water bodies is declining due to increased pollution from agriculture, industry, tourism, urban runoff and domestic sewage.

Desertification is also spreading as a consequence of the misuse of water resources, not only in Africa and Central Asia, but increasingly in other regions, such as in California and southern Europe. The dramatic shrinking of the Aral Sea in Central Asia and its consequences for biodiversity and human well-being have been well documented (UNEP, 2004b; Kreutzberg-Mukhina, 2004). There are many other water crises that have received less attention, such as the serious soil erosion and groundwater depletion occurring in parts of Spain and the eutrophication of many coastal waters as a result of intensive farming. In other regions, the problem may soon be one of too much water, threatening many low-lying coastal and floodplain areas. Predictions of the impacts of melting ice caps and increased discharge from Arctic rivers due to global warming remain uncertain, although it is clear that they will change the fragile Arctic Ocean ecosystem, with potentially devastating consequences further afield, especially along often highly populated coastlines (ACIA, 2004).

While many of the world's coastal and freshwater ecosystems are continuing to deteriorate at alarming rates, the reversal of these trends and the improvement of water quality in other areas indicate that this decline is neither inevitable nor always irreversible. The management of water and land resources requires a comprehensive understanding and careful consideration of ecosystem functions and interactions. The application of such knowledge in an integrated approach to land use and water management is often referred to as an 'ecosystem approach', and such a holistic response to the challenges facing the world's water resources is at the heart of international agreements and programmes like the Convention on Biological Diversity (CBD), the Global Programme of Action (GPA) for the Protection of the Marine Environment from Land-based Activities and the World Summit on Sustainable Development (WSSD).

The ecosystem approach, a key element of integrated water resources management (IWRM) (GWP, 2003), is a strategy for the integrated management of land, water and living resources which promotes conservation and sustainable use in an equitable way (CBD, 2000). There is no single way to implement the ecosystem approach, as it depends upon local, provincial, national, regional and global conditions. **Box 5.1** discusses one of the many systems in which an ecosystem approach should be implemented to solve a current ecosystem crisis.

IWRM is a systematic participatory planning and implementation process for the sustainable management of water, land and coastal resources, which promotes coordinated development and is based on credible science. It involves the participation of stakeholders who determine equitable resource allocation and the sharing of economic benefits and monitoring within set objectives in order to ensure the sustainability of vital ecosystems. It is also a process that promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems (GWP, 2000).

Integrated water resources management considers the following:

- **The hydrological cycle in its entirety:** downstream and upstream interests are taken into account (basin-wide, also across national borders), as well as surface and groundwater sources and, most importantly, rainfall.

There is a growing recognition of the need for a sustained global effort to meet the immense challenges of managing the Earth's water resources

- **The full range of sectoral interests:** integrated development and management implies close coordination between institutions that are often sectorally focused, the involvement of stakeholders in decision-making, and taking into account those stakeholders without a voice (such as the environment).

- **Future needs:** as legitimate claims to the water resource, such as future generations – sustainability (Institute of Water and Sanitation Development of Zimbabwe, 1997).

- **The management of water as a resource:** as well as the governance framework for provision of water services to stakeholders.

There is a growing recognition of the need for a sustained global effort to meet the immense challenges of managing the Earth's water resources. At the 2002 WSSD, participating countries committed themselves to halving the proportion of people who lack access to safe drinking water and sanitation by 2015 (Millennium Development Goal Target 10) and significantly reducing the rate of biodiversity loss in aquatic ecosystems by 2010. Reconciling these two goals constitutes a major challenge. The implementation of IWRM schemes on regional and local scales; the increasing use of ecosystem approaches focusing on river basins and their interaction with coastal zones; the decommissioning of dams in North America and Europe; and the many different river and wetland restoration projects taking place throughout the world all suggest that these commitments are starting to be taken seriously, although change is slow and not happening in every part of the world.

Indicators of ecosystems processes and functions are essential to the proper assessment of watershed resources by evaluating the pressures, state, driving forces and responses to change. Unfortunately, the necessary knowledge and data needed to develop and interpret indicators are often lacking. Data remain seriously incomplete and unharmonized at a global level, making detection and resolution of problems extremely difficult (see **Chapter 13**). Even more worrying is the fact that hydrographic and water quality monitoring networks have deteriorated in several parts of the world, further hampering the accurate assessment of global water resources. The Global Environment Monitoring System for freshwater (GEMS/Water), led by the United Nations Environmental Programme (UNEP), maintains a water quality database with information from over 1,500 monitoring stations covering 112 watercourses from more than eighty countries. However, most stations contain only patchy and sporadic information, making the detection of long-term trends in water quality difficult. Information on groundwater resources is even less complete because of the difficulty and the costs of obtaining accurate measurements. Furthermore, there are few systematic epidemiological studies that allow us to understand the impacts of low quality or contaminated water supplies on human health and well-being (see **Chapter 6**). Existing data and information on aquatic species and the extent and condition of their habitats are also limited and fragmented. Although there are some groups (e.g. water-birds and amphibians) for which trend data do exist, they remain the exception. Given the need for information to manage resources in an integrated fashion, and the reality of the dearth of data and monitoring, we have to depend on indicators that measure drivers of change, which are currently quite clear and, for the most part, easier to assess and monitor. This is especially true in those countries where resources for extensive fieldwork and capacity are limited. For example, using data on the extent of agriculture in a watershed, or the size and location of dams, we can draw some conclusions about the relative degree of alteration or stress affecting a system. These geospatial indicators are often called proxies or surrogates, because they are indicators of current threat and give only indirect information about actual ecological integrity.

It is clear that if we continue to ignore ecosystem processes and functions, human activities will lead to the continuing degradation of coastal and freshwater ecosystems, as well as the loss of biodiversity and a consequential decline in human well-being.

This chapter addresses the current condition of coastal and freshwater ecosystems and their capacity to deliver an array of life-supporting ecosystem goods and services. It looks critically at several different management approaches and policies, and concludes by identifying some of the challenges that human society must face in attempting to achieve the Millennium Development Goals (MDGs) related to water resources and other international targets, such as those for biodiversity and climate change.

BOX 5.1: LAKE VICTORIA: AN ECOSYSTEM IN DECLINE

Lake Victoria is the second largest lake in the world. It supports a very productive freshwater fishery with annual fish yields exceeding 500,000 tonnes, with a value of US $400 million. In addition, the lake provides freshwater for irrigation, hydroelectric power, recreation and transport (see **Chapter 14**).

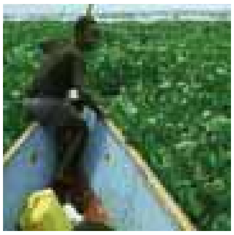
In some parts of the basin, its population density is well over 100 people per square kilometre (km^2) (Cohen et al., 1996) and has been increasing at the rate of 3 to 4 percent per year. The lake faces considerable pressure from a variety of natural or anthropogenic causes. It has undergone enormous environmental changes within the last forty years, caused by human activities such as overfishing, siltation from deforested watersheds, erosion from poor agricultural practices, introduction of alien species and industrial pollution. Seasonal variability attributed to climate change has also been noted. These combinations of natural and anthropogenic causes have led to rapidly evolving changes in the lake that seriously threaten its ecosystem function and dependent livelihoods. Three immediate causes of eutrophication so far identified include enhanced effluent discharge, from untreated municipal sewage, runoff and storm water, chemical pollutions from industries (such as small-scale mining in some parts of Tanzania, Panpaper Limited in Kenya, etc.) and agrochemicals from farms, including the expanding flower farms currently threatening internationally important wetland sites, such as Uganda's Lutembe Bay, which hosts large numbers of wintering waterbirds of global significance, including almost the entire population of the White-winged Tern (*Chlidonias leucopterus*).

Today, nearly half of the lake experiences prolonged anoxia (lack of oxygen) spells for several months of the year, whereas four decades ago anoxia was sporadic and localized. As a result, algal biomass concentration is almost five times greater in the surface waters today than reported in the 1960s, which indicates higher rates of photosynthesis. Also, water transparency values have decreased to one-third and the silica concentration to one-tenth of what they were about forty years ago.

The lake was until recently home to over 600 endemic haplochromine cichlid fish (not all yet formally catalogued), as well as a number of other non-cichlid species. The extinction of species of haplochromine cichlid fish in the lake, primarily as a result of the introduction of the Nile perch (*Lates niloticus)*, remains the single most dramatic event of vertebrate extinction attributable to specific human activities. More than 100 fish species have been driven into extinction since 1960. The lake's fisheries are currently dominated by three commercial species: the Nile perch, a non-native species introduced in the 1950s which now makes up 80 percent of the lake's fish population; the other 20 percent is formed by the indigenous tilapia (*Oreochromis niloticus* from the *Cichlidae* family) and dagaa (*Rastrineobola argentea*).

Sources: World Lakes Network (www.worldlakes.org/); Cohen et al., 1996; Kiremire, 1997; Verschuren et al., 2002; Dodman and Diagana, 2003; Hecky, 1993; Mugidde, 1993; Lehman, 1996; Johnson et al., 1996.

Algonquin National Park, Canada



Water hyacinth accidentally introduced in Lake Victoria from Latin America is having a huge impact on the lake's natural ecosystem

Part 2. The Environmental and Social Importance of Ecosystems

The first *United Nations World Water Development Report* (WWDR1) noted that a healthy and unpolluted natural environment is essential to human well-being and sustainable development, stressing that aquatic ecosystems and their dependent species are an integral part of our lives and provide a resource base that helps us to meet a multitude of human and ecosystem needs (UN-WWAP, 2003). These goods and services include water for human consumption, food production, irrigation, energy generation, regulating services (e.g. flood mitigation, water filtration, aquifer recharge and nutrient cycling), and transport and recreational services. Their value is irreplaceable, and they are an important part of the water, energy, health, agriculture and biodiversity (WEHAB) sectors, which are essential for poverty alleviation and socio-economic development. The ecosystem approach further focuses on coastal and freshwater ecosystems, which are stepping stones for migratory birds and fish species and provide global environmental services that underpin the natural functions of the Earth. But, as WWDR1 shows, these ecosystems are under severe pressures that threaten their ability to meet the multiple and growing demands placed upon them.

2a. Goods and services

All ecosystems, aquatic and terrestrial, play a role in regulating the way water flows through the landscape, highlighting the need to better understand the relations between them and manage them in an integrated way. Forests absorb precipitation and regulate streamflow, while wetlands act as sponges, absorbing excess water in times of heavy rain and high tides and releasing water slowly during dry periods. Aquatic ecosystems play a number of vital roles in human society: regulating climatic extremes, providing food resources and, in the case of freshwater, sustaining agricultural production. Many other human life-supporting goods and services (see **Table 5.2**) are derived from aquatic ecosystems, including:

- hydrological regulation of floods, availability and supply of water during dry periods
- sediment retention, water purification, and waste disposal
- recharge of groundwater supplies
- drinking water and sanitation for large populations
- irrigation water for crops and drinking water for livestock
- coastline protection
- climate change mitigation through greenhouse gas absorption and impact buffering
- recreation and tourism
- cultural and spiritual values
- a range of goods such as fibres, timber, animal fodder and other food products
- transport routes – sometimes the only accessible routes
- hydroelectric and mechanical power.

The ability of any particular aquatic ecosystem to supply the range of services listed above depends upon a variety of factors, such as the type of ecosystem, the presence of key species, management interventions, the location of human communities and the surrounding climate and topography. Few sites have the capacity to provide all of the above services. Whereas recreation opportunities may depend only on the presence of clean water, for example, the provision of fish for food usually depends upon the presence of a fully functioning food chain to sustain the fish populations. Generally speaking, the more biologically diverse an ecosystem is, the greater the range of services that can be derived from it. There is some evidence from aquatic systems that a rich regional species pool is probably needed to maintain ecosystem stability in the face of a changing environment (UNEP Millennium Ecosystem Assessment, 2006).

Aquatic ecosystems refer not only to coastal waters, rivers and lakes, but also to a complex and interconnected system of permanent and temporary habitats, with a high degree of seasonal variation. Temporary habitats play a key role in the overall value of water ecosystems. For example, coastal estuaries and river floodplains are among the most productive ecosystems on Earth (Junk et al., 1989). Some, such as the Amazon floodplain, stretch over thousands of kilometres, while others may be only a few metres wide. Seasonal variation is vital for the integrity of such ecosystems, as many fish depend on the seasonal inundation of river floodplains for breeding or feeding. The extent of flooding is in these cases positively correlated with fish catches (Welcomme, 1979). Many tropical freshwater wetlands have a low nutrient status, as in the black and clear floodplains in Amazonia (Furch, 2000). In these systems, high biodiversity is not an indicator of high productivity, but rather of quick and efficient nutrient recycling. These habitats are particularly vulnerable to overexploitation. Estuaries and river floodplains also have an important role in dissipating high tides and river flows and preventing flood damage and coastline erosion. In many countries, river floodplains also serve as nutrient-rich sites for agriculture.

The precise value of many of these services (particularly their monetary value) remain poorly understood. However, direct use values of water buffering (e.g. flood prevention) alone have been estimated at US $350 billion at 1994 prices, and recreational values at US $304 billion (Constanza et al., 1997). It was estimated that reef habitats provide human beings with living resources, such as fish, and services, such as tourism returns and coastal protection, worth about US $375 billion each year (Constanza et al., 1997). Economic losses from degradation can also be serious. One example is coastal erosion, which results from altered currents and sediment loads caused by changes in coastal and upstream land use. The beaches of Tangiers in Morocco, for instance, largely disappeared in the 1990s after new ports were built. The destination lost 53 percent of its international tourist night-stays and substantial tourism income, estimated at about US $20 million per year (Blue Plan, 2005). **Figure 5.1** roughly summarizes some of the estimates for marine ecosystems.

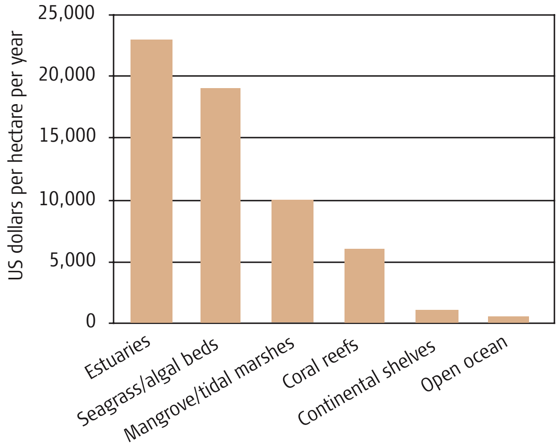
Studies of particular wetlands (coastal or inland) provide a fragmented picture of their physical and economic benefits in different regions of the world (see **Table 5.1**). For example, the value of using wetlands for waste treatment in Kampala, Uganda was estimated at US $2,000 to 4,000 per hectare (ha) (Emerton et al., 1999) (see **Chapter 14**). Zambia's wetlands were estimated to be around US $16.7 million per year, of which US $4.2 million was generated by the Barotse floodplain alone (Turpie et al., 1999).

2b. Fisheries

Fish are among the greatest and most obvious benefits that human societies derive from aquatic ecosystems. In 2001, the reported global marine capture amounted to 85 million tonnes of fish, crustaceans and molluscs (Fishstat, 2002). Unlike high-seas fisheries, however, coastal and inland fisheries are often dominated by small-scale and subsistence operations from the poorest sectors of society, for whom a catch provides a vital source of livelihood and affordable protein. Inland capture fishery production reported to the UN Food and Agriculture Organization (FAO) by 150 countries in 2001 indicated a total global production of 8.7 million tonnes, with the greatest continental catches reported in Asia (5.8 million tonnes) and Africa (2.1 million tonnes), mostly in developing or transition economies where fish production has rapidly increased over the past ten to fifteen years (FAO, 2002). Seven countries reported inland fisheries as their only source of fish, with twenty more considering inland fisheries extremely important, accounting for between 81 and 99 percent of their total fish production (Kura et al., 2004).

FAO (2002) recently estimated that marine and inland fisheries and aquaculture provide 16 percent of the global animal protein intake (see **Chapter 7**). This number exceeds 25 percent in the poorest countries, reaching up to 90 percent in some isolated rural areas. In the Upper Amazon Basin, for example, fish are reported to provide the majority of animal protein consumed by local households, with more than 200 kilograms (kg) of fish consumption per year per person (Batista et al., 1998). Fish are particularly important in communities relying primarily on a few staple foods such as rice, wheat, maize and cassava, which are deficient in essential nutrients and can be supplemented by fish (Thilsted et al., 1997). In areas where other economic opportunities may be declining, small-scale fisheries and related processing and trading offer an economic alternative for an increasing number of unskilled

Figure 5.1: Estimated mean value of marine biomes



Source: Constanza et al., 1998.

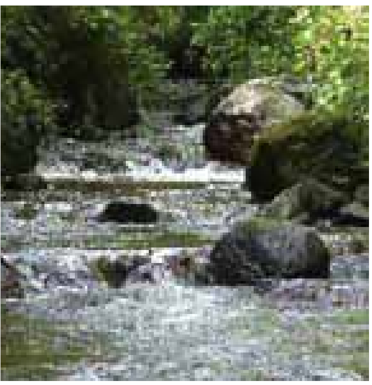
Aquatic ecosystems refer not only to coastal waters, rivers and lakes, but also to a complex and interconnected system of permanent and temporary habitats, with a high degree of seasonal variation

Table 5.1: Estimated value of selected wetlands in Africa and Asia

Location	Value in million US $/ha/year	Services	Source
Bangladesh: Hail Haor	649	Crops, fisheries, plants, flood control, recreation, transportation, water quality and supplies, existence values	Colavito, 2002
Cambodia: Koh Kong Province mangroves	2 32	Carbon sequestration Storm protection	Bann, 1997
Cambodia: Ream National Park	59	Crops, fishing, plant use, hunting	Emerton et al., 2002
Cameroon: Waza Logone floodplain	3,000	Plant resources, grazing, crops, water supplies, fisheries	IUCN, 2001
Fiji: mangroves	158 5,820	Forestry, fisheries, crops Water purification	Lal, 1990
India: Bhoj urban wetland	1,206	Water quality and supplies, resource use, amenity and recreational values, crop cultivation	Verma, 2001
Indonesia: mangroves	86	Forest products and fisheries	Burbridge and Maragos, 1985
Japan: Kushiro National Park	1,400	Recreational and amenity values	Kuriyama, 1998
Kenya: Lake Nakuru National Park	400–800	Recreational value of wildlife viewing	Navrud and Mungatana, 1994
Republic of Korea: coastal wetlands	22,000	Fishery production and habitat, waste treatment, aesthetic functions	Lee, 1998
Malawi: Lower Shire wetlands	123	Plant resources, hunting, crops, grazing	Turpie et al., 1999
Malaysia: mangroves	35	Forest products	Hamilton et al., 1989
Mozambique: Zambezi Delta coastal wetlands	9	Plant resources, hunting, crops, grazing	Turpie et al., 1999
Namibia: Chobe-Caprivi wetlands	22	Plant resources, hunting, crops, grazing	Turpie et al., 1999
Nigeria: Hadejia-Nguru floodplain	2	Doum palm utilization, firewood, potash, agriculture	Eaton and Sarch, 1997
Nigeria: Hadejia-Nguru floodplain	20	Groundwater recharge for domestic consumption	Acharya, 1998
Philippines: Pagbilao mangroves	211	Forestry and fisheries	Janssen and Padilla, 1996
Sri Lanka: Muthurajawela urban marsh	2,600	Water supplies, wastewater treatment, flood attenuation, support to downstream fisheries	Emerton and Kekulandala, 2002
Thailand mangroves	165	Coastline protection	Christensen, 1982
Thailand: Surat Thani mangroves	77	Coastline protection	Sathirathai, 1998
Uganda: Nakivubo urban wetland	2,155	Wastewater treatment	Emerton et al., 1999
Uganda: Pallisa District wetlands	485	Crops, grazing, fisheries, plant use, sand and clay, maintenance of soil fertility, water supplies and quality	Karanja et al., 2001
Zambia: Barotse floodplain	16	Plant resources, hunting, crops, grazing	Turpie et al., 1999

Below: Las Huertas, Mexico

Bottom: Anawilundawa, Sri Lanka



labourers. In the Lake Chad Basin, for example, fish provide a source of income that is reinvested in farming (Béné et al., 2003).

Much of the increase in fisheries production is the result of enhancement efforts such as fish stocking and the introduction of non-native fish species in lakes and rivers (Kura et al., 2004), although the latter can in turn create environmental problems as discussed below. In 2001, aquaculture produced 37.9 million tonnes of fishery products, or nearly 40 percent of the world's total fish consumption, valued at US $55.7 billion (FAO, 2002). Aquaculture is the fastest-growing food production sector in the world, with freshwater finfish alone accounting for over 50 percent of global production. Asia, especially China, dominates inland fishery production. China produced close to 15 million tonnes of fish (about one-quarter of the world's total catch) in 2001, mostly carp for domestic consumption. Other leading inland aquaculture-producing countries include Bangladesh, Cambodia, Egypt, India, Indonesia, Myanmar, Tanzania, Thailand and Uganda (Kura et al., 2004).

Inland fishing is almost entirely dominated by small-scale and subsistence operations. In China alone, more than 80 percent of the 12 million reported fishermen are engaged in inland capture fishing and aquaculture (Miao and Yuan, 2001). In the Lower Mekong River Basin, which covers part of Cambodia, Laos, Thailand and Viet Nam, a recent study estimated that 40 million rural farmers are also engaged in fishing, at least seasonally (Kura et al., 2004). This is also true in Africa. In the major river basins and lakes in West and Central Africa, FAO (2003) estimated that fisheries employ 227,000 fishermen, producing 569,100 tonnes of fish products per year, with a value of US $295.17 million and a potential value of nearly US $750 million (Neiland et al., 2004).

All of these benefits depend on the continuation of healthy, functioning aquatic ecosystems. Unfortunately, many hydrological systems are currently being modified and damaged, resulting in a decline in biodiversity and a consequent loss of many of the services mentioned. It should be noted, furthermore, that information on inland fishery production is notoriously poor, particularly for subsistence fisheries, since catches are often grossly underestimated by national governments (Kura et al., 2004). FAO estimates under-reporting by a factor of three or four (FAO, 1999 and 2001). Despite their key role in providing nutrition to the poorest and most vulnerable members of society, coastal and inland fisheries frequently suffer from poor management, competition from industrial fishing and degradation from land-based activities, such as deforestation, pollution and upstream development (Kura et al., 2004).

Even though inland and coastal harvests continue to increase, maintained mainly by aquaculture expansion, most coastal and freshwater systems are stressed by overfishing, habitat loss and degradation, the introduction and presence of invasive species, pollution, and the disruption of river flows by dams and other diversions (FAO, 1999 and Revenga et al., 2000). This degradation threatens not only the biodiversity of riverine and lacustrine ecosystems, but also the food security and livelihood of millions of people – particularly those of poor rural and coastal communities in the developing world. The following section provides a brief overview of the status of freshwater and coastal ecosystems around the world.

...most coastal and freshwater systems are stressed by overfishing, habitat loss and degradation, the introduction and presence of invasive species, pollution and the disruption of river flows by dams and other diversions...

School of freshwater fish in the State of Mexico, Mexico

Part 3. Status of and Trends in Ecosystems and Biodiversity

Freshwater and coastal ecosystems comprise a range of highly productive habitats, such as lagoons, estuaries, lakes, rivers, floodplains, small streams, ponds, springs, aquifers and wetlands. The term 'wetland' describes a particular group of aquatic habitats representing a variety of shallow, vegetated systems, such as bogs, marshes, swamps, floodplains, coastal lagoons, estuaries, coral reefs and seagrass beds, where the shallowest sites are often transitional areas and can be seasonally or intermittently flooded (Groombridge and Jenkins, 1998).[1]

3a. Status of coastal and freshwater ecosystems

Proximity to water bodies has been an incentive for the location of human settlements for millennia, and the human alteration of coastlines, rivers, lakes and wetlands has gone hand in hand with social and economic development. Coastal and freshwater ecosystems have suffered multiple pressures, often undergoing degradation in small, incremental steps that are difficult to recognize. General analyses and reviews over the past two decades have identified a range of pressures that cause adverse change in these ecosystems (Allison, 2004; Revenga and Kura, 2003; Revenga et al., 2000; Groombridge and Jenkins, 1998; McAllister et al., 1997; Abramovitz, 1996; Bryant et al., 1998; Burke et al., 2001). These show physical alteration, habitat degradation and destruction, water withdrawal, overexploitation, pollution and the introduction of non-native species to be the leading causes of aquatic species decline and ecosystem degradation (see also **Table 5.2**). Rarely is a given species or habitat imperilled as a result of a single threat, and it is often impossible to decipher the intertwined effects of the many disturbances occurring within a given river basin (Malmqvist and Rundle, 2002). This 'creeping' nature of degradation not only makes it difficult to identify serious problems early on, but also allows people to get used to degradation as it is occurring, so that over time degraded ecosystems become accepted as the norm (Glantz, 1999).

A variety of attempts have been made to assess the global extent and distribution of aquatic habitats. However, estimates vary considerably, depending on the type of source material used. And while inventories of coastal zones, river basins and lakes do exist, there are no good data sets or indicators at the global level which track changes in conditions over time. Unfortunately, there are no unequivocally accepted global measures or indicators that demonstrate the changes in the overall extent of wetlands. Finlayson and Davidson (1999) concluded that the information available is too patchy and inconsistent to provide a precise picture of global change. An often quoted estimate is that about 50 percent of the wetlands that existed in 1900 had been lost by the late 1990s as a result of the conversion of land to agriculture (Myers, 1997). However, this figure remains largely speculative.

Accurate information does exist, however, for some continents and regions. Junk (2002) recognized twenty-four major aquatic ecosystems in Africa, eight of which are strongly subjected to large-scale irrigation, with devastating environmental effects and losses of ecosystem services and biodiversity. If human population density is brought into the equation, south and Southeast Asian wetlands can be considered among the most severely degraded (see **Box 5.2**).

A global survey is beyond the scope of a chapter of this length. In the following section we first summarize some key global trends in wetland species and related ecosystem goods and services and then examine the range of pressures currently affecting aquatic ecosystems. Lastly, we discuss some specific examples of changes to the status of particular wetland habitats. Again, freshwater systems are covered in more detail than coastal systems, even though all these systems are interlinked and provide many specific goods and services.

3b. Global trends in key species

Species richness in relation to the extent of habitat is extremely high for many coastal and freshwater groups. It has been estimated, for example, that 12 percent of all animal species live in freshwater ecosystems (Abramovitz, 1996), while virtually all terrestrial species depend upon such ecosystems for their survival. In Europe, for example, 25 percent of birds and 11 percent of mammals use freshwater wetlands as their

1. The Ramsar Convention on Wetlands defines wetlands as 'areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres'.

BOX 5.2: THREATENED SOUTH AND SOUTHEAST ASIAN WETLANDS

Given high population densities, increased rates of deforestation (particularly in Indonesia) and the large degree of ecosystem fragmentation in India, which has more than 4,000 dams, Southeast Asia's wetlands are probably the most degraded in the world. This is reflected in the rapid decrease or local extinction of large grazing wetland species, such as the Indian rhinoceros (*Rhinoceros unicornis*) and swamp deer (*Cervus duvauceli, C. eldi, C. schomburgki*), and the high number of globally threatened fish, amphibians, water turtles and bird species in the region. In addition, more than half of the region's coral reefs, the most species-rich on Earth, are at high risk, primarily from coastal development and fishing-related pressures. Southeast Asia's mangroves, also the most biodiverse in the world, are under increasing pressure from timber industries, aquaculture and conversion to agriculture despite their widely documented importance for coastal protection, water purification, carbon dioxide absorption, and as breeding and nursing grounds for many valuable subsistence and commercial fish species (see also **Chapter 14**).

Sources: IUCN, 2003a; IUCN et al., 2004; Bryant et al., 1998; Burke et al., 2001.

main breeding and feeding areas (EEA, 1995). Of the approximately 25,000 ray-finned (*Actinopterygii*) fish species described to date, 41 percent are considered primarily freshwater species. Individual freshwater systems can be extremely important in supporting high numbers of endemic species. According to the Ramsar Convention on Wetlands, Lake Tanganyika in Central Africa, for example, supports 632 endemic animal species. It is also important to note that the resilience of ecosystems increases with biodiversity, thus providing a relevant linkage between management and biodiversity conservation.

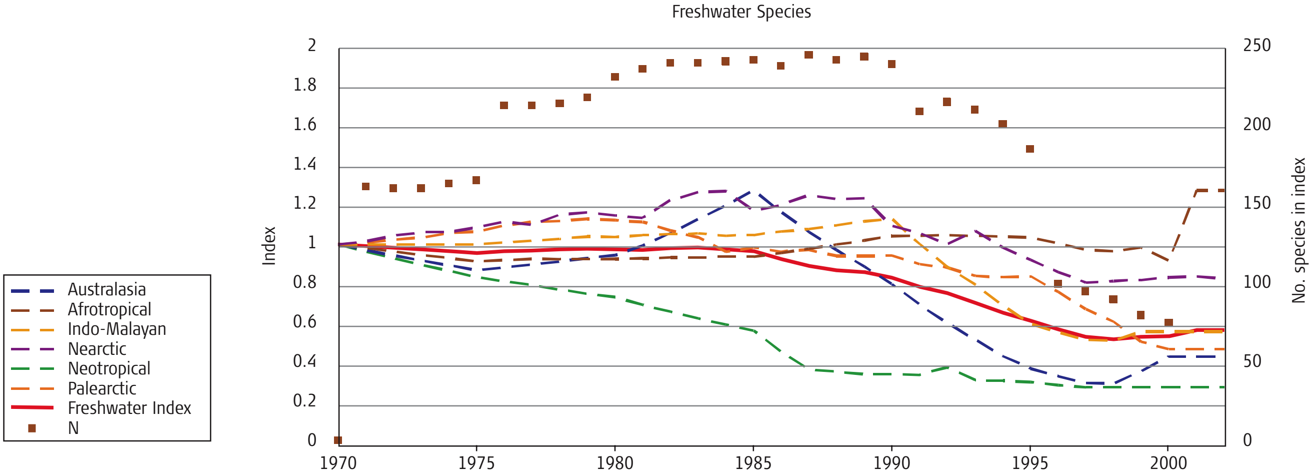
As for coastal waters, Conservation International (CI) has identified twenty-five biodiversity 'hotspots' around the world, twenty-three of which are at least partially located within coastal zones, mainly in Asia, the Caribbean, Africa and South America (UNEP, 2005). Coral reefs alone, representing only 0.2 percent of the total area of oceans (Bryant et al., 1998), harbour more than 25 percent of all known marine fish, with some reefs reaching densities of around 1,000 species per square metre, especially in parts of the Pacific and Indian Oceans (Tibbets, 2004). Semi-enclosed seas can also have a wealth of endemic flora and fauna. The Mediterranean, for example, contains 7 percent of the world's known marine species, although it covers only 0.8 percent of the ocean surface: 694 species of marine vertebrates have been recorded (580 fish, 21 mammals, 48 sharks, 36 rays and 5 turtles) and 1,289 marine plant taxons (Blue Plan, 2005).

Serious concern for the global status of aquatic biodiversity was raised in the early 1990s (e.g. Moyle and Leidy, 1992), focusing mainly on data relating to the conservation status of fish. Most of the relatively few global reviews have appeared only during the past decade (Abramowitz, 1996; McAllister et al., 1997; Groombridge and Jenkins, 1998; Revenga et al., 1998; Revenga et al., 2000). These still rely heavily on information relating to fish, but draw from available case studies of other groups (e.g. molluscs in US waters), and also deal in increasing detail with threat factors and their sources. For instance, FAO's 2004 assessment of marine fish stocks for which information is available, concludes that about half of the stocks (52 percent) were fully exploited, 16 percent were overexploited, and 7 percent were depleted. Only about one-quarter were either underexploited (3 percent), moderately exploited (21 percent) or recovering from previous exploitation (1 percent).

Pressures on aquatic ecosystems have caused a severe decline in the condition of species, with more freshwater species threatened with extinction than in either terrestrial or marine environments (WRI et al., 2000; Revenga et al., 2000; Loh et al., 2004). Available indices tend to support the hypothesis that freshwater species are more threatened by human activities than species in other realms. The Living Planet Index (LPI) developed by UNEP's World Conservation Monitoring Centre (WCMC) and the World Wide Fund for Nature (WWF) is based on trends in populations of vertebrate species. The LPI found that on average freshwater species populations fell by about 50 percent between 1970 and 2000, representing a sharper decline than measured in either terrestrial or marine biomes. Furthermore, freshwater species declined most sharply in the Neotropical and Australasian realms (see **Figure 5.2**). However, this does not mean that marine species are in good condition. The Marine Species Population Index recorded a decline of about 35 percent over the same period.

Pressures on aquatic ecosystems have caused a severe decline in the condition of species. Freshwater species are more threatened with extinction than in terrestrial or marine environments

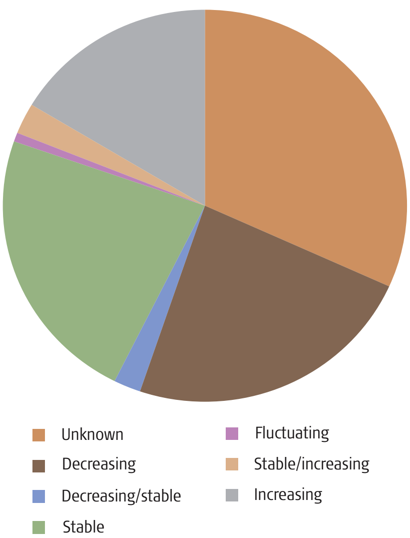
Figure 5.2: Living Planet Index, 1970–2000



Source: Loh et al., 2004.

Other similar measures that reflect the level of threat to freshwater species include conservation status assessments, such as those compiled by the Species Survival Commission of the World Conservation Union (IUCN) and BirdLife International through the Red List of Threatened Animals and its derived red list indices. According to the 2003 IUCN Red List, 3,011 freshwater species are listed as threatened or extinct. Of these, 1,039 are fish and 1,856 are amphibian. Among other freshwater groups, four of the five river dolphins and two of the three manatees are threatened, as are several smaller aquatic mammals. About 40 freshwater turtles, more than 400 inland water crustaceans and hundreds of bivalve and gastropod molluscs are also listed as being threatened with extinction. However, the accuracy of available information tends to decline with lower taxa. Figures for crustaceans and molluscs, for example, may not reflect a true picture of the current global situation.

Figure 5.3: Trends in waterbird populations in the African-Eurasian (AEWA) regions



Source: Wetlands International, 2002.

Note: The Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA) covers 117 countries from Europe, parts of Asia and Canada, the Middle East and Africa. In fact, the geographical area covered by the AEWA stretches from the northern reaches of Canada and the Russian Federation to the southernmost tip of Africa. The available evidence suggests that aquatic habitats and species are suffering a disproportionate decline in comparison to other habitats.

All of the world's amphibian species were recently assessed for the first time (IUCN et al., 2004), providing important new insights into the condition of this large faunistic group. The survey shows that amphibians are experiencing declines unprecedented in modern times, with nearly one-third (32 percent) of the world's 5,743 amphibian species threatened and 168 species already thought to have become extinct. Most amphibians are dependent on freshwater habitats during their larval stages (with the exception of arboreal species), and almost all species are highly sensitive to changes in habitat and water quality. The decrease in amphibian abundance and their threat status around the world are of major concern from a global biodiversity perspective. At least 43 percent of all amphibian species are declining in population, indicating that the number of threatened species can be expected to rise in the near future. The largest numbers of threatened species occur in Latin America. Although habitat loss and fragmentation clearly pose the greatest threat to amphibians, a newly recognized fungal disease is seriously affecting an increasing number of species, which might have developed in response to the increasing global eutrophication of aquatic ecosystems. Perhaps most disturbing is the fact that many species are declining for unknown reasons – complicating efforts to design and implement effective conservation strategies.

Birds have generally been recorded in more detail and over longer periods than any other group of species. Although there are limitations in using them as general indicators, the relative richness of data means they are often the best available proxy to suggest overall trends in biodiversity. The latest trend estimates from BirdLife International (Butchart et al., 2004) confirm that waterbird species are facing disproportionately serious problems. Some 22 percent of the world's seabirds alone are threatened species (WWF/IUCN, 2001). Additionally, global population estimates for waterbirds compiled by Wetlands International (2002) show a declining trend in the African-Eurasian flyway region (see **Figure 5.3**).

Part 4. Pressures and Impacts

Most aquatic ecosystems are vulnerable to a range of human activities. The likely impact of these activities varies from place to place and according to the type of habitat involved. Table 5.2 **summarizes some of the key pressures with respect to different coastal and freshwater ecosystem types, as well as some of the goods and services that these ecosystems supply. Some specific pressures are discussed in greater detail below.**

4a. Habitat alteration

Many aquatic ecosystems have undergone major alterations as a result of deliberate habitat change, either directly or through changes to nearby habitats. Various forms of land use changes have a major influence on water resources and ecosystems around the world (UNEP, 2004b). Several such changes are briefly described below.

Increased suspended loads

Increased concentrations of suspended solids in coastal waters, rivers and lakes resulting from human activity can cause significant changes in habitats. Examples include intensive agriculture, deforestation, road construction, urbanization, tourism, mining, dredging for harbours and shipping lanes, and gravel pit operations. Increased particulate matter in water leads to higher levels of turbidity, and thus reduces photosynthesis. In inland waters, it can fill downstream reservoirs faster than anticipated (UNEP, 2002b). As the suspended (occasionally polluted or even toxic) material settles out of the water column, the habitat for benthic organisms can change in ways that reduce biodiversity (Cobb et al., 1996). Some freshwater mammals are threatened with extinction because of increased silt loads in rivers, including the Spot-necked Otter (*Lutra maculicollis)* in South Africa, the Malagasy Web-footed Tenrec (*Limnogale mergulus*) in Madagascar, and the Giant Otter Shrew (*Potamogale velox*) in Cameroon (Revenga and Kura, 2003). Near shore coastal habitats are particularly impacted by suspended solids. Deltas, mangrove forests, beaches and other coastal habitats are affected by altered currents and sediment delivery – to the benefit of some locations and the detriment of others (UNEP, 2002b). Coral reefs, mangrove forests and sea-grass beds may be smothered and deprived of light due to increases in sediment loads, thereby degrading important breeding and nursing grounds for many commercially valuable and subsistence fish species (Spalding et al., 2002). Fish populations are affected, both through reduced sources of food and by direct physical effects – such as clogging and abrasion of gills, behavioural changes (e.g. movement and migration), reduced resistance to disease, blanketing of spawning grounds and other habitat changes – and physical constraints that prevent functional egg and fry development (Singleton, 1985). Similarly, invertebrate communities are impacted if photosynthetic communities (e.g. periphyton) are affected. The direct invertebrate effects of suspended solids include smothering, clogging of interstices in gravel and cobble beds affecting microhabitats, abrasion of respiratory surfaces, and interference of food intake for filter-feeding species (Singleton, 1985).

Increased concentrations of suspended solids in coastal waters, rivers and lakes resulting from human activity can cause significant changes in habitats

Drainage and conversion of wetlands

Uncontrolled or poorly regulated wetland drainage has created severe threats to aquatic ecosystems and species in some parts of the world, with impacts sometimes affecting entire river basins or coastal habitats. While some drainage is often an essential step in agriculture and coastal development, done in the name of ensuring local

Table 5.2: Major threats to coastal and freshwater ecosystems and services

Ecosystem	Goods and services	Threats
Rivers	Many environmental, economic (e.g. fish, water supplies, transport, disposal, biological cleaning, climate regulation, etc.), religious and spiritual values	Reclamation, drainage, regulation of flow including dam construction, hydroelectric power, pollution, deforestation, soil erosion and degradation, climate change and alien invasive species
Estuaries	High biodiversity, fish, waterfowl, sedimentation, buffer zones, biological cleaning, recreation	Reclamation, drainage, irrigation, hydroelectric power, regulation of water flow, dams and dykes, pollution, agricultural intensification, deforestation, soil erosion/degradation, overexploitation of fish and other food species, climate change, waterborne disease control, and alien invasive species
Coral reefs	High species diversity, coastal protection, biological cleaning, tourism	Climate change, suspended solids from coastal construction, upstream agriculture and logging, tourism; nutrients from untreated sewage and agricultural runoff; pollution from industrial discharges, urban, agricultural and landfills runoff, mining
Mangroves	High species diversity, coastal protection, water purification, CO_2 absorption, breeding and nursing grounds for commercial fish species, source of firewood and timber, coastal protection, tourism	Cutting for firewood and building materials, timber industry, road construction, reclamation for aquaculture, agricultural, urban and industrial areas, tourism developments, and sea-level rise
Sea-grass beds	High species diversity, nursing grounds for commercial fish species, coastal protection, water purification, CO_2 absorption, sediment stabilization	Dredging for harbours, ports and shipping lanes, fishing by benthic trawling, aquaculture, coastal pollution, and clearance for beaches and other tourism developments and facilities
Inland deltas	Water supplies, sediment and nutrient retention, recreation	Drainage, irrigation, regulation of water flow, pollution, agricultural intensification, deforestation, soil erosion/degradation, overexploitation of fish and other food species, climate change
Floodplains	High productivity, high fish and fibre productivity, flood buffers, fire protection, carbon storage, recreation, groundwater recharge	Reclamation, drainage, irrigation, hydroelectric power, regulation of water flow, dams and dykes, pollution, agricultural intensification, deforestation, soil erosion/degradation, overexploitation of fish and other food species, climate change, waterborne disease control, and alien invasive species
Lakes	Water supplies, fibre, fish, waterfowl, recreation, groundwater recharge, religious and spiritual values	Pollution, agricultural intensification, eutrophication, deforestation, soil erosion/degradation, overexploitation of fish and other food species, climate change, waterborne disease control, and alien invasive species
Freshwater marshes	Flood buffers, carbon storage, reed, willow, food and fibre, purification	Drainage, regulation of water flow, dams and dykes, pollution, agricultural intensification, soil erosion/degradation, overexploitation of fish and other food species, and waterborne disease control
Raised bogs	Carbon storage, fossil fuels, purification	Reclamation, drainage, regulation of water flow, pollution, agricultural intensification, eutrophication and climate change
Fen mires	Carbon storage, pastoralism, willow, reed, groundwater recharge	Reclamation, drainage, regulation of water flow, pollution, agricultural intensification, and climate change
Alpine meadows	Species diversity, husbandry, pastoralism, recreation, groundwater recharge	Drainage, agriculture and climate change
Tundra wetlands	Carbon storage, climate regulation, water flow, subsistence hunting and herding, groundwater recharge	Pollution, climate change, overexploitation of fish and other food species
Forest swamps/ shrubs	Timber and fibre, biological cleaning, sanitation, flood buffers, groundwater recharge, purification	Deforestation, soil erosion, degradation and pollution
Groundwater aquifers	Water reservoirs, water storage, storage of nutrients	Irrigation, pollution, agricultural intensification, eutrophication, deforestation, soil erosion/degradation, overexploitation of food species and waterborne disease control
Freshwater springs and oases	Water and food supplies, stop-over sites for migratory species, recreation, religious and spiritual values	Irrigation, agricultural intensification, pollution, overexploitation of fish and other food species, and alien invasive species
Wet grasslands	Carbon storage, food supply, flood buffers (mostly on floodplains), groundwater recharge	Regulation of water flow, drainage, agricultural intensification, eutrophication, overexploitation of food species, and climate change
Ponds, gravel pits, drainage channels	Water supplies, recreation	Pollution, eutrophication and overexploitation of fish and other food species

Source: UNEP and UNEP-WCMC, 2004.

livelihoods, many such efforts usually bring short-term economic gains while neglecting the long-term impact on local communities. Draining wetlands can have serious effects on their natural regulatory functions, causing not only species and habitat loss but also significant detrimental impacts on human populations through increased and unpredictable droughts and flooding, and erosion and saline intrusions along coastlines.

The Pripyat River, for example, between Ukraine and Belarus previously had about 25 percent of its basin covered by peatlands, the subsequent clearance of which resulted in a long-term decline in river water quality (Bragg and Lindsay, 2003). Temperate wetlands, including peatlands, have been heavily modified by conversion to agriculture and other land uses in Western Europe, where many countries have lost more than 90 percent of their wetlands. Much of the wet grassland in Europe has also diminished due to drainage and land conversion. In England and Wales, for instance, less than 20 percent of traditional wet grasslands remained by the late 1990s. Similarly, wet grassland decreased in northern Germany on average by more than 50 percent between 1945 and the early 1990s, with devastating effects on biodiversity, as well as on water holding and carbon storage capacity. In Eastern Europe, socio-economic changes after 1990 led to the abandonment of agriculture on many wet grasslands in northern Russia, Poland and the Baltic States, thereby allowing them to develop into bushy wetlands with little or no drainage. If this trend continues, degraded fen mires and other habitats sensitive to intensive land use could regenerate and once again provide reservoirs of clean water, carbon storage and other services. When wetlands are drained, the natural flow of sediments also changes, with various impacts in habitats. It is sometimes possible, however, to reverse such changes.

Deforestation

Forests are often highly diverse systems, and water flowing through forested catchments is generally of high quality. However, these areas are also very sensitive to changes in land use, and any conversion of forest, including the loss of biomass and biodiversity (Krebs, 1978; Tischler, 1979), can disrupt the dynamics of water flow and recharge functions. Apart from the potential changes in water quality, quantity and flow continuity, deforestation also often results in increased sediment loads, with various impacts on downstream and coastline habitats.

Deforestation in the 1990s was estimated at a net loss of 14.6 million ha per year (taking into account reforestation), or 4.2 percent of the world's natural forests (FAO, 2001). According to a recent report by the World Bank (Dudley and Stolton, 2003), much of the world's drinking water comes from catchments that are, or would naturally be, forested. This report also found that a third of the world's largest 100 cities rely on forests in protected areas for a substantial proportion of their drinking water, demonstrating that metropolitan authorities are increasingly recognizing the importance of the link between forests and water supplies (see **Chapter 12**). It is clear that forests often provide the basis for the integrated management of water resources, although precise effects vary from place to place; a topic that has been controversial among hydrologists. Knowledge of the type and age of trees, soil conditions and user needs can help determine what kind of forest management policies will be most beneficial in a given situation.

Agricultural land-use changes

Agriculture is the largest user of freshwater. Irrigation is responsible for almost 70 percent of all water withdrawals, involving around 250 million ha of land (Millennium Project, 2004), particularly in arid lands and in the larger rice-growing areas of the world. As a result, some rivers (e.g. the Colorado in the US, and the Nile in Africa) have no discharge to the sea during certain periods of the year (Postel, 1995). This, in and of itself, causes a range of downstream and coastal problems and in some cases accelerates the salinization of soils in irrigated regions and aquifers near coastlines. No global figures for salinization exist, but in the early 1990s a World Bank study estimated that up to 2 million ha of land were being withdrawn from agriculture each year due to water logging and salinization (Umali, 1993). While the majority of the world's crops are still grown in rainfed farmlands, 17 percent of the world's cultivated land currently produces 40 percent of its food (Wood et al., 2000), with an increasing trend towards irrigation.

Intensified agricultural practices that rely on the application of soluble fertilizers and pesticides can result in increased nutrient runoff – one of the major causes of deterioration in water quality. In extreme cases severe eutrophication and harmful algal blooms can result in both inland and coastal waters, leading to hypoxia, a condition where rapid algal growth depletes oxygen as it decomposes. Besides severely impacting human uses of water, eutrophication can cause major changes in aquatic food webs and ecosystem productivity.

Toxic algae warning sign on boating lake in Portishead, UK

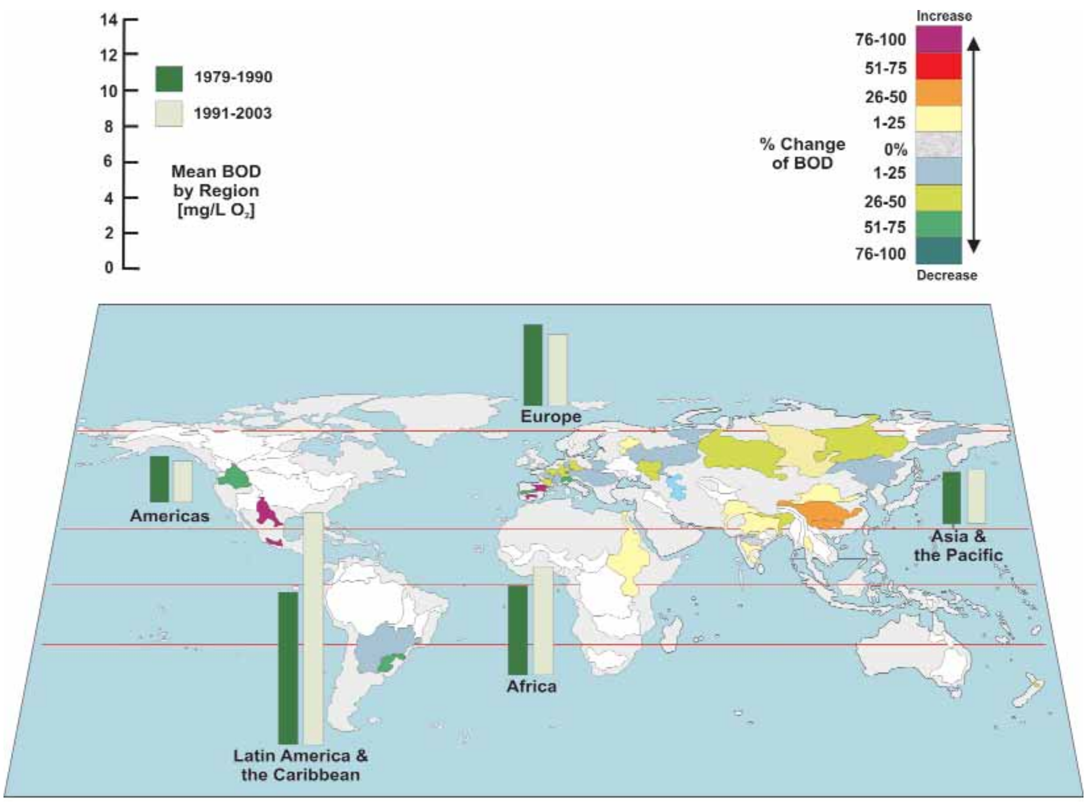
Intensified agricultural practices that rely on the application of soluble fertilizers and pesticides can result in increased nutrient runoff – one of the major causes of deterioration in water quality

In addition, silt being washed into water from ploughed land and changes in the way stream and river banks are managed can damage fish spawning grounds and coastal habitats. For instance, the drainage of Dartmoor and Bodmin Moor in the UK has damaged salmon spawning in the Tamar, Fowey and Camel rivers, which together are worth a total of about US $27.3 million in rod fisheries.

Nutrients from agricultural runoff, aquaculture operations, and human and industrial wastes – including atmospheric depositions – can cause severe eutrophication and changes in the trophic conditions of coastal waters, rivers, lakes, reservoirs and wetlands. Nitrogen and phosphorus compounds are usually the major nutrients responsible for increases in unnaturally rapid growths of algae and other plants, which are symptomatic of eutrophic water bodies. Besides severely impacting human uses of water, eutrophication can cause major changes in aquatic food webs and ecosystem productivity. The die-off of excessive plant matter can lead to the deoxygenation of the water, killing many aquatic species and affecting chemical cycles that fuel biological productivity. Bacteria and other micro-organisms require oxygen to decompose pollutants that enter aquatic systems.

Biological oxygen demand (BOD) is a measure of the quantity of oxygen necessary for biological oxidation of waterborne substances and therefore an indicator of organic pollution. Some aquatic species are particularly susceptible to declines in oxygen concentrations and thus to pollution from sewage or fertilizers. For example, salmon (*Salmonidae*) species require dissolved oxygen concentrations greater than 5 milligrams per litre (mg/L) and cyprinids and members of the Carp (*Cyprinus carpio)* family, more than 2 mg/L (Gleick et al., 2001). When nutrient levels increase, the delicate balance between corals and algae is also destroyed. The algae may overgrow and smother the corals, thereby affecting the marine organisms that depend on them. This may in turn affect humans who depend on these marine resources for their livelihoods. **Map 5.1** shows the distribution and changes in BOD for the regions of the world and major river basins. Oxygen-depleted coastal waters are also widespread along the eastern and southern coasts of North America, the

Map 5.1: Biological oxygen demand (BOD) for major watersheds by region, 1979–90 and 1991–2003



Note: Coloured areas on the map indicate percentage change and histograms the mean concentration changes by region. BOD is a measure of the amount of dissolved oxygen consumed as a result of decay of organic matter in the water column or at the sediment–water interface. Pollution in the form of municipal and industrial effluents is often high in organic matter and, thus, BOD is an indicator of ecosystem stress from municipal and industrial pollution. Watersheds in white indicate insufficient data in one of the time periods to calculate % change.

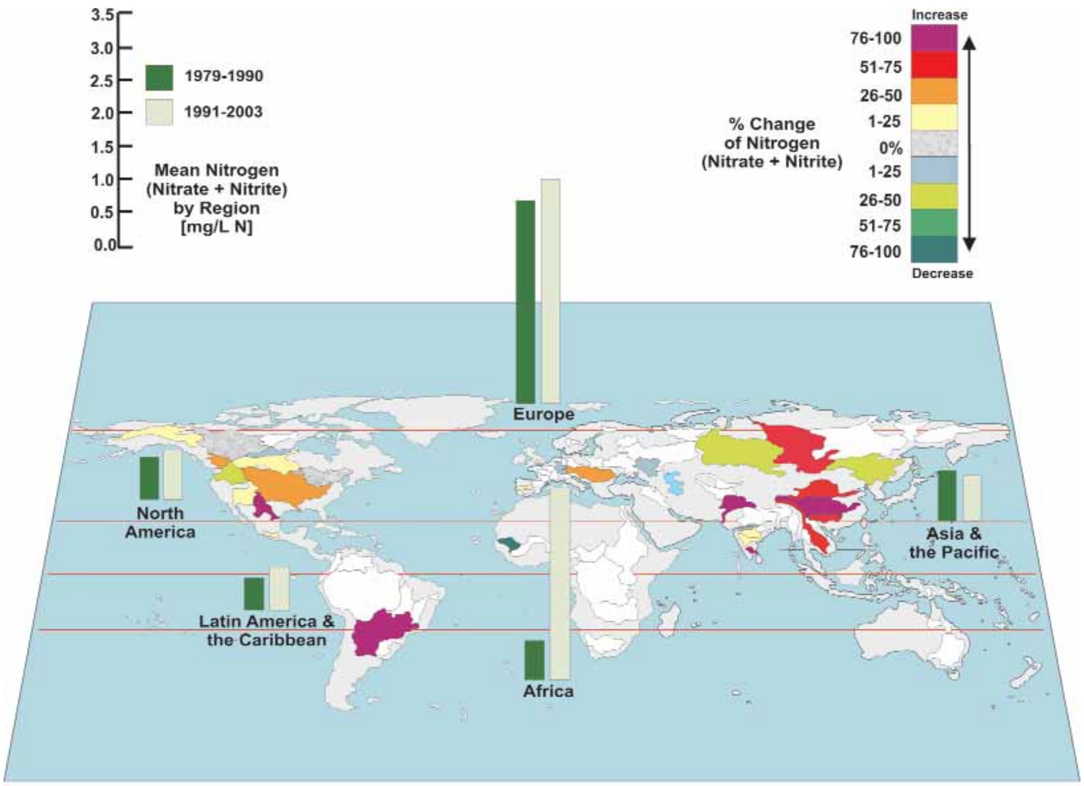
Source: Based on global water monitoring data maintained by the UNEP GEMS/Water programme, www.gemswater.org southern coasts of Japan and China, and large parts of the many, often semi-enclosed, seas surrounding Europe (various sources compiled in UNEP, 2004b).

High concentrations of nitrate in water make it unusable for drinking purposes. A comparison of dissolved nitrogen concentrations in eighty-two major watersheds from the late 1970s (see **Map 5.2**) indicates that twenty-five watersheds had increased nitrate concentrations, thirteen had lower concentrations, probably due to improved nutrient control programmes for wastes, and the remainder showed no significant change or had insufficient data for accurate assessments to be made. The results suggest that, while conditions appear to be deteriorating in more areas than improving, significant improvements can be achieved if there is sufficient political will to improve wastewater treatment and modify agricultural policy.

In a global assessment of the human impacts on phosphorus leaching and its relation to eutrophication, it was found that even though households and industry tend to be the most significant sources, the mining of phosphorus, and its subsequent use in fertilizers, animal feeds and other products is altering the global phosphorus cycle, causing it to accumulate in soils in some locations (Bennett et al., 2001). This can increase phosphorus runoff and subsequent loads to aquatic ecosystems, inland and coastal alike. The authors estimated that phosphorus storage in soils and aquatic systems was 75 percent greater than pre-industrial levels. In agricultural areas, the rate of phosphorus accumulation appears to be decreasing in developed nations and increasing in developing nations. As phosphorus is the key to biological production in most aquatic systems, in the future eutrophication problems are likely to increase in developing countries. Stored soil phosphorus can be transported to aquatic systems during storms and other events, which means there will be an inevitable lag before management actions taken to control eutrophication have a significant effect. Furthermore, phosphorus can build up in lake and coastal sediments. As this phosphorus can be remobilized under certain circumstances, it may threaten severe eutrophication in the future.

A waterfall in Sri Lanka

Map 5.2: Inorganic nitrogen concentrations for major watersheds by region, 1979–90 and 1991–2003



Source: Figure generated based global water monitoring data maintained by the UNEP GEMS/Water programme, at www.gemswater.org

Note: Inorganic nitrogen, measured as nitrate + nitrite, is an indicator of trophic stress on ecosystems as a result of human activities. Inorganic nitrogen can enter aquatic ecosystems through agricultural activities, in the form of runoff from fertilizer applications, as well as from industrial and municipal processes. Nitrogen, in conjunction with phosphorus, controls the growth of plants and algae in aquatic systems and elevated levels of these nutrients can lead to overly productive or eutrophic conditions that can impair ecosystem health. Watersheds in white indicate insufficient data in one of the time periods to calculate % change.

Once species become extinct, they can never be recovered, with severe potential effects on entire food webs and ecological processes

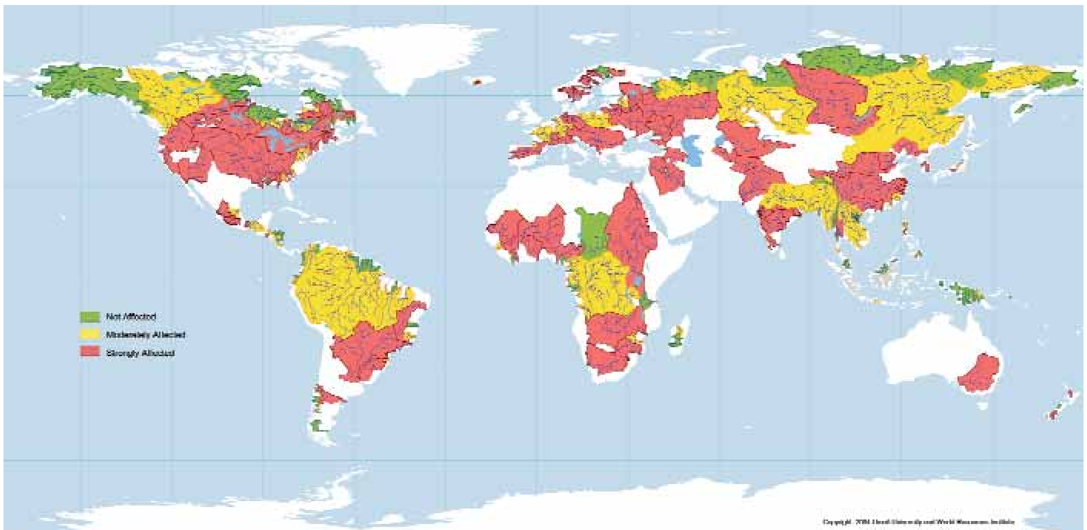
4b. Fragmentation and flow regulation (dams and reservoirs)

While it is difficult to obtain a single and absolute measure of the condition of freshwater ecosystems, some indicators are available that can help to illustrate their overall status. The fragmentation and flow regulation indicator is a case in point. This indicator provides a measure of the degree to which freshwater systems have been altered by the construction of dams and reservoirs. According to the World Commission on Dams (WCD, 2000), most of the world's large dams were built during the second half of the twentieth century and, as of 2000, between 160 and 320 new large dams are still being built every year. Today, there are more than 45,000 dams of over 15 metres (m) high, with about 15 percent of the total annual river runoff being sequestered behind dams (Gornitz, 2000). Almost half of the existing large dams (22,000) are in China, followed by the United States with 6,390 (WCD, 2000).

Dams play a major role in fragmenting and modifying aquatic habitats, transforming lotic (flowing) ecosystems into lentic (still) and semi-lentic ecosystems, altering the flow of matter and energy and establishing barriers to the movement of migratory species. Waterfalls, rapids, riparian vegetation and wetlands can all disappear when rivers are regulated or impounded (Dynesius and Nilsson, 1994). These habitats are essential feeding and breeding grounds for many aquatic and terrestrial species and also contribute significantly to maintaining other vital ecosystem services, including water purification. The fragmentation indicator presented here suggests that many unique riverine habitats have been fragmented or even eliminated. Given that habitat loss is the leading cause of species extinction in freshwater ecosystems, this indicator gives a measure of the risk that many freshwater species face. Once species go extinct, they can never be recovered, with severe potential effects on entire food webs and ecological processes.

This fragmentation and flow regulation indicator was developed by Umeå University in Sweden, in collaboration with the World Resources Institute (Nilsson et al., 2005). It assesses 292 of the world's largest river systems, which comprise approximately 60 percent of the world's river runoff, and occupy more than half (54 percent) of the world's land area. A large river system (LRS) is defined as a river system that has a river channel section with a virgin mean annual discharge (VMAD, the river discharge before any significant direct human manipulations) of at least 350 cubic metres per second (m^3/s) anywhere in its catchment (Dynesius and Nilsson, 1994). Results of the analysis (see **Map 5.3**) show that there are 105 strongly affected, 68 moderately affected, and 119 unaffected LRSs. Unaffected river systems are those without dams in their catchments, although dams in tributaries may not disqualify a river from being classified as 'unaffected' if flow regulation is less than 2 percent of the VMAD. A river system is never considered unaffected if there are dams in the main channel, and is never classified as strongly affected if

Map. 5.3: Fragmentation and flow regulation by Large River System (LRS)



Note: This map presents the results of the river fragmentation and flow regulation indicator. Of the 292 of the world's LRSs, 173 are either strongly or moderately affected by dams; while 119 are considered unaffected. In terms of areas, strongly affected systems constitute the majority (52 percent or about 4,367 km^2) of total LRS catchment area. Grey colour represents potential LRSs in Indonesia and Malaysia that were not assessed due to lack of data.

Source: Nilsson et al., 2005.

there are no dams in the main channel. All river systems with no more than one-quarter of their main channel length left without dams are considered strongly affected.

The world's two river systems with the largest discharges, the Amazonas-Orinoco and the Congo rivers, are moderately affected, while the third largest, the Yangtze River in China, is strongly affected by fragmentation and altered flows. The largest river remaining unaffected by fragmentation and altered flows is the Yukon River system in Alaska. The other unaffected river systems are mainly smaller catchments in areas with low population densities, such as catchments surrounding the Hudson Bay in Canada and others in southern Chile and Argentina as well as in northern Siberia. Although fewer in number, river systems classified as moderately affected represent, on average, both the largest basins and those with higher discharges. On the other hand, strongly affected systems constitute the majority (52 percent) of total LRS catchment areas, despite contributing less VMAD per system.

At the continental level, Europe has the smallest number (four) and smallest proportion (10 percent) of free-flowing or unaffected large river systems. The highest number (forty) of unaffected LRSs is found in North and Central America, whereas Australasia contains the highest proportion (74 percent) of unaffected systems. In South America, the unaffected systems are on average smaller than affected systems both in discharge and catchment area. The situation is similar in Africa. For example, the moderately affected Congo River (Central Africa) system contributes 51 percent of total African LRS runoff.

This indicator does not address the within-basin distribution of impacts, which can be significant in large basins. For example, the Mackenzie (Northwest Territories, Canada) and the Amazonas-Orinoco systems, which are moderately affected, include extensive, virtually pristine areas as well as strongly affected areas. This within-basin variation is likely to have significant ecological implications. Furthermore, the data used are conservative and represent minimum values, implying that the LRS at a global scale may be more affected than depicted. An example can be seen with the Brahmaputra, a river thought to have more dams in Tibet than official sources report. If true, this would increase the Ganges-Brahmaputra system (Tibet, China, Bangladesh and India) classification to a higher fragmentation level. If irrigation pressure, planned dams and dams under construction are taken into account, the current fragmentation classifications will also change.

Despite gains in information, there are still data gaps that limit our understanding of the relationships between impacts on LRSs and ecosystem conditions. Most river systems in Indonesia, for example, are omitted, along with several in Malaysia, because reliable data are not available. This is particularly unfortunate because the region harbours some of the most unique and rich species assemblages on the planet, representing great conservation potential.

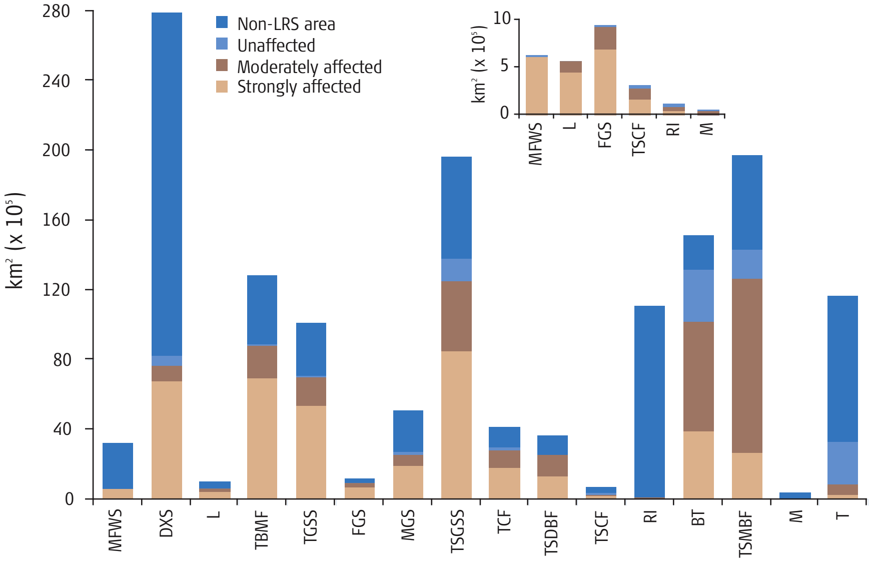
When the fragmentation and flow regulation indicator is correlated with terrestrial biome distribution, as classified by Olson et al. (2001), the analysis shows that unaffected LRS catchments are most represented in large biomes: tundra; boreal forests; tropical and subtropical moist broadleaf forests; and tropical and subtropical grasslands, savannahs and shrublands (see **Figure 5.4**). In fact, tropical and subtropical moist broadleaf forests and boreal forests contain low proportions of strongly affected river systems in terms of area. Smaller biomes retain little or no unaffected large river systems. Strongly affected systems are dominant in three biomes – temperate broadleaf and mixed forests; temperate grasslands, savannahs and shrublands; and flooded grasslands and savannahs – each of which retain less than 1 percent of their total surface area as unaffected LRSs. An important result is that strongly affected catchments alone constitute 80 percent of LRS area in deserts and xeric shrublands, and 99 percent for Mediterranean forests, woodlands and scrubs – highlighting the pressure on these ecosystems from altered river catchments and water abstraction. Furthermore, the eight most biogeographically diverse LRSs[2], spanning seven or more biomes each, are all moderately or strongly impacted.

Dams are often promoted as a means of meeting water and energy needs and supporting economic growth. We can therefore anticipate that the demand for large dams will continue to increase, particularly in regions with high water demand driven by growing populations and agricultural needs. The latest accounts of current dam development support this hypothesis. There are currently 270 dams over 60 m high planned or under construction around the world. Of the LRSs assessed, 46 presently have large dams planned or under construction, with anywhere between 1 and 49 new dams per basin (WWF and WRI, 2004). In addition, interbasin exchange of dam benefits may play a strong role in future decisions about dam construction. For example, over thirteen dams are planned or proposed for the currently unaffected Salween River (Tibet, China and Myanmar), the most imminent of

Approximately nine rivers are at risk of entering a higher impact class: from unaffected to affected, or from moderately to strongly affected

2. The eight most biogeographically diverse LRSs are the Amazonas-Orinoco Basins in South America; the Zambezi in Africa; the Amur, Ob and Yenisey in northern Asia (Russia, Mongolia); and the Irrawaddi, Ganges-Brahmaputra and Indus in Asia.

Figure 5.4: Fragmentation and flow regulation by biome type



Note: The figure represents the distribution of surface area within each of the world's sixteen terrestrial biomes as belonging to unaffected, moderately affected or strongly affected LRSs. Biomes are listed in descending order from left to right by proportion of strongly affected area within LRS-covered area; the inset presents increased resolution of impact class distribution for six biomes with little LRS-covered area.
MFWS = Mediterranean forests, woodlands and scrub; DXS = desert xeric shrubs; L = lakes; TBMF = temperate broadleaf mixed forests;
TGSS = temperate grasslands, savannahs and shrublands; FGS = flooded grasslands and savannahs; MGS = montane grasslands and shrublands; TSGSS = tropical and subtropical grasslands, savannahs and shrublands; TCF = temperate conifer forests; TSDBF = tropical and subtropical dry broadleaf forests; TSCF = tropical and subtropical coniferous forests; RI = rock and ice; BT = boreal forests/taiga; TSMBF = tropical and subtropical moist broadleaf forests; M = mangroves; T = tundra. Grey colour represents non-LRS area, including potential LRSs in Indonesia and Malaysia that were not assessed because of lack of data.

Source: Nilsson et al., 2005.

which (the Tasang Dam on the main stem) is based on international and interbasin benefits and would alone make the Salween moderately affected.

Almost half of the new dams are located on just four rivers: forty-nine on the Yangtze (China), twenty-six on the Rio de la Plata (Argentina and Uruguay), twenty-six on the Tigris-Euphrates (Iraq, Syrian Arab Republic and Turkey), and twenty-five on the Ganges-Brahmaputra (WWF and WRI, 2004). In addition to the Salween, new dams are planned for several other unaffected LRSs, including the Cá and the Agusan rivers in Southeast Asia, and the Jequitinhonha in South America (see **Chapter 14**). Approximately nine rivers are at risk of entering a higher impact class: from unaffected to affected, or from moderately to strongly affected. Some of the impacts of these new dams may be limited by adopting recommendations from the WCD. Understanding and maintaining ecosystem functions in river systems where new dams are planned can be partly achieved by considering and balancing all the social, environmental and economic forces surrounding each dam proposal.

Fragmentation poses serious problems that can, in some cases, more than counteract any of the advantages of dams (see **Box 5.3**). The foregoing analysis identifies three biomes dominated by strongly affected LRSs (temperate broadleaf and mixed forests; temperate grasslands, savannahs and shrublands; and flooded grasslands and savannahs) that deserve immediate action to mitigate the impacts of existing alterations to flow regimes.

A reasonable goal might be to protect remaining unaffected basins from dam construction, as most of the unaffected basins are relatively small and free-flowing because their location and form have not made damming feasible, thereby making them easier to protect. For example, rivers with long, gently-sloping runs instead of large falls do not meet most hydroelectric requirements (see **Chapter 9**). Rivers on large plains, rather than distinct valleys, are also poor sites for constructing impoundments.

The possibility of decommissioning more dams might be considered, especially those that are old and no longer

BOX 5.3: DAMS AND THEIR ALTERNATIVES

The World Commission on Dams report proposed a new decision-making framework to improve the planning and management of dams and their alternatives. One of its strategic priorities, 'sustaining rivers and livelihoods', addresses the need for a basin-wide understanding of ecosystem functions and the livelihoods that depend on them, as well as adopting options and decision-making to avoid impacts, followed by minimization and mitigation of harm to the health and integrity of the river systems. Environmental flows are water flow allocations that are reserved for the river to sustain their ecological functions and species. While the core values and strategic priorities put forward in the report are widely accepted by all major stakeholders, the full set of recommendations, including policy principles and guidelines, has been the subject of dispute among some stakeholder groups and governments, which has limited the extent to which the recommendations have been applied on a global scale. The UNEP Dams and Development Project aims to promote dialogue on improving decision-making, planning and management of dams and their alternatives on the basis of WCD core values and strategic priorities.

Source: WCD, 2000.

fulfil their original purpose, those that have created serious environmental impacts, and those where endangered species and ecosystems face a high risk of extinction. These issues are now beginning to be addressed in some locations. In the US, for example, more dams are being removed each year than are being built. By 2000, 465 dams had been decommissioned in the US, the majority of which were followed by successful ecological and fisheries restoration (Postel and Richter, 2003). In some cases, improved dam operations, such as the implementation of fish ladders, the occasional flooding of downstream areas and the maintaining of minimum river flows, may be more feasible than removal and can also help to restore key habitats.

4c. Pollution

In addition to the pollution that generally accompanies agricultural intensification, aquatic ecosystems are affected by a wide range of pollutants that are leached from the soil, released directly into waterways or deposited from the atmosphere. Domestic and industrial effluents can seriously impact aquatic ecosystems, particularly in developing countries where wastewater treatment is minimal or non-existent and untreated effluents are often discharged directly into waterways. An estimated 80 percent of the pollutants entering coastal waters, mostly from land-based sources, are transported via rivers, and there are clear links between upstream river basins and associated coastal zones (UNEP, 2004b). Furthermore, at least eight of the ten regions defined by UNEP's Regional Seas Programmes[3] with sufficient data report that over 50 percent of their wastewater is still discharged into coastal and freshwaters untreated; and for five of these, it is over 80 percent (UNEP/GPA, 2004). Untreated sewage from municipal sources and animal wastes from agricultural activities also add high concentrations of carbon-rich organic material to these pollutant loads.

Even in the developed world, industrial effluents can have significant negative impacts on aquatic ecosystems (see **Chapter 8**). In the US alone, it is estimated that industry generates about 36.3 billion kg of hazardous organo-pollutants each year, with only about 10 percent disposed of in an environmentally responsible manner (Reddy and Mathew, 2001). Concentrations of organochlorine pesticides, such as DDT and BHC[4], have been declining over the past decade in some countries' surface waters, as regulations to curtail their use have been put in place. Such compounds are the focus of major global studies (e.g. Li and Macdonald, 2005; Ueno et al., 2003), because they are harmful to aquatic biota, persistent in ecosystems, and their derivatives can bio-accumulate in food chains, having potentially significant impacts on animals at the top of these chains. Studies undertaken in the northern rivers of Russia clearly show the degree of decline in both river water quality and Burbot fish (*Lota lota*) (see **Figure 5.5**) (Zhulidov et al., 2002). Similarly, BHC concentrations in China have exhibited a significant decline over time. However, because of their persistence, the impacts of DDT and other organochlorines continue to be seen for many years after their use has been discontinued.

In recent years, there has been a growing concern about the impacts that personal care products[5] and pharmaceuticals are having on water quality and the productivity of aquatic systems and ecological functioning – through the disruption of endocrine systems in fish, for example (UN-WWAP, 2003). Between the 1940s and 1984, it is estimated that over 1 million tonnes of antibiotics were released into the biosphere (Mazel and

3. See www.unep.org/regionalseas/About/default.asp for more information about this programme.

4. Dichloro diphenyl trichloroethane and hexachlorocyclohexane, respectively.

5. This refers to a wide range of products used to, e.g., soften your water, boost the cleaning power of laundry detergents and other household products, skin protecting lotions, deodorants, compounds used to prevent things like shampoos and conditioners from spoiling after purchase, and increasing the protective power of sunscreens.

6. Invasive alien species (IAS) are defined as 'an alien species (species, subspecies or lower taxon, introduced outside its natural past or present distribution; and includes any part, gametes, seeds, eggs or propagules of such species that might survive and subsequently reproduce), whose introduction and/or spread threaten biological diversity' (CBD Decision VI/23).

Davis, 2003). As few studies have been undertaken to quantify the effects of personal care products and pharmaceuticals on components of aquatic ecosystems (e.g. effects on algal assemblages in freshwater, Wilson et al., 2003), very little is known generally about their distribution, fate and effects on aquatic systems and potable water supplies (Jones et al., 2005; Sharpe, 2003).

4d. Invasive species

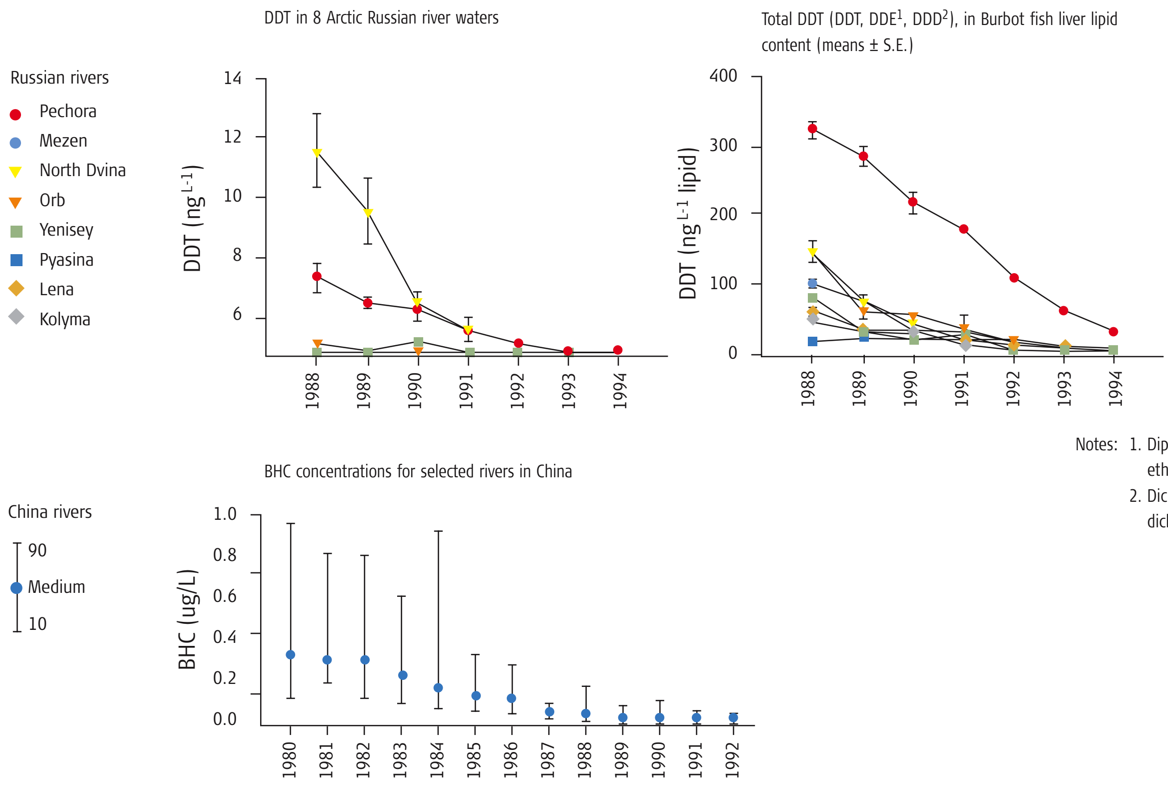
Invasive alien species (IAS) are thought to be the second most important cause of biodiversity loss in freshwater systems after habitat loss and degradation. However in some lake ecosystems, they are now considered by some to be the primary cause of biodiversity loss (Ciruna et al., 2004).[6]

There are many ways in which invasive species can become established in an ecosystem, as a result of political, demographic, cultural, socio-economic or ecological factors. Introductions can either be intentional – through introduction of 'exotic' plants and organisms into gardens or waterways, or government-sanctioned releases of organisms for propagation or harvest – or unintentional, as a result of the escape of aquaculture operations or the accidental transport of organisms attached to boats, structures, garbage or in ballast water.

There appears to be some correlation between levels of human activity, trade, ecological integrity and the resistance of ecosystems to invasion from introduced species (Ciruna et al., 2004). Where ecosystem functions have been degraded, there is generally a greater susceptibility to invasions. Once an IAS has established in a new region, it can cause severe damage to local species and habitats. **Table 5.3** indicates the scale of introductions in different regions.

In Mexico (see **Chapter 14**), for example, of the 500 or so known fish species, 167 are considered to be at risk and, of this total, 76 are thought to be threatened by invasive alien species (Ciruna et al., 2004). Changes in biodiversity through predation and competition for resources can lead to decreased local biodiversity. The Nile Perch (*Lates niloticus*) was originally introduced into Lake Victoria in 1954 to counteract the impacts of overfishing of native

Figure 5.5: Declines in the concentrations of organic contaminants in Russian and Chinese rivers



Notes: 1. Diphenyl dichloro ethylene
2. Dichloro diphenyl dichloroethane

Sources: Russian data: Zhulidov et al., 2002; Chinese data: GEMS/Water www.gemswater.org fish stocks (as seen in **Box 5.1**). However, aggressive competition and predation by this species on the native fish has since resulted in the apparent disappearance of up to 132 endemic fish (Stiassny, 2005). The introduction of the Atlantic comb jellyfish that caused the collapse of fisheries in the enclosed Black Sea is another well documented example of the detrimental effects of IAS (e.g. in UNEP, 2002b). And in the semi-enclosed Mediterranean, the accidentally introduced algae (*Caulerpa taxifolia*) now affects six western Mediterranean and Adriatic countries, covering 13,000 ha of the sea floor over 180 km of shoreline, where it has colonized precious sea-grass beds. IUCN classifies it as one of the 100 most dangerous invading species (Blue Plan, 2005).

Dominant invasive species can cause a rapid decrease in the productivity of the ecosystem. The water hyacinth (*Eichhornia crassipes*) is one of the most aggressive and fastest growing aquatic weeds in the world. Originating in South America, it is now present in more than fifty countries, primarily as a result of its introduction as an attractive ornamental plant. Within a matter of days, water hyacinth infestations can block waterways, preventing the passage of boats and interrupting economic activities, as well as dramatically reducing the availability of light and oxygen in the water – usually killing off endemic species in the process (Lowe et al., 2004).

4e. Climate change

The current and likely future impacts of climate change on coastal and freshwater ecosystems, as outlined by the Intergovernmental Panel on Climate Change (IPCC), are not yet fully understood. Sea-level rise, higher temperatures, greater carbon dioxide concentrations in seawater, increased droughts and floods, and increasingly frequent extreme weather events are all anticipated, with major implications for aquatic ecosystems. Warmer water, combined with anticipated changes in ocean currents, could have a devastating impact on water ecosystems and species diversity. One potential result is a reduction in the upwelling of nutrients, which would in turn reduce productivity in key fishing areas. Decreased growth may also be seen in coral reefs, with high concentrations of carbon dioxide in the water, impairing the deposition of limestone required for coral skeletons. A significant sea-level rise will cause some low-lying coastal areas to become completely submerged, while others will increasingly face high but short-lived water levels. These anticipated changes will have major impacts on coastal habitats and populations. Coastal zones harbour

Table 5.3: Introductions of invasive species by region

Region	Percentage of total recorded invasive species introductions
Europe	25.1
Asia	16.4
Africa	14.7
Oceania	14.7
South and Central America	14.1
Middle East	8.4
North America	6.3

Source: Ciruna et al., 2004.

approximately 38 percent of the global population and nine of the ten most densely populated cities in the world. The most vulnerable coastal nations, as recently assessed by UNEP through a vulnerability index, are Bangladesh, China, India, the Netherlands, Pakistan, the Philippines, the United States and the small island developing states, especially Barbados, Fiji, Haiti, the Maldives and the Seychelles (UNEP, 2005; see also **Chapter 10**).

More detailed scenarios for such areas as North America (Schindler, 1997) and southern Africa (Hulme, 1996) predict major changes, particularly for dynamic shallow-surface water systems, which will in turn affect their biodiversity and the livelihood of the populations that depend on them.

On a global level, polar and arid systems appear to be the most vulnerable to climate change (see also **Chapter 4**). Polar systems store the vast majority of freshwater, and most scenarios suggest they are likely to develop a considerably increased discharge of water, driven by higher temperatures in both the polar regions and particularly in the Arctic (ACIA, 2004). Arid regions are also expected to experience drastic changes.

While global warming may increase productivity in some regions and habitats, the overall predictions are that the impacts of climate change on aquatic ecosystems will be detrimental. Coastal wetlands such as mangroves and coral reefs (Southeast Asia), coastal lagoons (Africa and Europe) and river deltas (the Nile, Niger and Congo in Africa; the Ganges and Mekong in Asia) will be seriously affected by rising water levels, as well as other coastal lowland areas with an elevation of less than 0.5 m (UNEP, 2002c).

The crash of the European eel population (*Anguilla rostrata*) is an example of the detrimental effects of

The current and likely future impacts of climate change on coastal and freshwater are not yet fully understood

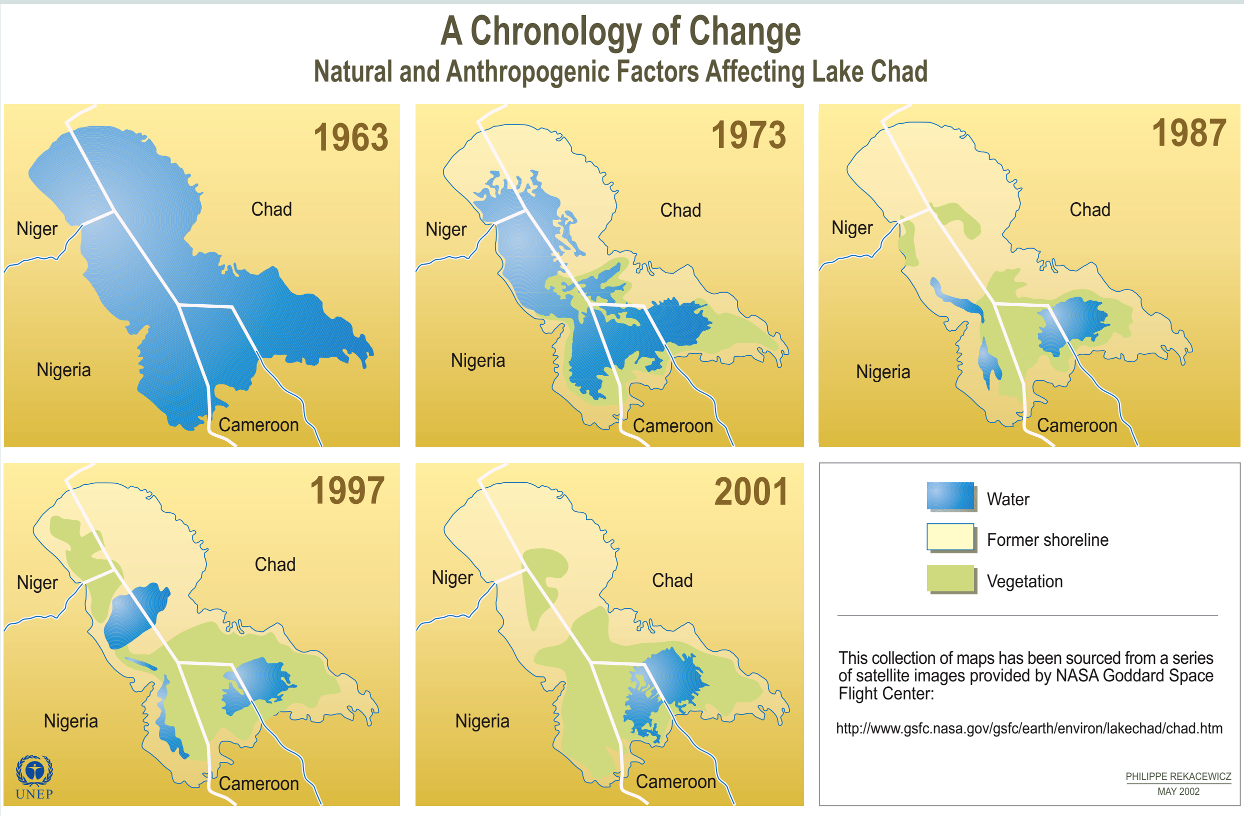
BOX 5.4: BIODIVERSITY IN LAKE CHAD

Lake Chad is 250 metres above sea level and its drainage basin is shared by Cameroon, Chad, Niger and Nigeria. As one of the largest wetlands in Africa, it hosts a biodiversity of global significance. These wetlands were once home to many large mammals, including elephants, hippopotami, gazelle, hyenas, cheetahs and wild dogs and also provided a habitat for millions of migratory birds. The lake supports fish populations that feed local communities and provide an important export trade, with 95 percent of the catch going to Nigeria in a trade worth an estimated US $25 million a year. During the severe drought periods of the 1970s, 1980s and early 1990s, Lake Chad shrunk significantly, from approximately 23,000 km^2 in 1963 to less than 2,000 km^2 in the mid-1980s. The key reasons for this phenomenon have been identified as overgrazing, deforestation contributing to a drier climate and large, unsustainable irrigation projects in Cameroon, Chad, Niger and Nigeria which have diverted water from the lake and the Chari and Logone rivers. Since the 1990s, the lake levels have started to rise as rainfall has increased. However, the Intergovernmental Panel on Climate Change (IPCC) predicts reduced rainfall and increased desertification in the Sahel near Lake Chad, and drought frequencies are likely to increase again. The size of the affected region and the duration of the phenomenon are unprecedented. The changes have contributed to a widespread lack of water, major crop failures, livestock deaths, a collapse of local fisheries, rising soil salinity, and increasing poverty throughout the region. *Alestes naremoze*, a fish species that once made up approximately 80 percent of the catch, is now rare due to the disappearance of its natural spawning beds. Sarch and Birkett report an annual fish catch in the Lake Chad Basin between 1986 and 1989 of 56,000 tonnes, compared to an annual catch of 243,000 tonnes between 1970 and 1977. The implications do not stop in the Sahel.

The decline in migratory bird species, such as the Central European wet grassland waders, including Ruff (*Philomachus pugnax*) and Black-tailed Godwit (*Limosa limosa*), is also related to the changes in conditions in Lake Chad and other wetland areas in the Sahel zone (see **Map 5.4**).

Sources: UNEP, 2004a, 2004c; Nami, 2002; Coe and Foley, 2001; FEWS, 2003; IPCC, 2001; Sarch and Birkett, 2000; Zöckler, 2002.

Map. 5.4: Levels of Lake Chad 1963–2001



Source: UNEP, 2002c, 2004c.

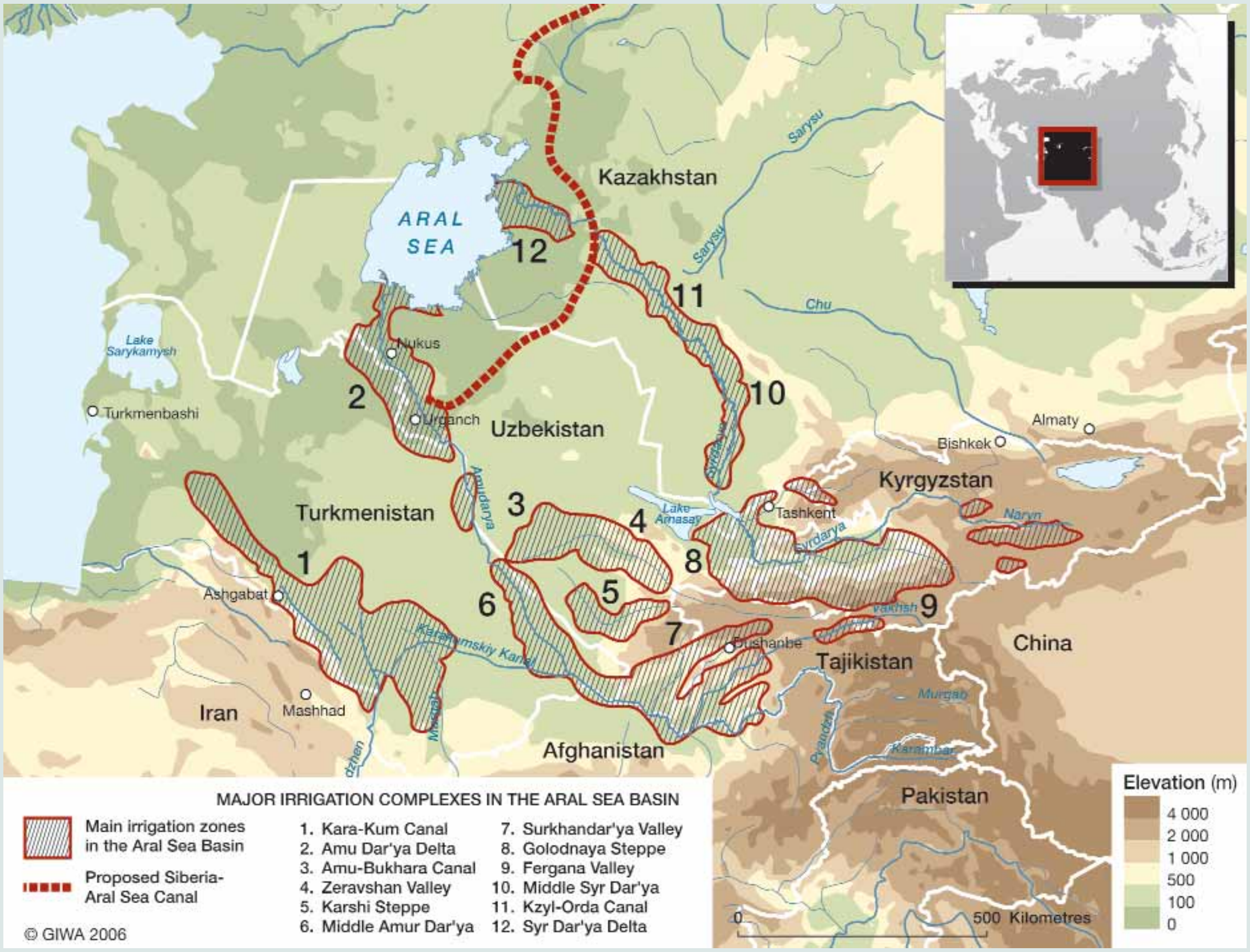
BOX 5.5: DRAMATIC DECLINE OF THE ARAL SEA

In Central Asia, the Aral Sea has also declined dramatically in recent decades, with devastating consequences for both biodiversity and human well-being. **Map 5.5** shows the impact of highly intensive agriculture on the Aral Sea Basin, including the construction of ninety-four water reservoirs and 24,000 km of channels on the Amu Darya and Syr Darya rivers to support the irrigation of 7 million ha of agricultural land. As a direct result of these developments, the volume of water in the Aral Basin has been reduced by 75 percent since 1960. This loss of water, combined with the impact of excessive chemicals from agricultural runoff, has caused a collapse in the Aral Sea fishing industry, a loss of biodiversity and wildlife habitat in the area's rich wetlands and deltas, and an increase in human pulmonary diseases and infant mortality resulting from the high toxicity of the salt concentrations in the exposed seabed. Whereas in 1959 the Aral Sea's fisheries produced almost 50,000 tonnes of fish, by 1994 the annual catch was only 5,000 tonnes. Biodiversity has also declined, with many local species extinctions in the region. The sensitive Turgay riverine forests, once a hotbed of biodiversity, have been reduced to marginal fragments in four nature reserves in Uzbekistan.

Sources: UNESCO, 2000; Postel, 1999; Kreutzberg-Mukhina, 2004.

Stranded boats on the exposed, former seabed of the Aral Sea

Map. 5.5: Major irrigation areas in the Aral Sea Basin



Source: Kreutzberg-Mukhina, 2004.

climate change at the species level. The European eel fishery, which once sustained 25,000 fishermen, has systematically declined over the past thirty years, due in part to climate change and the weakening of the Gulf Stream. By the mid-1980s, the number of new glass eels (eel juveniles) entering European rivers had declined by 90 percent. Recent figures indicate that this level has now dropped to 1 percent of former levels (Dekker, 2003). While the major causes for this drastic decline are believed to be overfishing of eel juveniles for aquaculture operations (particularly in Japan), freshwater habitat loss and degradation, pollution, disease, and changes in climate and ocean currents are also contributing to reducing the number of juveniles (Dekker, 2003). Scientists now believe that the glass eels may be unable to reach Europe because the Gulf Stream has slowed so much that they cannot survive for a sufficiently long period to make the 5,000-mile journey (Brown, 2004).

Dryland areas are naturally vulnerable to water stress. Changes have been well documented for sites such as Lake Chad and the Aral Sea (UNEP, 2002b), which are examined in **Boxes 5.4** and **5.5**, because they illustrate the extreme effects of current ecological changes. For many dryland waters, however, there is little information, including for much of Central Asia, the Middle East, and most parts of Africa.

Part 5. Policy and Management Responses: Implementing the Ecosystem Approach

This chapter has thus far discussed some of the most serious problems facing the world's coastal and freshwater ecosystems, from both a social and an environmental perspective. While recent improvements in some areas suggest that the situation is far from hopeless, failure to address these problems will have immediate social and economic costs and long-term – in some cases irreversible – impacts on biodiversity. It is perhaps not too alarmist to talk about a crisis currently facing water resources management. The following section considers some of the current and potential responses to this crisis.

According to the Global Water Partnership (GWP), current problems of water management often stem from the lack of integrating ecosystem functions and processes into natural resource management efforts. The ecosystem approach is not sufficiently implemented. The GWP also stresses that current management efforts suffer from a widespread lack of governance structures and legal frameworks for integrating the policies that can have a positive impact on the management of water resources. Good water governance exists where the responsible government bodies establish effective policies and legal frameworks to allocate and manage water in ways that are responsive to national and relevant international, social and economic needs, and to the long-term sustainability of the resource base. Such policies need to recognize the finite and sensitive nature of water resources, incorporate notions of the sustainable use of aquatic systems, and negotiate and develop partnerships with relevant stakeholder groups. In this way, government policies can be supported by the population, rather than being opposed and resisted. This suggests that current water management frequently fails to meet these ideals (Rast and Holland, 2003), thus jeopardizing many of the goods and services provided to humanity by healthy aquatic ecosystems.

This is perhaps not surprising; negotiations over freshwater are among the oldest and most intractable problems relating to the use of the Earth's natural resources (see **Chapter 11**). Choices and trade-offs must often be made between a range of potential benefits that could be derived from an aquatic ecosystem. If a particular aquatic system is managed to maximize fisheries production, for example, then benefits that could be derived from the diversion of water for irrigation are likely to be reduced. Different needs have to be balanced within the natural limitations and functions of the ecosystem and between local communities (see **Chapter 12**), and local needs have to be balanced with those of more distant users, who may be far downstream or in recipient coastal areas (see

Chapter 11). Achieving the sustainable use of our readily available water resources in order to equitably share and value them is the reason for developing approaches associated with Integrated Water Resources Management.

5a. IWRM and its implementation challenges

It is becoming increasingly accepted that the most effective approach to the sustainable use of aquatic ecosystems is embodied in the concept of IWRM. A primary difference between the traditional sectoral approach to water management and IWRM is that the latter makes the link between water resources and human activities throughout the hydrological cycle and allows ecological and socio-economic issues to be considered within an ecosystem approach.

IWRM specifically considers the relationships between freshwater and coastal zones, along with other interactions between freshwater, land use and development. It seeks to reduce the negative impacts of development in a river basin through, for example, the use of alternative land-use practices that mitigate damage while maintaining economic and social benefits (Falkenmark et al., 1999; GWP, 2000). At the same time, integrated coastal zone management (ICZM) is widely accepted as the most appropriate policy framework for the coastal–marine interface, while the integrated coastal area and river basin management (ICARM) merges the two. The close link between freshwater and coastal ecosystems is further recognized by the Convention on the Protection and Use of Transboundary Watercourses and International Lakes, the Global Programme of Action (GPA) for the Protection of the Marine Environment from Land-based Activities, and the European Union (EU) Water Framework Directive (UNEP, 2004b).

Some governments and international development and conservation organizations use the integrated river basin management (IRBM) approach, a similar concept to IWRM, which considers the river or lake basin/aquifer as the ecologically defined management unit. The application of IRBM can therefore take place at a variety of scales, depending upon the size of the river basin, ranging from small catchments of a few square kilometres to major national basins (e.g. the Loire and Vistula in Europe), as well as transboundary basins where allocation and pollution issues cross international borders (e.g. Lake Chad and the Danube, Oder and Rhine river basins). Special institutional and governance structures, such as river basin organizations or authorities, have sometimes been established to set operational and legal frameworks within which freshwater resources can be managed to meet different stakeholder interests (see **Chapter 14**).

Although IWRM is simple to envision, experience over the past decade suggests that it is difficult to implement effectively because of the need to integrate a complex, and often competing, combination of elements. These elements can include the following (GWP, 2000):

- land and water issues
- freshwater bodies and downstream coastal zones
- water consumed in the direct production of biomass as opposed to that flowing in rivers and aquifers (green versus blue water)
- surface-water and groundwater resources
- water quantity and quality
- differing water interests upstream and downstream.

IWRM becomes even more complex when transboundary water systems are involved, because this situation frequently requires that one or more countries subordinate some of their national interests in favour of their neighbours' needs (see **Chapter 11**). The World Lake Vision Committee has identified the lack of proper accountability on the part of citizens and governments as one of the most significant root causes of unsustainable water use, along with a general lack of accountable environmental stewardship, inadequate stakeholder participation, and inappropriate or ineffective governmental institutions and regulatory mechanisms (World Lake Vision Committee, 2003).

A series of regional workshops, convened by UNEP in various developing countries to address and redress the fact that IWRM schemes have frequently experienced serious problems, concluded that some of the major barriers to implementing IWRM (Rast, 1999) include the following:

- lack of proper coordination of management activities
- lack of appropriate management tools
- inability to integrate water resources policies
- institutional fragmentation
- insufficiently trained or qualified manpower
- shortfalls in funding
- inadequate public awareness
- limited involvement by communities, non-governmental organizations (NGOs) and the private sector.

Attempts to resolve some of these issues have included the establishment of freshwater and regional seas

...negotiations over freshwater are among the oldest and most intractable problems relating to the use of the Earth's natural resources

Looking beyond freshwaters to consider links with coastal waters has often proved difficult, partly because river managers are often water engineers, concerned with issues of water quantity and quality, food production and flood management

agreements at local, basin or regional levels (e.g. in the Mekong, the Black Sea and the Danube, the Mediterranean, and Lake Chad). While such initiatives have met with some success, they often still lack the policy tools necessary to promote long-term integrated water resources management.

UNEP has proposed four overall principles for the development of such approaches (UNEP, 2004b):

- **An adaptable management structure:** effective institutional management structures must incorporate a certain degree of flexibility, allowing for public input, changing basin priorities, and the incorporation of new information and monitoring technologies. The adaptability of management structures must also extend to non-signatory riparian countries (i.e. those within the same hydrological system) by incorporating provisions that address their needs, rights and potential accession.

- **Clear and flexible criteria for water allocations and quality:** water allocations, which are often at the heart of most water disputes, are a function of water quantity and quality, as well as political fiat. Effective institutions must therefore identify clear allocation schedules and water quality standards, which simultaneously provide for extreme hydrological events, new understandings of basin dynamics, and changing societal values and aquatic ecosystem needs. Riparian states may also consider prioritizing uses throughout the basin. Establishing catchment-wide water precedents may not only help to avert inter-riparian conflicts over water uses, but also to protect the environmental health of the basin as a whole.

- **Equitable distribution of benefits:** this concept, subtly yet powerfully different from equitable water use or allocation, is at the root of some of the world's most successful water management institutions, a noteworthy example being the US-Canada International Joint Commission (IJC, 1998). The idea concerns the distribution of the benefits derived from water use – whether from hydropower, agriculture, economic development, aesthetics, or the preservation of healthy aquatic ecosystems – rather than equal distribution of the water itself. Distributing water-use benefits allows for positive-sum agreements, whereas dividing the water itself among competing users may only allow for winners and losers (see **Chapter 12**).

- **Detailed conflict resolution mechanisms:** many basins may continue to experience disputes even after a treaty is negotiated and signed. Therefore, incorporating clear mechanisms for resolving conflicts is a prerequisite for effective long-term basin management for sustainable water use (UNEP, 2002a; see **Chapter 11**).

Other examples of integrated approaches are recommended for applying water management efforts in areas of water scarcity, as well as those with water abundance. The recommendations of a World Bank report (Abdel-Dayam et al., 2004) on agricultural development include the following:

- Evolving institutions for the governance, management and financing of agricultural drainage, as well as (re)designing physical interventions and technical infrastructure from the perspective of multi-functionality and plurality of values.

- Drafting policies that create environments conducive to change and empower actors to make the necessary changes.

Fortunately, IWRM is becoming increasingly accepted and ingrained in the planning and decision-making processes of water managers and policy-makers. It has become clear that there are great similarities between management issues in coastal and river areas, and the concept of IWRM has been extended from its initial freshwater focus to establish appropriate links to coastal waters. One major impetus towards the adoption of IWRM is the Plan for Implementation from the 2002 WSSD, through which participating governments agreed to develop IWRM and water-efficiency plans by 2005 (see **Chapter 2**). To this end, the GWP is also promulgating principles and approaches to assist governments to meet this deadline (see **Chapter 1**).

Looking beyond freshwaters to consider links with coastal waters has often proved difficult, partly because river managers are often water engineers, concerned with issues of water quantity and quality, food production and flood management. In contrast, much of the concern regarding coastal zones is focused on the impacts of land-based activities on downstream coastal areas. UNEP has promoted this management link since 1999 through its ICARM programme. The FreshCo Partnership was launched at the World Summit on Sustainable

BOX 5.6: THE ECOSYSTEM APPROACH IN ACTION

Quito Catchment Conservation Fund, Ecuador

About 80 percent of Quito's drinking water comes from two protected areas, the Cayambe Coca Ecological Reserve and the Antisana Ecological Reserve. A nominal water use fee on citizens of Quito together with 1 percent of revenues of hydroelectric companies and contributions expected from other sources in the future is used to finance conservation of the reserves.

The Komadugu-Yobe Integrated Management Project, Nigeria

To combat increasing tensions among local stakeholders about scarce water resources in the North Nigerian River Basin, the Nigerian National Council on Water Resources established the Hadejia-Jama'are-Komadugu-Yobe Coordination Committee in 1999, with support from the Komadugu-Yobe Integrated Management Project. The project will establish a framework for broad-based and informed decision-making, based upon agreed principles for equitable use and sustainable management of the Komadugu-Yobe Basin.

European Union Water Framework Directive

This Directive, adopted in 2000, stipulates that EU governments should adopt IRBM to achieve 'good' or 'high' ecological status in all water bodies (coastal and inland) by 2015 (see **Chapter 14**). Status is assessed by indicators measuring departure from natural or pristine conditions for any given category of water body. Data are evaluated against five categories of ecological status, ranging from 'high', representing the absence of anthropogenic disturbance in all variables, or only very minor alteration, to 'bad', reflecting an extensive departure from natural conditions.

Sources: Echavarria, 1997; IUCN, 2003b; EU, 2000.

Development (FreshCo Partnership, 2002)[7] to provide further impetus to this process.

IWRM is increasingly being recognized by the global community, and has become the subject of international commitments and targets that are starting to develop necessary legal and policy frameworks. There is now an urgent need to move beyond these preliminary steps to widespread implementation, and doing this effectively will require developing a series of tools and methodologies or adapting those already used in different biomes and situations. Of equal importance, the partnerships – between governments, communities, NGOs, industry interests and research groups – must move beyond general commitments to specific actions and active, flexible and durable working arrangements. In pursuing these partnerships, it will be essential that the case for conservation be rooted in the most reliable and accessible information on aquatic ecosystems, particularly with respect to their values, uses and flow requirements, and how these properties may vary between basins and ecosystems. Examples for implementing this ecosystem approach are provided in **Chapter 1**.

As demand for water grows with the need for hard decisions to meet this demand, so too will conservation need to be rooted in the soundest possible science.

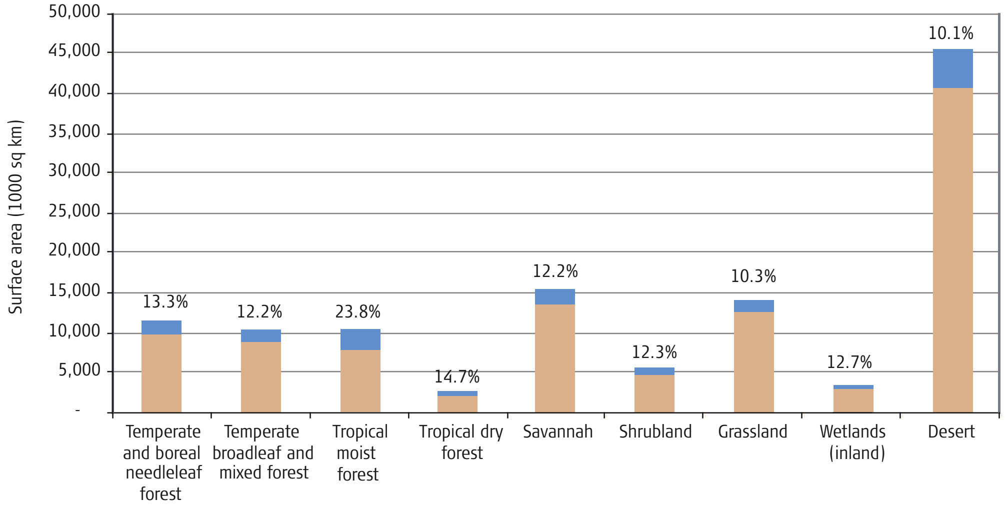
None of these goals will be easy to achieve, but the fact that political commitment is growing along with the recognition of the urgency of these needs provides some cause for cautious optimism.

5b. Protecting and restoring habitats

One management response to pressures on wetlands is to protect a certain proportion through protected areas, such as national parks or wilderness areas. While most such areas are primarily designated to protect their biodiversity values, they can also serve other beneficial functions, such as the protection of fish breeding stocks or of coastlines, flood mitigation and the maintenance of water purity. Protected areas can be an important component within watersheds and coastal ecosystems managed under IWRM approaches. According to the latest report on the state of the world's protected areas (Chape et al., 2004), some 12.7 percent of wetlands are contained within protected areas recognized by the IUCN. Because these figures are based on remote sensing data, smaller wetland protected areas and wetlands classified as other kinds of habitat, such as forests or grassland, may have been missed, and the real degree of protection may be higher (see **Figures 5.6** and **5.7**). If tropical moist forest is included, of which a large proportion is regularly flooded, the value potentially increases to almost 20 percent.

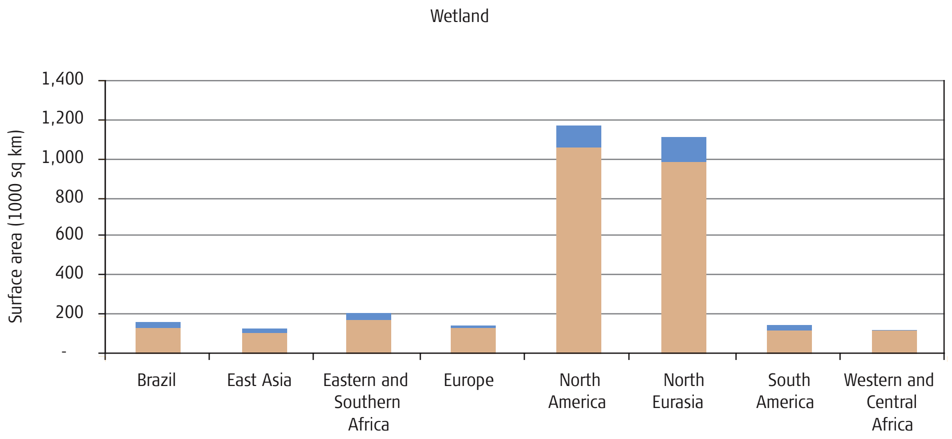
7. See www.ucc-water.org/freshco/ for more information.

Figure 5.6: Surface area and degree of protection of major terrestrial habitats



Source: Chape et al., 2004.

Figure 5.7: Distribution and degree of protection of wetland habitats by region



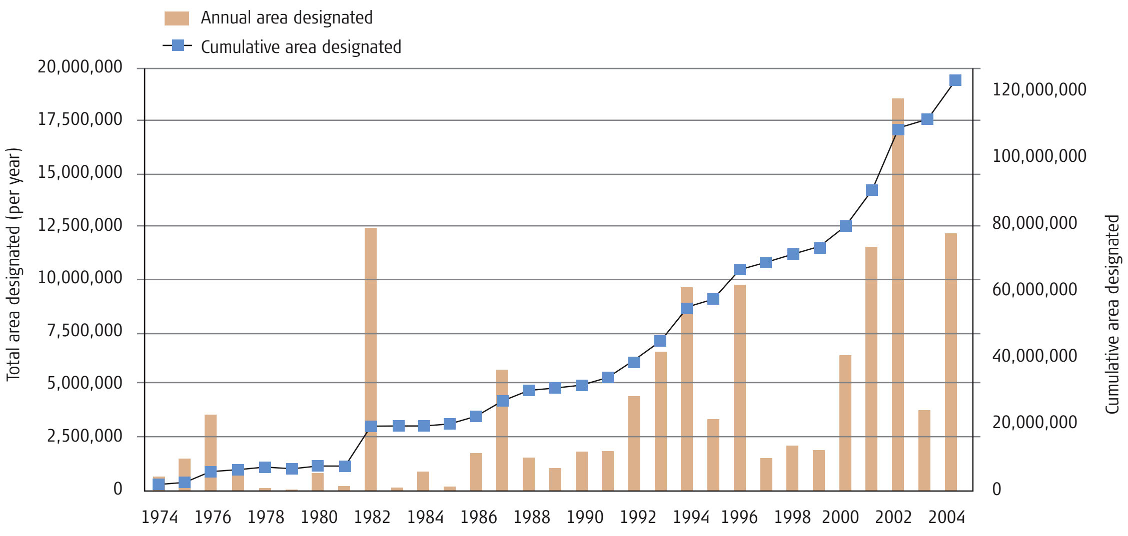
Source: Chape et al., 2004.

In addition to fully protected area status, a number of other important instruments exist to help safeguard freshwater and coastal ecosystems, while integrating their protective functions with other forms of sustainable development.

Ramsar sites

The Ramsar Convention on Wetlands, signed in Ramsar, Iran, in 1971, is one of the oldest intergovernmental treaties explicitly dedicated to the conservation of wetlands. It provides a framework for national action and international cooperation for the preservation and wise use of wetlands and their resources (see **Chapter 12**).
There are presently 144 Contracting Parties to the Convention, with 1,420 wetland sites, totalling 123.9 million ha, designated for inclusion in the Ramsar List of Wetlands of International Importance (See **Figure 5.8**). While many Ramsar sites are also officially protected areas, the Ramsar designation has been used as a 'softer' instrument to generate commitments to sustainable use and guarantee some degree of protection without necessarily ruling out all forms of sustainable development. According to a recent study by the World Bank, the designation of aquatic ecosystems as Ramsar sites is likely to have improved the conservation prospects of these sites for a variety of reasons, including increased awareness of their ecological importance, increased

Figure 5.8: Total area designated as Ramsar sites (1974–2004)



Source: Wetlands International, 2005: www.wetlands.org/RDB/global/AreaTrend.html

conservation funding (both international and domestic), increased participation by local stakeholders in conservation, and reduction of threats (Castro et al., 2002).

African-Eurasian Migratory Waterbird Agreement (AEWA)

Migratory bird species are particularly vulnerable to water degradation and habitat fragmentation. They utilize several different types of habitats, depending on the stage they have reached in their lifecycle and the possibility of unhindered movement between habitats. The Convention on Migratory Species (CMS) is another treaty with particular relevance to aquatic ecosystems, through its role in sustaining migration routes for waterbird species. The Convention helps to inform national and international agreements on the protection of migratory birds, fish and coastal species, such as whales and marine turtles, often also including official or voluntary protection of habitats. The AEWA is the largest agreement developed so far under the CMS, which came into force on 1 November 1999. The agreement covers 235 species of birds that are ecologically dependent upon wetlands for at least part of their annual cycle. The AEWA aims to enhance waterbird protection by establishing a site network and promoting the sustainable use of waterfowl and their habitats (Boere, 2003).

5c. Ecosystem restoration

Efforts to address the serious degradation problems facing many freshwater and coastal ecosystems are already demonstrating that ecosystem restoration is indeed possible. To date, most restoration activities have been initiated and carried out by NGOs, although an increasing number of governments and local communities are now undertaking such projects. Restoration has become a central activity in modern environmental management, as well as a growing stage for long-term sustainable management systems. However, it should be noted that restoration is not a panacea for poor management. Such projects are generally very costly, and some habitats are extremely difficult, if not impossible, to restore. As an example, raised bogs and fen mires are, at best, very difficult to restore, and in some cases, restoration is not possible because irreversible soil changes have occurred. The goal of preventing damage must still be the most important management objective, although restoration remains an important option when damage has already occurred. **Box 5.7** briefly describes some current restoration projects, both large and small, in the very different conditions that characterize Africa, Asia and Europe.

Many more examples of successful freshwater and marine restoration schemes could be cited, from large-scale government initiatives such as the restoration of the

BOX 5.7: RESTORED ECOSYSTEMS AND LIVELIHOODS

Mauritania

The Diawling Delta had been virtually destroyed by a combination of years of low rainfall and the construction of a dam in 1985, leading to an ecological crisis, loss of wetland-dependent livelihoods and the mass migration of its inhabitants. Restoration started in 1991, when the government declared 16,000 ha as a national park. Although the population was initially hostile to the declaration, acceptance of this designation grew as protected area managers and the World Conservation Union (IUCN) staff worked with communities to restore the region's biodiversity and local livelihood options. There is now an agreed management plan, increased management capacity and procedures to resolve resource conflicts. The restoration area covers 50,000 ha, larger than the national park area itself. Artificial flooding began in 1994, with the aim of reconstructing former flooding patterns and saltwater inflow, which has restored a diverse delta ecosystem, with fish catches rising from less than 1,000 kg in 1992 to over 113,000 kg in 1998. Seeds of the restored acacia trees are used in the tanning industry, and the indigenous women once again produce famous traditional mats from *Sporobulus robustus*, a brackish floodplain grass that again grows abundantly. Bird counts have risen from a meagre 2,000 in 1992 to over 35,000 waterbirds in 1998. The total value added to the region's economy as a result of this effort is approximately US $1 million per year.

Mozambique

The Kafue Flats, named after the Kafue River, a tributary of the Zambezi, consist of extensive savannah wetland of approximately 5,600 km^2, where the natural flooding regime was dramatically altered by two dams built in the 1970s. The dams had reduced the flooded area, changed the timing of the flooding, affected wetland productivity and reduced water resources, grazing areas and wildlife and fish populations, as well as the potential for tourism. The World Wide Fund for Nature (WWF) has been working with the Ministry of Energy and Water Development, and the Zambia Electricity Supply Cooperation, in a project that aims to restore the natural flooding regime of the Kafue and, in turn, restore wetland productivity and biodiversity. This can only be achieved by changing the operation rules of both dams. At the end of Phase I in 2002, an integrated river basin management (IRBM) strategy for the Flats was accepted by the Zambian Government. The first results of improvement are anticipated in the next few years.

The Netherlands

In 1982 the Dutch Government funded the creation of small ponds to replace the loss or simplification of natural wetlands and traditional canals. About 600 ponds were created in the first year, immediately colonized by the most common amphibian species, with some also being colonized by rarer species. Several thousand more ponds have been created throughout the country in subsequent years, and an International Pond Project has been launched under the auspices of the EU LIFE fund.

Germany

In order to reverse serious losses in natural habitats, the German Government implemented a programme to conserve and restore sites of national concern. By 2002, a total of fifty-three projects had been initiated, with forty-two of these relating to freshwater and coastal wetland habitats, conserving and restoring more than 180,000 ha. With NGOs or local communities as partners, a large proportion of the approximately US $400 million budget has been used over the past ten years for land purchases, which are often necessary before restoration can begin. In all of these projects, restoration work has started and mostly been completed, covering river stretches, wetland areas and fen mires.

United Kingdom

Restoration does not have to involve governments or international grants, as demonstrated by the increasing number of private reserves and restoration areas in many countries. One British farmer has converted 65 ha of former sugar-beet and wheat crops near the River Cam in East Anglia into a rich, diverse wetland, with meres, reedbeds and wet grassland areas to enrich local biodiversity. Since restoration work began in 1995, the project has resulted in the successful recovery and re-establishment of seventy-nine species of breeding waterbirds, including a rapid increase in the numbers of Lapwings (*Vanellus vanellus*), the establishment of Avocets (*Recurvirostra avocetta*), a colony of Common Terns (*Sterna hirundo*), and the successful breeding of endangered Bitterns (*Botaurus stellaris*) and Marsh Harriers (*Circus aeruginosus*).

Japan

Kushiro River, a Class A river originating in Kussharo Lake in Akan National Park in eastern Hokkaido, winds gently through the expansive Kushiro Swamp before reaching the Pacific Ocean. Its total length is 154 km with a basin dimension of 2,510 km^2, and 180,000 inhabitants in the area, approximately 75,000 of whom live in a flood area. Since salmon and trout run the river and artificial salmon hatching is operated, it is an important river for conservation. Kushiro Swamp, located downstream on the Kushiro River, is the biggest swamp in Japan: 18,000 ha, 5,012 ha of which are registered as a natural monument and 7,863 ha of which are designated under the Ramsar Convention. Located near an urban area, the swamp serves as an important flood barrier as well as a scenic tourist attraction. In the past fifty years, however, this area has decreased by 20 percent, as the swamp slowly gives way to alder forests. The Ministry of Land, Infrastructure and Transport has now joined forces with the Hokkaido Prefectural Government to explore various innovative options for restoring the river and swamp to their former glory. Ongoing research focuses on stream restoration, swamp vegetation management and control of sediment flows.

Sources: Hamerlynck and Duvail, 2003; WWF Mozambique, 2003; Stumpel, 1998; Scherfose et al., 2001; Hokkaido Regional Developement Bureau, 2003; Cadbury, 2003.

Everglades in the US and Australia's Great Barrier Reef, to local-level efforts in the coastal zones of the Mediterranean and Caribbean seas and the Pacific, Indian and Atlantic oceans. In all of these cases, the key aspects that have contributed to their success are as follows:

- the involvement of all stakeholders (government, community groups, environmental organizations, private sector, scientists and others) at all decision levels
- cross-sectoral planning and management (environment, development, agriculture, forestry, urban planning, tourism, public works, etc.)
- an appropriate landscape scale
- sufficient funding (e.g. using tourism returns)
- long-term planning.

Activities can vary widely and complement each other:

- closing damaging industries
- establishing 'no-take' sanctuaries
- banning illegal fishing
- promoting alternative livelihoods through micro-enterprise development
- launching public awareness campaigns
- supporting environmental clean-up
- developing disaster response strategies for oil spills and the like
- regulating tourism
- creating and maintaining mooring schemes.

Positive results do not come overnight, but experiences obtained over the past decade are very promising (UNEP, 2002a, 2004b; WRI, 2000; Bryant et al., 1998; Blue Plan, 2005).

Part 6. Facing Challenges and Managing Trade-offs

Accepted indicators, such as trends in the status of biodiversity, and pollution measurements, such as BOD and nitrate concentrations in water, indicate the continuing deterioration of our coastal and freshwater ecosystems. In addition, the global indicator of river fragmentation and flow regulation presented in this chapter shows that most of the large river systems are strongly or moderately affected by dams and altered flows. For the past decade, despite efforts to minimize or reverse these trends, aquatic ecosystems have continued to deteriorate – with freshwater systems declining at an even faster rate than marine or terrestrial ecosystems. Some specific habitats, such as freshwaters in arid areas and semi-enclosed seas, have been particularly affected. Furthermore, due to a widespread lack of comprehensive and coordinated monitoring programmes, our understanding of the status of many of these ecosystems remains poor or incomplete. The best available information currently focuses on coral reefs, waterbirds, amphibians and marine commercial fish, although even this information remains largely incomplete.

It is critical that we recognize the direct links between the loss of biodiversity and ecosystem degradation and the loss of ecosystem resilience

As demonstrated in this chapter, ecosystem changes do not only concern those interested in biodiversity, but also have direct and immediate impacts on human societies in terms of lost services such as drinking water, food production, employment opportunities, and recreational and aesthetic values. The poorest members of society generally suffer the most when coastal and freshwater are degraded, undermining national and international efforts at poverty alleviation (see **Chapter 1**).

It is critical that we recognize the direct links between the loss of biodiversity and ecosystem degradation and the loss of ecosystem resilience. Biodiversity and the conservation of coastal and freshwater ecosystems are not separate issues from sustaining clean water and food security, but rather an integral part of the same agenda. As such, they must become an integral part of all future plans for water management and restoration.

These problems are now generally recognized by most governments, intergovernmental agencies, non-governmental organizations, major industries and – most crucially – by the communities directly involved. More importantly, there is general agreement regarding the appropriate way to move forward, based on the ecosystem approach and the harmonization of conservation and development through what has become known as Integrated Water Resources Management.

However, despite all the fine words about this approach, the reality is that it has at most been implemented only locally, and even then often reluctantly. Many stakeholders remain ill-informed and unconvinced about the value of the ecosystem approach, and many communities continue to shun long-term benefits and values in favour of destructive short-term gains. Better public information and incentives for stakeholders to act in an 'environmentally friendly' manner are becoming vital if we are to improve the current situation.

The next challenge for national governments and the international community is to start implementing these approaches on a broader scale. Successful implementation will depend on winning the acceptance of the ecosystem approach by the majority of stakeholders and developing and providing implementing tools and applying methodologies to facilitate IWRM, many of which are related to managing the inevitable trade-offs involved. Rather than arguing about whether dams are good or bad, for instance, we need more robust criteria for deciding when they are, or are not, likely to produce net benefits, and how to best build dams to achieve societal needs while sustaining ecosystem functions. Similar tools are needed for weighing the trade-offs of different approaches to agricultural production and tourism. Better monitoring and evaluation systems are also needed to ensure that the impacts of management actions can be tracked over time and adjustments made as necessary. Those involved in managing water resources and ecosystems also need participatory and conflict resolution skills, in addition to greater technical expertise. The relevant organizations, strategies and frameworks for methodologies and partnerships are already being developed in many cases, although the urgency of the problems means that many of these efforts must be further accelerated. A clear, unequivocal lead from governments and the international community is needed to ensure that the good work developing in this critically important area is maintained and enhanced in the future.

Although data on biodiversity and water quality exist for some species groups, habitats and regions, there are still large gaps in the information available on many species, and very little information is available on the extent and quality of aquatic ecosystems. If the global community is serious about monitoring indicators that accurately describe the status of these ecosystems, habitats, species and their protection, in order to evaluate progress towards the WSSD's and Convention of Biological Diversity's 2010 target of reducing the rate of biodiversity loss, considerable improvements in the data quality, formats and geographical coverage are urgently required. Indeed, the ecosystem indicators presented today are only ever as good as the data that support them.

Global warming has caused the Vatnajokull glacier in Iceland to retreat, revealing this spectacular lagoon

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