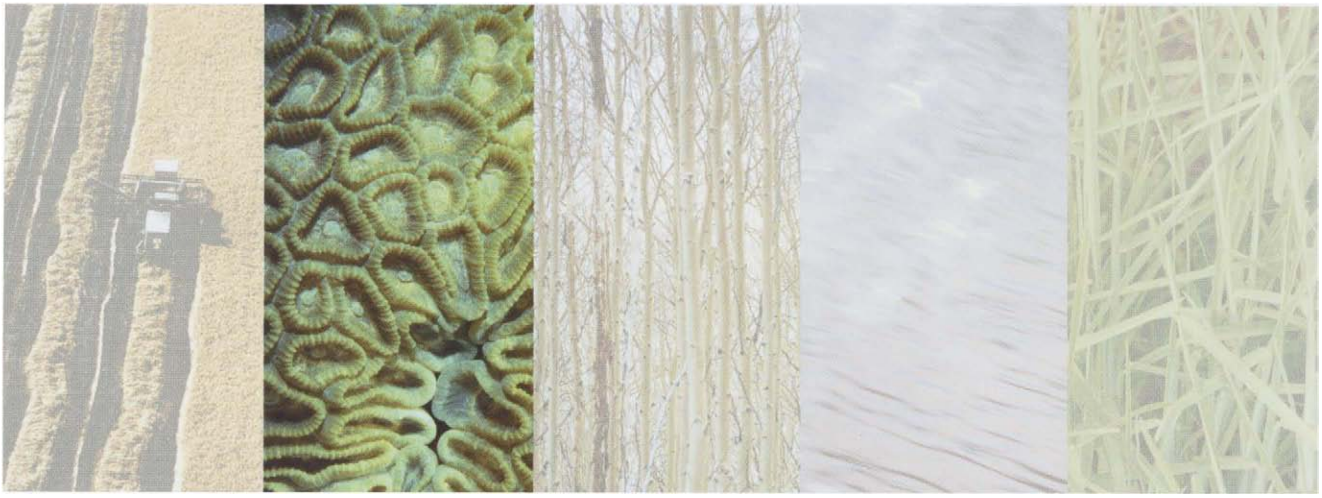

COASTAL ECOSYSTEMS

The continental margins, where coastal ecosystems reside, are regions of remarkable biological productivity and high accessibility. This has made them centers of human activity for millennia. Coastal ecosystems provide a wide array of goods and services: they host the world's primary ports of commerce; they are the primary producers of fish, shellfish, and seaweed for both human and animal consumption; and they are also a considerable source of fertilizer, pharmaceuticals, cosmetics, household products, and construction materials.

Encompassing a broad range of habitat types and harboring a wealth of species and genetic diversity, coastal ecosystems store and cycle nutrients, filter pollutants from inland freshwater systems, and help to protect shorelines from erosion and storms. On the other side of shorelines, oceans play a vital role in regulating global hydrology and climate and they are a major carbon sink and oxygen source because of the high productivity of phytoplankton. The beauty of coastal ecosystems makes them a magnet for the world's population. People gravitate to coastal regions to live as well as for leisure, recreational activities, and tourism.

Extent and Modification

Many different definitions of *coastal zone* are in use. For the purpose of the ecosystem analysis, PAGE researchers define coastal regions as "the intertidal and subtidal areas above the continental shelf (to a depth of 200 m) and adjacent land area up to 100 km inland from the coast." The PAGE analysis of coastal ecosystems also includes marine fisheries because the bulk of the world's marine fish harvest–as much as 95 percent, by some estimates–is caught or reared in coastal waters (Sherman 1993:3). Only a small percentage comes from the open ocean (Box 2.10 Taking Stock of Coastal Ecosystems).

EXTENT

Because the world's coastal ecosystems are defined by their physical characteristics (their proximity to the coast) rather than a distinct set of biological features, they encompass a much more diverse array of habitats than do the other ecosystems in the PAGE study. Coral reefs, mangroves, tidal wetlands, seagrass beds, barrier islands, estuaries, peat swamps, and a variety of other habitats each provides its own distinct bundle of goods and services and faces somewhat different pressures.

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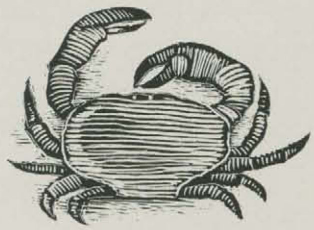
Box 2.10 Taking Stock of Coastal Ecosystems



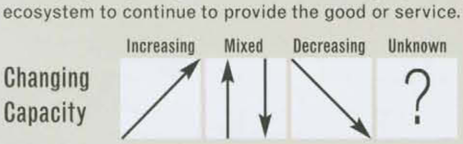
Highlights

- Almost 40 percent of the world's population lives within 100 km of a coastline, an area that accounts for only 22 percent of the land mass.
- Population increase and conversion for development, agriculture, and aquaculture are reducing mangroves, coastal wetlands, seagrass areas, and coral reefs at an alarming rate.
- Fish and shellfish provide about one-sixth of the animal protein consumed by people worldwide. A billion people, mostly in developing countries, depend on fish for their primary source of protein.
- Coastal ecosystems have already lost much of their capacity to produce fish because of overfishing, destructive trawling techniques, and destruction of nursery habitats.
- Rising pollution levels are associated with increasing use of synthetic chemicals and fertilizers.
- Global data on extent and change of key coastal habitats are inadequate. Coastal habitats are difficult to assess from satellite data because areas are small and often submerged.

Key

Condition assesses the current output and quality of the ecosystem good or service compared with output and quality of 20–30 years ago.

Changing Capacity assesses the underlying biological ability of the ecosystem to continue to provide the good or service.



Scores are expert judgments about each ecosystem good or service over time, without regard to changes in other ecosystems. Scores estimate the predominant global condition or capacity by balancing the relative strength and reliability of the various indicators. When regional findings diverge, in the absence of global data weight is given to better-quality data, larger geographic coverage, and longer time series. Pronounced differences in global trends are scored as "mixed" if a net value cannot be determined. Serious inadequacy of current data is scored as "unknown."

Conditions and Changing Capacity

FOOD PRODUCTION

Global marine fish production has increased sixfold since 1950, but the rate of increase annually for fish caught in the wild has slowed from 6 percent in the 1950s and 1960s to 0.6 percent in 1995–96. The catch of low-value species has risen as the harvest from higher-value species has plateaued or declined, masking some effects of overfishing. Approximately 75 percent of the major fisheries are fully fished or overfished, and fishing fleets have the capacity to catch many more fish than the maximum sustainable yield. Some of the recent increase in the marine fish harvest comes from aquaculture, which has more than doubled in production since 1990.

WATER QUALITY

As the extent of mangroves, coastal wetlands, and seagrasses declines, coastal habitats are losing their pollutant-filtering capacity. Increased frequency of harmful algal blooms and hypoxia indicates that some coastal ecosystems have exceeded their ability to absorb nutrient pollutants. Although some industrial countries have improved water quality by reducing input of certain persistent organic pollutants, chemical pollutant discharges are increasing overall as agriculture intensifies and industries use new synthetic compounds. Furthermore, while large-scale marine oil spills are declining, oil discharges from land-based sources and regular shipping operations are increasing.

BIODIVERSITY

Indicators of habitat loss, disease, invasive species, and coral bleaching all show declines in biodiversity. Sedimentation and pollution from land are smothering some coastal ecosystems, and trawling is reducing diversity in some areas. Commercial species such as Atlantic cod, five species of tuna, and haddock are threatened globally, along with several species of whales, seals, and sea turtles. Invasive species are frequently reported in ports and enclosed seas, such as the Black Sea, where the introduction of Atlantic comb jellyfish caused the collapse of fisheries.

RECREATION

?

Tourism is the fastest-growing sector of the global economy, accounting for $3.5 trillion in 1999. Some areas have been degraded by the tourist trade, particularly coral reefs, but the effects of tourist traffic on coastal ecosystems at a global scale are unknown.

SHORELINE PROTECTION

Human modification of shorelines has altered currents and sediment delivery to the benefit of some beaches and detriment of others. Coastal habitats with natural buffering and adaptation capacities are being modified by development and replaced by artificial structures. Thus, the impact from storm surges has increased. Furthermore, rising sea levels, projected as a result of global warming, may threaten some coastal settlements and entire small island states.

Data Quality

FOOD PRODUCTION

Global data on fish landings are underreported in many cases or are not reported by species, which makes assessing particular stocks difficult. Data are fragmentary on how many fish are unintentionally caught and discarded, how many boats are deployed, and how much time is spent fishing, which obscures the full impact of fishing on ecosystems. Many countries fail to report data on smaller vessels and their fish landings.

WATER QUALITY

Global data on extent and change of wetlands and seagrasses are lacking, as are standardized and regularly collected data on coastal or marine pollution. Monitoring of nutrient pollution by national programs is uneven and often lacking. Current information relies heavily on anecdotal observation. Effective national programs are in place in some countries to monitor pathogens, persistent organic pollutants, and heavy metals, but data are inconsistent. No data are available on oil pollution from nonpoint sources.

BIODIVERSITY

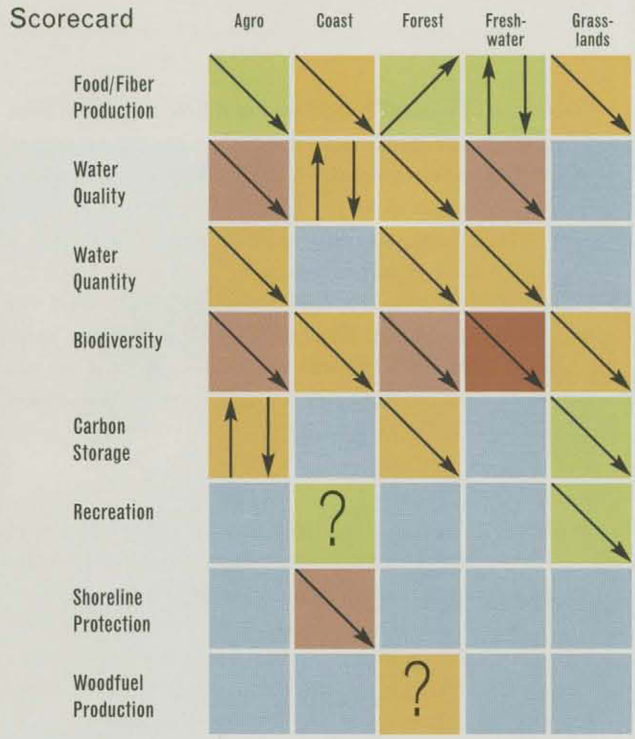
Detailed habitat maps are available for only some areas. Loss of mangrove, coastal wetlands, and seagrasses are reported in many parts of the world, but little is documented quantitatively. Species diversity is not well inventoried, and population assessments are available only for some key species, such as whales and sea turtles. Data on invasive species are limited by difficulty in identifying them and assessing their impact. Few coral reefs have been monitored over time. Information on the ecological effects of trawling is poorly documented.

RECREATION

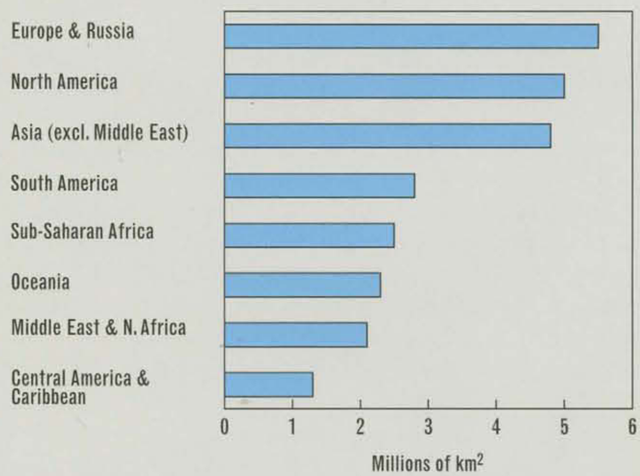
Typically, only national data on tourism are available, rather than data specific to coastal zones. Not all coastal countries report tourism statistics, and information on the impacts of tourism and the capacity of coastal areas to support tourism is very limited.

SHORELINE PROTECTION

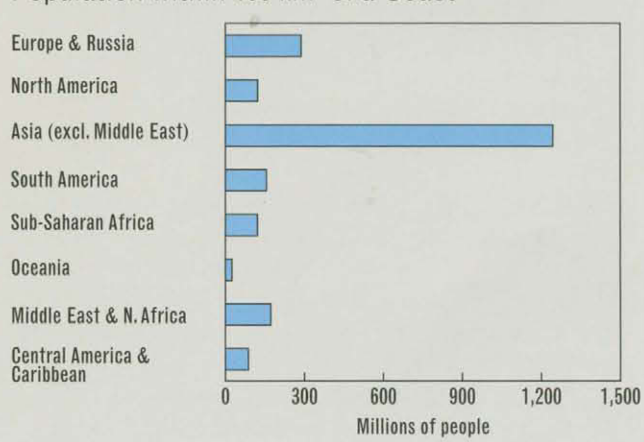
Information on conversion of coastal habitat and shoreline erosion is inadequate. Information is lacking on long-term effects of some coastal modifications on shorelines. Predictions of sea level rise and storm effects as a result of climate change are speculative.



Area within 100 km² of a Coast



Population within 100 km² of a Coast



The extent of coastal ecosystems and how they have been modified over time is less well known than are the extents of the other ecosystems examined in the PAGE study. Individual coastal habitats such as wetlands or coral reefs tend to cover relatively small areas, and detailed mapping is necessary to accurately measure extent or change in these areas. Until the advent of satellite imagery, such mapping was beyond the capacity of most nations. Even today, high-resolution mapping of these systems is imperfect and expensive and has not been attempted at a global scale for the entire 1.6 million km of coastlines (Burke et al. [PAGE] 2000).

MODIFICATIONS

In the absence of such maps, PAGE researchers used satellite imagery to estimate how much coastal area remains in natural vegetation (dunes, wetlands, wooded areas, etc.) versus how much is now urban and agricultural land. Overall, 19 percent of all lands within 100 km of the coast is classified as highly altered, meaning they have been converted to agricultural or urban uses, 10 percent semialtered (involving a mosaic of natural and altered vegetation), and 71 percent are unaltered (Burke et al. [PAGE] 2000) (Box 2.11 Coastal Population and Altered Land Cover).

Mangroves and Coral Reefs

More detailed information is available about the extent and modification of a few coastal habitats, such as mangroves and coral reefs, than is known about the extent of coastal ecosystems. Mangroves line approximately 8 percent of the world's coastline (Burke et al. [PAGE] 2000) and about one-quarter of tropical coastlines, covering a surface area of approximately 181,000 km^2 (Spalding et al. 1997:23). Some 112 countries and territories have mangroves within their borders (Spalding et al. 1997:20). Although scientists cannot determine exactly how extensive mangroves were before people began to alter coastlines, based on historical records, anywhere from 5 to nearly 85 percent of original mangrove area in various countries is believed to have been lost. Extensive losses have occurred in the last 50 years. For example, much of the estimated 84 percent of original mangroves lost to Thailand were lost since 1975 (MacKinnon 1997:167; Spalding et al. 1997:66); Panama lost 67 percent of its mangroves just during the 1980s (Davidson and Gauthier 1993) (Box 2.12 Mangroves). Overall, it is estimated that half of the world's mangrove forests have been destroyed (Kelleher et al. 1995:30). Although the net trend is clearly downward, in some regions mangrove area is actually increasing as a result of plantation forestry and small amounts of natural regeneration (Spalding et al. 1997:24).

Knowledge of the extent and distribution of coral reefs is probably greater than for any other marine habitat. Rough global maps of coral reefs have existed since the mid-1800s because of the hazard they posed to ships. WCMC has compiled a coarse-scale (1:1,000,000) map of the world's shallow coral reefs; more detailed maps exist for many countries. Worldwide, an estimated 255,000 km^2 of shallow coral reefs exist, with more than 90 percent in the Indo-Pacific region (Spalding and Grenfell 1997:225, 227) (Box 2.13 Coral Reefs). Adding deep water reefs would make the total reef area much higher–perhaps more than double the area–but these deeper reefs are poorly mapped.

Both reef-building corals and coral reef fish show broadly similar patterns in the distribution of species richness, with highest species diversity in the Indo-Pacific region and lower diversity in the Atlantic. Currently, on a global basis, coral reef degradation is a more serious problem than outright loss of coral through, for example, land reclamation and coral mining. Nonetheless, coral area has been significantly reduced in some parts of the world.

Other Coastal Ecosystems

No comprehensive global information, and only limited reliable national information, is available to document change in seagrass habitats, peat swamps, or other types of coastal wetlands besides mangroves. Where data do exist, however, the habitat loss is often dramatic. For example, 46 percent of Indonesia's and as much as 98 percent of Vietnam's peat swamps are believed to have been lost (MacKinnon 1997:104, 175). Similarly, the extent of change in seagrass habitats is thought to be high. In the United States, more than 50 percent of the historical seagrass cover has been lost from Tampa Bay, 76 percent from the Mississippi Sound, and 90 percent from Galveston Bay because of population growth and changes in water quality (NOAA 1999:19).

PRESSURES ON COASTAL ECOSYSTEMS

Along with direct loss of area, a variety of other factors are significantly altering coastal ecosystems. Chief among these are population growth, pollution, overharvesting, and the looming threat of climate change.

Population

Globally, the number of people living within 100 km of the coast increased from roughly 2 billion in 1990 to 2.2 billion in 1995–39 percent of the world's population (Burke et al. [PAGE] 2000). However, the number of people whose activities affect coastal ecosystems is much larger than the actual coastal population because rivers deliver pollutants from inland watersheds and populations to estuaries and surrounding coastal waters. As coastal and inland populations continue to grow, their impacts–in terms of pollutant loads and the development and conversion of coastal habitats–can be expected to grow as well.

Pollution

A vast range of pollutants affects the world's coasts and oceans. These can be broadly classified into toxic chemicals (including organic chemicals, heavy metals, and radioactive

(continues on p. 76)

Box 2.11 Coastal Population and Altered Landcover

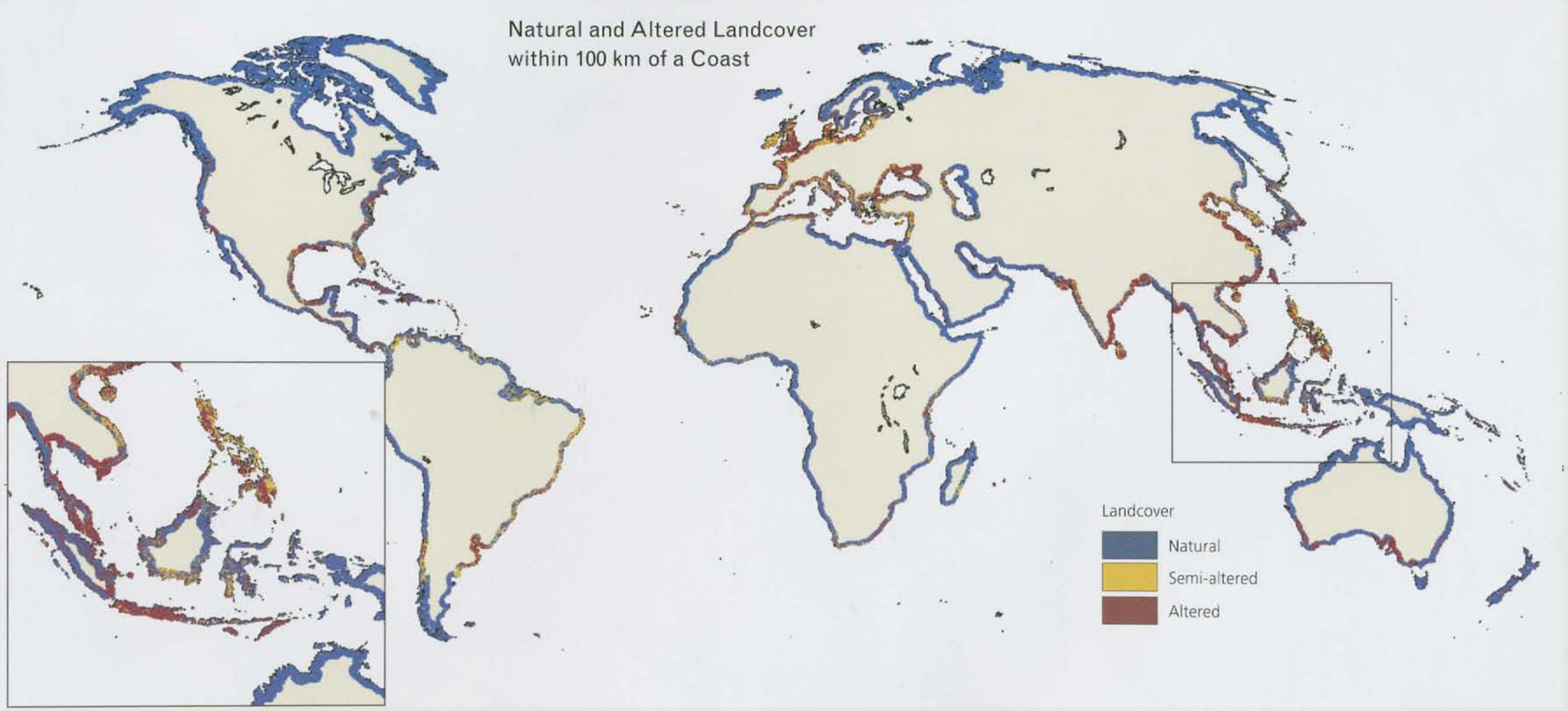
In 1990, 2 billion people lived within 100 km of the sea. By 1995, coastal areas were home to 200 million more, or 39 percent of the population.

Concentrated coastal populations are having a profound impact on marine coastal ecosystems. Much of the shoreline has been developed to meet needs for shelter, subsistence, commerce, and recreation. Even inland populations have an impact on coastal ecosystems. Coastal problems such as algal blooms and eutrophication can be attributed to added pollutants and nutrients from inland freshwater systems.

Overall, 29 percent of all lands within 100 km of a coastline is classified as altered—19 percent is highly altered, converted to agricultural and urban uses; and 10 percent is semialtered, with natural vegetation and cropland interspersed. Some 71 percent remains unaltered.

Population Living Near a Coastline, 1995

Proximity to Coastline	Population (cumulative totals in thousands)	Percentage of Total Population
Within 25 km	1,143,828	20
Within 50 km	1,645,634	29
Within 100 km	2,212,670	39



Sources: Burke et al. [PAGE] 2000. The map is based on Global Land Cover Characteristics Database Version 1.2 (Loveland et al. [2000]). The table is based on CIESIN (2000).

Box 2.12 Mangroves

Mangroves line 8 percent of the world's coasts and about one-quarter of the world's tropical coastlines, covering a surface area of approximately 181,000 km^2 (Spalding et al. 1997:23). Adapted to conditions of varying salinity and water level, they flourish in sheltered coastal areas, such as river estuaries.

Mangroves are crucial to the productivity of tropical fisheries because they act as spawning grounds for a wide range of fish species. They also provide local communities with timber and fuelwood and help stabilize coastlines.

Historical records indicate that the original extent of mangrove forests has declined considerably under pressure from human activity. National proportions of original mangrove cover lost vary from 4 to 84 percent, with the most rapid losses occurring in recent decades. Overall, as much as half of the world's mangrove forests may have been lost (Kelleher et al. 1997:30)

Excessive cutting for fuel and timber as well as clearance for agriculture and shrimp farming and for coastal development have all contributed to these high loss rates. In a few regions, however, mangrove area is actually increasing as a result of plantation forestry and natural regeneration.

Mangrove Area in Selected Countries

Region and Country	Current Extent (km^2)	Approximate Loss (%)	Period
Africa			
Angola	*1,100*	50	Original extent to 1980s
Cote d'Ivoire	640	60	Original extent to 1980s
Gabon	*1,150*	50	Original extent to 1980s
Guinea-Bissau	*3,150*	70	Original extent to 1980s
Kenya	*610*	4	1971–88
Tanzania	*2,120*	60	Original extent to 1980s
Latin America and the Caribbean			
Costa Rica	*413*	–6	1983–90
El Salvador	*415*	8	1983–90
Guatemala	161	31	1960s–90s
Jamaica	106	30	Original extent to 1990s
Mexico	5,315	65	1970s–90s
Panama	*1,581*	67	1983–90
Peru	51	25	1982–92
Asia			
Brunei	200	20	Original extent to 1986
Indonesia	*24,237*	55	Original extent to 1980s
Malaysia	*2,327*	74	Original extent to 1992–93
Myanmar	*4,219*	75	Original extent to 1992–93
Pakistan	*1,540*	78	Original extent to 1980s
Philippines	*1,490*	67	1918–80s
Thailand	1,946	84	Original extent to 1993
Vietnam	2,525	37	Original extent to 1993
Oceania			
Papua New Guinea	*4,627*	8	Original extent to 1992–93

Source: Burke et al. [PAGE] 2000. The table is based on *World Resources 1990–91*; UNEP Kenya Coastal Zone Database (1997), Spalding et al. (1997), Davidson and Gauthier (1993), MacKinnon (1997), World Bank (1989), and BAP Planning (1993). Current extent estimates in italics are not in agreement with recent estimates in the Data Tables in this volume, because of differences in year assessed and methodology.

Box 2.13 Coral Reefs

Coral reefs exist mostly in shallow tropical waters with minimal silt content. Shallow coral reefs occupy only 255,000 km^2 of the world's surface. Nonetheless, they support nearly 1 million species of plants and animals (Reaka-Kudla 1997; Spalding and Grenfell 1997:225). Besides harboring rich biodiversity, coral reefs provide an accessible area for small-scale fishing and help to protect coastlines from storm damage.

Coral reefs are most extensive around the islands and coasts of the Western Pacific and Southeast Asia, which together encompass two-thirds of the world's coral ecosystems. These areas are also the richest in species diversity.

Coral ecosystems are extremely vulnerable to the direct and indirect effects of human activity. In many parts of the world, reef area has been reduced by land reclamation, coastal development, and coral mining. Such direct threats can be combated by extending protected-area status, but the indirect effects of human activity such as increased siltation, pollution, and increases in sea level and temperature are broader in impact and harder to counter.

The mass bleaching of reefs that occurred during the 1997–98 El Niño was the most extensive such event yet recorded. If, as is generally thought, coral bleaching is caused by elevated sea temperatures, global warming is likely to make these events more severe and more threatening to the long-term survival of reefs.

Global and Regional Reef Areas, 1997

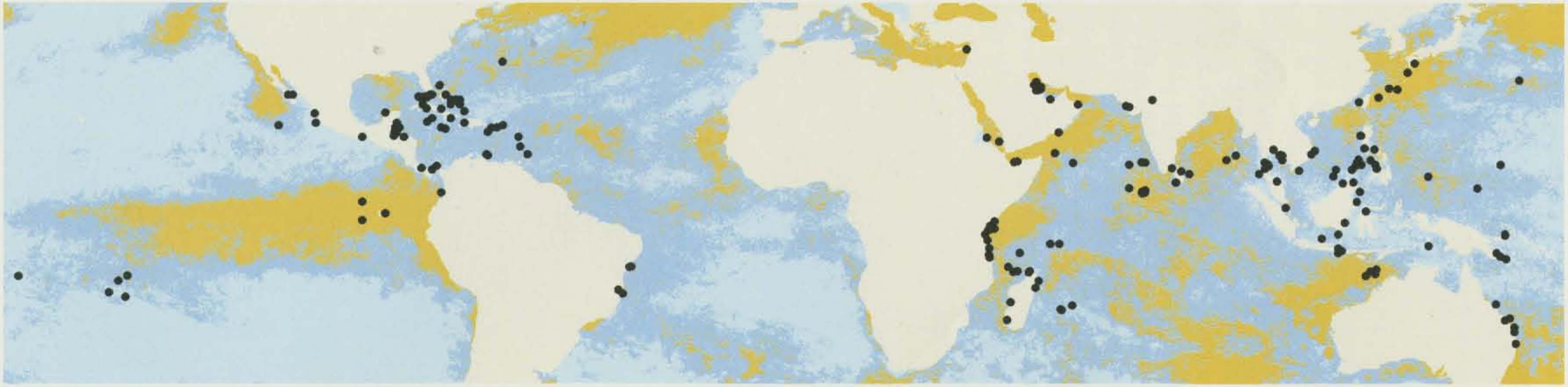
Region	Area (thousands of km^2)	Percentage of Total Area
WORLD	255	100.0
Indo-Pacific	233	91.4
Western Pacific (including Hawaii)	105	41.2
Eastern Pacific	3	1.2
Red Sea	17	6.7
Arabian Gulf	3	1.2
Indian Ocean	36	14.1
Southeast Asia	68	26.7
Atlantic	22	8.6
Wider Caribbean	21	8.2
West Africa	1	0.4

Coral Bleaching Events in 1997–98

● Observed bleaching event

Sea Surface Temperature HotSpots
(degrees over mean maximum monthly climatology)

- 0 - 1
- 1 - 2
- ≥ 2



Sources: Burke et al. [PAGE] 2000. The map shows observations of coral bleaching from NOAA/NESDIS (2000) and WCMC (1999) and sea surface temperature data from NOAA/NESDIS (2000).

waste), nutrients (including agricultural fertilizers and sewage), sediments, and solid waste. The occurrence of bacterial contamination is a special case, often associated with nutrient pollution. Oil pollution (from spills and seepage) includes toxic, nutrient, and sediment-based pollutants.

Most pollution of coastal waters comes from the land, but atmospheric sources and marine-based sources such as oil leaks and spills from vessels also play a role. Approximately 40 percent of toxic pollution in Europe's coastal waters is thought to stem from atmospheric deposition; the percentage could be even greater in the open ocean (Thorne-Miller and Catena 1991:18; EEA 1998:213).

In some regions, such as North America and Europe, heavy metal and toxic chemical pollution has decreased in recent decades as the use of these compounds has decreased, but toxic chemicals continue to be a major problem worldwide (NOAA 1999:14; EEA 1998:216). Some progress has also been achieved in reducing the volume of oil spilled into the oceans. Both the number of oil spills and total amounts of oil spilled have decreased considerably since the 1970s (ITOPF 1999; Etkin 1998:10). Indeed, spills from vessels, although they can be catastrophic, are not the major source of oil pollution; runoff and routine maintenance of oil infrastructure are estimated to account for more than 70 percent of the total annual oil discharged into the ocean (National Research Council 1985:82).

Nutrient pollution, especially nitrates and phosphates, has increased dramatically this century. Greater use of fertilizers, growth in quantities of domestic and industrial sewage, and increased aquaculture, which releases considerable amounts of waste directly into the water, are all contributing factors (GESAMP 1990:96). Some local improvements in nutrient pollution have been achieved through sewage treatment and bans on phosphate detergents (NOAA 1999:iv; EEA 1999:155). However, the Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) identified marine eutrophication, caused by these nutrients, as one of the most immediate causes of concern in the marine environment (GESAMP 1990:3) (Box 2.14 Pollution in Coastal Areas).

Overharvesting

Forty-five years of increasing fishing pressure have left many major fish stocks depleted or in decline. Yet overfishing is not a new phenomenon; it was recognized as an international problem as long ago as the early 1900s (FAO 1997:13). Prior to the 1950s, however, the problem was much more confined, since only a few regions such as the North Atlantic, the North Pacific, and the Mediterranean Sea were heavily fished and most world fish stocks were not extensively exploited. Since then, the scale of the global fishing enterprise has grown rapidly and the exploitation of fish stocks has followed a predictable pattern, progressing from region to region across the world's oceans. As each area in turn reaches its maximum productivity, it then begins to decline (Grainger and Garcia 1996:8, 42–44) (Box 2.15 Overfishing).

Overexploitation of fish, shellfish, seaweeds, and other marine organisms not only diminishes production of the harvested species but can profoundly alter species composition and the biological structure of coastal ecosystems. Overharvest stems in part from overcapacity in the world fishing fleet. Worldwide, 30–40 percent more harvest capacity exists than the resource can withstand (Garcia and Grainger 1996:5). A recent review of Europe's fisheries by the European Union indicates that the fishing fleet plying European waters would need to be reduced by 40 percent to bring it into balance with the remaining fish supply (FAO 1997:65).

Trawling. Not only is harvesting excessive, but many modern harvesting methods are destructive as well. Modern trawling equipment that is dragged along the sea bottom to catch shrimp and bottom-dwelling fish such as cod and flounder can devastate the seafloor community of worms, sponges, urchins, and other nontarget species as it scoops through the sediment and scrapes over rocks. Extent of damage to sea-bottom habitats that have been swept by trawling equipment may be light, with effects lasting only a few weeks, or intensive, with some impacts on corals, sponges, and other long-lived species lasting decades or even centuries (Watling and Norse 1998:1185–1190).

One global estimate puts the area swept by trawlers at 14.8 million km^2 of the seafloor (Watling and Norse 1998:1190). To better estimate the percentage of the continental shelf areas affected by trawling, PAGE researchers mapped the total area of trawling grounds for 24 countries for which sufficient data were available. These countries include about 41 percent of the world's continental shelves. The PAGE analysis shows that trawling grounds covered 57 percent of the total continental shelf area of these countries (Burke et al. [PAGE] 2000) (Box 2.16 Trawling).

Bycatch. Another destructive practice associated with commercial fishing comes from the "bycatch" or unintended catch of nontarget species as well as juvenile or undersized fish of the target species. Some of these fish are kept for sale, but many are discarded and eventually thrown back to the sea, where most die of injuries and exposure. Fisheries experts estimate that bycatch accounts for roughly 25 percent of the global marine fish catch–some 20 million metric tons per year (FAO 1999a:51). In certain fisheries, bycatch can outweigh the catch of target species. For example, in the shrimp capture fishery, discards may outweigh shrimp by a ratio of 5 to 1 (Alverson et al. 1994:24).

Climate Change

Global climate change may compound other pressures on coastal ecosystems through the additional effects of warmer ocean temperatures, altered ocean circulation patterns,

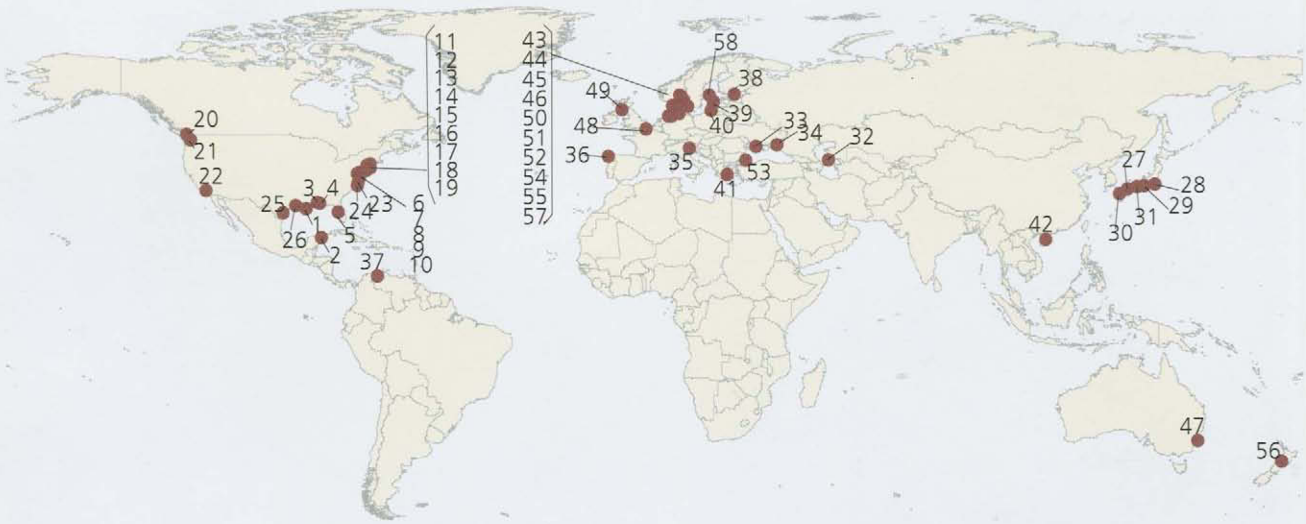
Box 2.14 Pollution in Coastal Areas

Marine nutrient pollution, especially from nitrates and phosphates, has increased dramatically this century largely because of increased use of agricultural fertilizers and growing discharges of domestic and industrial sewage (GESAMP 1990:96). Excessive nutrient concentrations in water can stimulate excessive plant growth—eutrophication. As the plant matter becomes more abundant, its decomposition can reduce oxygen concentrations in the water to less than the 2 parts per million needed to support most aquatic animal life. This not only jeopardizes native species, it also jeopardizes human health, livelihoods, and recreation.

Harmful algal blooms, which consist of algae that produce harmful biotoxins, can also be fueled by excessive nutrient runoff. More than 60 kinds of algal toxins are known today (McGinn 1999), and the number of incidents annually affecting public health, fish, shellfish, and birds has increased from around 200 in the 1970s to more than 700 in the 1990s (HEED 1998).

Hypoxia, the depletion of dissolved oxygen, is also related to nutrient pollution of coastal waters. Fish leave or avoid hypoxic areas and bottom-dwellers such as shrimp, crabs, snails, clams, starfish, and worms eventually suffocate. Current data suggest that hypoxic zones occur most frequently in enclosed waters adjacent to intensively farmed watersheds and major industrial centers off the coasts of Europe, the United States, and Japan.

Global Distribution of Hypoxic Zones



1 Dead Zone
2 Nichupti Lagoon
3 Mobile Bay
4 Perdido Bay
5 Hillsborough Bay
6 Chesapeake Mainstream
7 Potomac River
8 Rappahannock River
9 York River
10 Pagan River
11 Long Island Sound
12 New York/New Jersey Bight
13 Flushing Bay
14 Raritan Bay
15 Barnegatt Inlet
16 Mullica River Estuary
17 Townsend-Hereford Inlet
18 Great Egg Harbor River
19 New York City
20 Puget Sound
21 Saanich Inlet
22 Los Angeles
23 Pamlico river
24 Cape Fear River
25 Corpus Christi Bay
26 Freeport
27 Seto Inland Sea
28 Tokyo Harbor
29 Mikawa & Ise Bays
30 Omura Bay
31 Osaka Bay
32 Caspian Sea
33 Black Sea NW Shelf
34 Sea of Azov
35 Gulf of Trieste
36 Rias Baixas
37 Fosa de Cariaco
38 Gulf of Finland
39 Baltic Sea Channel
40 Bornholm Basin
41 Elefsis Bay
42 Tolo Harbor, Hong Kong
43 Kattegat
44 Laholm Bay
45 Byfjord
46 Gullmarsfjord
47 Port Hacking
48 Sommone Bay
49 Lough Ine
50 German Bight, North Sea
51 Kiel Bay
52 Wadden Sea
53 Marmara Sea
54 Limfjorden
55 Arhus Bay
56 New Zealand
57 Oslofjiord
58 Stockholm Inner Archipeligo

Source: Burke et al. [PAGE] 2000. The map is based on R.J. Diaz, Virginia Institute of Marine Science, personal communication (1999), updating Diaz and Rosenberg (1995).

Box 2.15 Overfishing

Prior to the 1950s, overfishing was confined to heavily fished regions in the North Atlantic, North Pacific, and Mediterranean Sea. Today overfishing is global, and current harvest trends put fishing, as both a source of food and a source of employment, at risk.

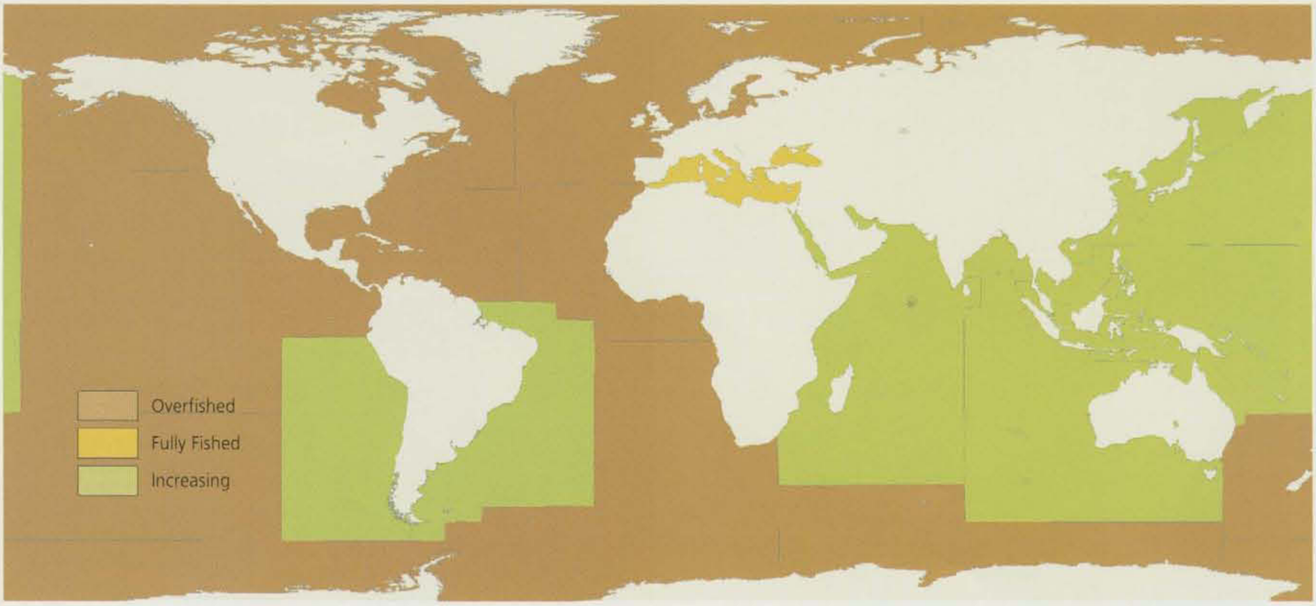
Fish account for one-sixth of all animal protein in the human diet, and around 1 billion people rely on fish as their primary protein source. As demand for fish has increased, many major stocks have declined or have been depleted. FAO reports that as of 1999, more than a quarter of all fish stocks are already depleted as a result of past overfishing or are in imminent danger of depletion from current overharvesting. Almost half of all fish stocks are being fished at their biological limit and are therefore vulnerable to depletion if fishing intensity increased.

Employment within fisheries is likely to change profoundly, especially for small-scale fishers who fish for the local market or for subsistence. Over the past 2 decades, these fishers, who number some 10 million worldwide, have been losing ground as competition from commercial vessels has grown. However, commercial fleets don't face bright prospects, either. Worldwide the fishing industry has 30–40 percent more harvest capacity than fish stocks can support, and the European Union recently estimated that the fleet working in Europe would need to be reduced 40 percent to bring it into balance with the remaining supply of fish.

A History of Decline: Peak Fish Catch vs. 1997 Fish Catch, by Ocean

Fishing Area	1997 Catch (thousand tons)	Maximum Catch (thousand tons)	Year of Maximum Catch
Atlantic			
Northeast	11,663	13,234	1976
Northwest	2,048	4,566	1968
Eastern Central	3,553	4,127	1990
Western Central	1,825	2,497	1984
Southeast	1,080	3,271	1978
Southwest	2,651	2,651	1997
Pacific			
Northeast	2,790	3,407	1987
Northwest	24,565	24,565	1997
Eastern Central	1,668	1,925	1981
Western Central	8,943	9,025	1995
Southeast	14,414	20,160	1994
Southwest	828	907	1992
Indian			
Eastern	3,875	3,875	1997
Western	4,091	4,091	1997
Mediterranean	1,493	1,990	1988
Antarctic	28	189	1971

Fishing Grounds Overfished or Fully Fished, 1994



Source: Burke et al. [PAGE] 2000. The map is based on Grainger and Garcia (1996); analysis is based on landings data collected between 1950 and 1994 for the top 200 species-/fishing-area combinations, which represent 77 percent of the world's marine production, as explained in the technical notes for Data Table 4 in Coastal, Marine, and Inland Waters. Table is based on FAO (1999c, 1999d).

changing storm frequency, and rising sea levels. Changing concentrations of CO_2 in ocean waters may also affect marine productivity or even change the rate of coral calcification (Kleypas et al. 1999). The widespread coral bleaching observed during the 1997-98 El Niño is a dramatic example of the effect of elevated temperatures at the sea surface. Similarly, changes in ocean currents and circulation patterns could dramatically affect the biological composition of coastal ecosystems by changing both the physical characteristics of the habitat–the water temperature and salinity–and the pattern of migration of larvae and adults of different species.

Rising sea level, associated with climate change, is likely to affect virtually all of the world's coasts. During the past century, sea level has risen at a rate of 1.0-2.5 mm per year (IPCC 1996:296). The Intergovernmental Panel on Climate Change (IPCC) has projected that global sea level will rise 15-95 cm by the year 2100, due principally to thermal expansion of the ocean and melting of small mountain glaciers (IPCC 1996:22).

Some of the areas most vulnerable to rising seas are coastal lands whose highest points are within 2 m of sea level, in particular the so-called "lands of no retreat"–islands with more than half of their area less than 2 m above sea level. Rising sea levels will also increase the impact of storm surges. This, in turn, could accelerate erosion and associated habitat loss, increase salinity in estuaries and freshwater aquifers, alter tidal ranges, change sediment and nutrient transport, and increase coastal flooding. River deltas are at risk from flooding as a result of sea-level rise as are saltwater marshes and coastal wetlands if they are blocked from migrating inland by shoreline development (NOAA 1999:20).

Assessing Goods and Services

FOOD FROM MARINE FISHERIES

The forecast for world fisheries is grim despite the fact that fish provided 16.5 percent of the total animal protein consumed by humans in 1997 (Laureti 1999:63). On average this accounts for 6 percent of all protein–plant and animal–that humans eat annually. Approximately 1 billion people rely on fish as their primary source of animal protein (Williams 1996:3). Dependence on fish is highest in developing nations: of the 30 countries most dependent on fish as a protein source, all but four are in the developing world (Laureti 1999:v). In developing countries, production of fish products is almost equal to the production of all major meats–poultry, beef, sheep, and pork (Williams 1996:3).

Global marine fish and shellfish production has increased sixfold from 17 million tons in 1950 to 105 million metric tons in 1997 (FAO 1999c). This rapid growth–particularly in the last 20 years–has come partly from growth in aquaculture, which now accounts for more than one-fifth of the total harvest (marine and inland) (FAO 1999a:10). From 1984 to 1997, aquaculture production in marine and brackish environments tripled and continues to expand rapidly (FAO 1999c). Another 30 percent of the marine harvest consists of small, low-valued fish like anchovies, pilchard, or sardines, many of which are reduced to fish meal and used as a protein supplement in feeds for livestock and aquaculture. Over time, the percentage of the global catch made up by these low-value species has risen as the harvest of high-value species like cod or hake has declined, partially masking the effects of overfishing (FAO 1997:5).

Fish and shellfish production is of global economic importance and is particularly significant for developing countries, where more than half of the export trade in fish products originates (FAO 1999a:21). The value of fishery exports in 1996 amounted to US$52.5 billion, 11 percent of the value of agricultural exports that year (FAO 1999a:20).

Employment

Fishing and aquaculture are major sources of employment as well, providing jobs for almost 29 million people worldwide in 1990 (FAO 1999a:64). Some 95 percent of these fish-related jobs were in developing countries (FAO 1999b). The pattern of employment within the fisheries sector is likely to shift dramatically in coming years, especially for small-scale fishers harvesting fish for local markets and subsistence. Small-scale fishers have been losing ground over the last 2 decades as competition from commercial vessels has grown. Surveys off the west coast of Africa show that fish stocks in the shallow inshore waters where artisanal fishers ply their trade dropped by more than half from 1985 to 1990 because of increased fishing by commercial trawlers (FAO 1995:22). This trend is likely to intensify as fish stocks near shore continue to decrease under heavy fishing pressure.

Ecosystem Condition

The condition of coastal ecosystems, from the standpoint of fisheries production, is poor. Yields of 35 percent of the most important commercial fish stocks declined between 1950 and 1994 (Grainger and Garcia 1996:31). As of 1999, FAO reported that 75 percent of all fish stocks for which information is available are in urgent need of better management–28 percent are either already depleted from past overfishing or in imminent danger of depletion due to current overharvesting, and 47 percent are being fished at their biological limit and therefore vulnerable to depletion if fishing intensity increased (Garcia and DeLeiva 2000).

Another indicator of the condition of coastal fisheries is the relative abundance of fish stocks at different levels of the food web. In many fisheries, the most prized fish are the large predatory species high on the food web, such as tuna, cod, hake, or salmon. When these "top predators" are depleted through heavy fishing pressure, other species lower on the

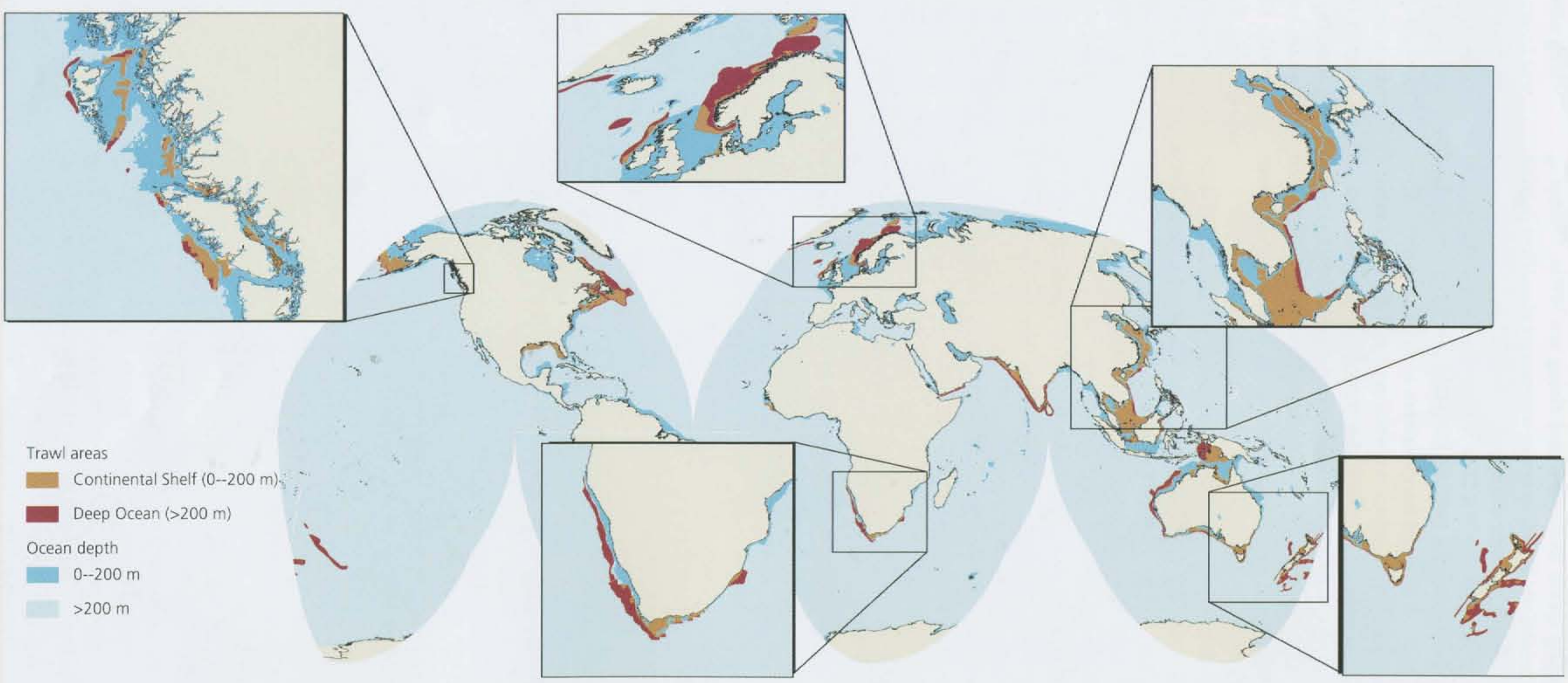
Box 2.16 Trawling

Increasingly, trawling—dragging weighted nets across the sea floor to catch shrimp and bottom-dwelling fish—is taking place beyond the continental shelf. Harvesters are trawling at depths up to 400 m and, in some places, more than 1,500 m. An estimated 14.8 million km^2 of the sea floor is swept by trawlers (Watling and Norse 1998:1190). PAGE researchers mapped the total area of trawling grounds for 24 countries for which sufficient data were available. Trawling grounds in these countries encompass 8.8 million km^2. Extrapolating from these figures suggests that the world's trawling grounds total approximately 20 million km^2, nearly two and one-half times the size of Brazil.

Trawling sea floors is a major source of pressure on the biodiversity of coastal ecosystems. Modern trawling techniques are capable not only of rapidly depleting targeted fish stocks, but also of damaging or destroying nontarget species including corals and sponges. Because deep-living species tend to grow more slowly than shallow-water species, the long-term impact of trawling is magnified as trawl depths increase.

The thick natural carpet of bottom-dwelling plants and animals is important for the survival of the fry of groundfish such as cod, which find protection there (Watling and Norse 1998:1184). Thus, destruction of sea-floor habitats is one of the principal factors in the decline of fishing stocks in heavily trawled areas.

Trawled Areas of the World



Source: Burke et al. [PAGE] 2000. The map is based on McAllister, D., et al. (1999). Data reflect preliminary results of a partial global trawling survey.

food web–plankton eaters–may begin to dominate the fish catch. This pattern of exploitation was described by Pauly et al. (1998) as "fishing down the food web," and it may signal a deterioration in the species structure of the ecosystem.

On behalf of the PAGE study, FAO analyzed global catch statistics for signs of ecosystem change, particularly for signs of "fishing down the food web." The results of the analysis show relatively strong evidence of this exploitation pattern only in the Northern Atlantic. Other regions show shifts in the relative abundance of species; but only in the North Atlantic did fishing practices seem to be the major influence causing this broad-scale ecosystem shift (Burke et al. [PAGE] 2000). In other areas such as the Mediterranean and Baltic Seas, an increase in plankton-eating fish low on the food web may indicate the presence of excess nutrients, which stimulates plankton growth and thus provides a larger food supply for plankton eaters (Caddy et al. 1998).

Continued deterioration of coastal ecosystems and the fish stocks they support could have serious implications for future fish consumption. FAO expects demand for fish and shellfish as a human food source to continue to increase well beyond today's consumption of 93 million tons per year. FAO warns that only under the most optimistic scenario–where aquaculture continues to expand rapidly and overfishing is brought under control so that fish stocks can recover–will there be enough fish to meet global demand (FAO 1999d). If the present deterioration continues, however, a substantial gap between supply and demand will likely develop, raising the price of fish and threatening food security in some regions (Williams 1996:14–15, 25–26).

The Bottom Line for Food Production. Global marine fish stocks still yield significant supplies of fish and shellfish, and marine aquaculture production is growing rapidly. However, current fishing practices show a global pattern of stock depletions and destructive fishing techniques that harm coastal ecosystems. Currently, nearly 75 percent of assessed fish stocks are either overfished or fished at their biological limit and susceptible to overfishing. Other factors, such as water pollution and loss of spawning habitat compound the harm. As a result, the capacity of the world's coastal and marine ecosystems to produce fish for human harvest is highly degraded and is continuing to decline. This could have a significant impact on nutrition and local and national economies in many countries.

WATER QUALITY

Coastal ecosystems provide the important service of maintaining water quality by filtering or degrading toxic pollutants, absorbing nutrient inputs, and helping to control pathogen populations. But the capacity of estuaries and coasts to provide these services can easily be exceeded in at least three ways. First, toxic pollutants can build to levels in fish and shellfish that are harmful to human health. Second, polluted coastal waters can harbor pathogens such as cholera and hepatitis A, which are also significant health hazards. Third, excessive nutrient inputs from agricultural and urban runoff, and sewage effluent, can cause eutrophication, whereby the additional nutrients stimulate rapid growth of algae. This in turn depletes the dissolved oxygen level in the water as it decomposes, which then harms or drives away all but the hardiest species.

Coastal pollution is most commonly measured by how much pollution is being discharged into the sea, such as the number of oil spills or the amount of sewage. However, this does not indicate what effect the pollution is having on coastal ecosystems. Consequently, the PAGE researchers examined several other indicators that better reflect biological changes in coastal ecosystems, although global data are available for relatively few of these indicators.

Oxygen Depletion

One such indicator is oxygen depletion in the water–a condition known as hypoxia. Hypoxia, which is often associated with more severe forms of eutrophication, can be quite harmful to marine organisms, especially sedentary organisms that live on the sea floor. Although historical information on hypoxia is limited, experts believe that the prevalence and extent of hypoxic zones have increased in recent decades (Diaz 1999; Diaz and Rosenberg 1995). One of the most well-known examples of hypoxic conditions is the so-called "Dead Zone" at the mouth of the Mississippi River in the northern Gulf of Mexico. Over the last 4 decades, the amount of nitrogen delivered to the coast by the Mississippi River–which drains the entire midsection of North America–has tripled, helping to create a hypoxic zone that covers 7,800–10,400 km^2 at mid-summer, when the zone is at its worst (Rabalais and Scavia 1999).

Somewhat better historical information exists for algal blooms, which also may be exacerbated by nutrient pollution.

Harmful Algal Blooms

Scientists have assembled information on harmful algal blooms (HABs)–rapid increases in the populations of algae species that produce toxic compounds. More than 60 harmful algal toxins are known today. They are responsible for at least six types of food poisoning, including several that can be lethal (McGinn 1999:21; NRC 1999:52). In the United States, HABs have caused nearly $300 million in economic losses since 1991 from fish kills, public health problems, and lost revenue from tourism and the seafood industry (McGinn 1999:25). From the 1970s to the 1990s, the frequency of recorded HABs has increased from 200 to 700 incidents per year (NRC 1999:52; HEED 1998). Some of this increase may be due to better reporting, since awareness of HABs has been heightened; but much of the increase is real, confirmed in areas with long-term monitoring programs.

Pathogens and Toxic Chemicals

Information about the ecosystem effects of pathogens, toxic chemicals, and persistent organic pollutants is less available than information about nutrient pollution. Limited data are available from some regions of the world–mostly industrialized countries–where programs have been established to monitor shellfish beds to guard against consumption of shellfish contaminated with pathogens. Data from the United States' shellfish monitoring program show gradually improving conditions; 69 percent of U.S. shellfish-growing waters were approved for harvest in 1995, up from 58 percent in 1985 (Alexander 1998:6).

Persistent Organic Pollutants

Persistent organic pollutants (POPs) include a number of chemicals that do not exist naturally in the environment, including polychlorinated biphenyls (PCBs), dioxins and furans, and pesticides such as DDT, chlordane, and heptachlor. POPs persist in the environment and can accumulate through the marine food web or in coastal sediments to a level that is toxic to aquatic organisms and humans.

"Mussel Watch" programs in North America, Latin America and the Caribbean, and France have provided a tool for monitoring changes in POPs (as well as other toxic compounds) in coastal ecosystems. These monitoring programs measure accumulations of toxic compounds in the tissues of mussels, which feed by filtering large quantities of sea water, and thus are prone to accumulate any available toxins. Mussel Watch data indicate that chlorinated hydrocarbons, though still high in coastal sediments near industrial areas and in the fat tissue of top predators such as seals, are now decreasing in some northern temperate areas where restrictions on their use have been enforced for some years (O'Conner 1998; GESAMP 1990:52). However, contamination appears to be rising in tropical and subtropical areas because of the continued use of chlorinated pesticides (GESAMP 1990:37).

↑↓ **The Bottom Line for Water Quality.** Although there is relatively little monitoring of the actual condition of coastal waters (as opposed to the pollutants discharged into them), evidence indicates decreasing capacity of coastal ecosystems to maintain clean water in many regions of the world. In particular, the increased frequency of harmful algal blooms and hypoxia suggests that the capacity of ecosystems in these regions to absorb and degrade pollutants has been exceeded. Only within some of the OECD countries is there evidence of water quality improvements, which appear to be the result of reduced input of certain pollutants such as POPs.

BIODIVERSITY

Only 250,000 of the 1.75 million species cataloged to date in all ecosystems are found in marine environments, but experts believe that the majority of marine species have yet to be discovered and classified (Heywood 1995:116; WCMC In preparation). Life first evolved in the sea, and marine ecosystems still harbor an impressive variety of life forms. Of the world's 33 phyla (groups of related organisms), 32 are found in the marine environment, and 15 of these are found only there (Norse 1993:14–15). Coral reefs are one coastal marine ecosystem often singled out for their high biodiversity. Although coral reefs inhabit less than a quarter of 1 percent of the global sea bottom, they are the most diverse marine environment, with 93,000 species identified so far, and many more yet to be found (Reaka-Kudla 1997:88–91).

Evidence abounds of the significant pressures on coastal biodiversity. The loss of coastal habitats such as mangroves, seagrasses, and wetlands is one direct measure of declining condition of biodiversity in coastal habitats. Coral reefs face degradation at a global scale, with loss of area, overfishing of reef fish, and degradation of near-coastal water quality having inevitable consequences for reef biodiversity. A 1998 study that mapped pressures on coral reef ecosystems concluded that 58 percent of the world's reefs are at risk from human activities, with 27 percent at high risk (Bryant et al. 1998:20).

Invasive Species

One of the most significant changes in the condition of coastal biodiversity has been growth in the number and abundance of invasive species. For example, the marine ecosystems in the Mediterranean now contain 480 invasive species, the Baltic 89, and Australian waters contain 124 species (Burke et al. [PAGE] 2000). A principal source of biological invasion is from the ballast water of ships. On any one day, 3,000 different species are thought to be carried alive in the ballast water of the world's ocean fleets (Bright 1999:156).

The introduction of the Leidy's comb jellyfish from the western Atlantic into the waters of the Black Sea in 1982 provides one of the most dramatic examples of how a nonnative species can impact marine ecosystems. Unchallenged by natural predators in the Black Sea, the Leidy's comb jellyfish proliferated to a peak in 1988 of 0.9–1 billion tons wet weight (about 95 percent of the entire wet weight biomass in the Black Sea). These animals devastated the natural zooplankton stocks, which allowed the unleashing of massive algal blooms. Natural food webs were disrupted, ultimately contributing to the collapse of the Black Sea fish harvest (Bright 1999:157; Travis 1993:1366).

Other causes of biological invasion include intentional introduction of nonnative species for fisheries stocking or even for ornamental purposes, accidental introduction from aquaculture, and species migration through artificial canals, most notably through the Suez Canal from the Red Sea into the Mediterranean and vice versa.

Depletion

Another measure of direct change in the condition of coastal ecosystem biodiversity is the reduced abundance of various commercially important fish species. Excessive harvests of fish reduce their populations, sometimes to the point they become threatened with extinction, at least in substantial portions of their original range. The IUCN Red List of threatened species includes species such as the Atlantic cod, Atlantic halibut, five species of tuna, and yellowtail flounder–all species heavily exploited for food (IUCN 1996:70-88).

Disease

Additional evidence of declining condition of coastal biodiversity is found in the incidence of new diseases in coastal organisms (Harvell et al. 1999:1505). These diseases cause mass mortalities among plants, invertebrates, and vertebrates, including kelp, seagrasses, shellfish, corals, and marine mammals such as seals and dolphins. Better detection of new diseases may be a factor in the increase in reported incidents, but a careful review of the evidence shows that the number of new diseases is indeed rising (Harvell et al. 1999:1505).

Corals provide one of the best examples of the increase in disease incidence in marine ecosystems. A recent worldwide survey has documented more than 2,000 individual coral disease incidents from more than 50 countries. The earliest records date back to 1902, but the vast majority have occurred since the 1970s (Green and Bruckner In press). In Florida, for example, more than a fourfold increase in coral disease has been observed at 160 monitoring sites since 1996 (Harvell et al. 1999:1507). Although the exact causes of these diseases remain unclear, researchers have linked them to the increasing vulnerability of corals caused by stresses such as pollution and siltation.

Coral Bleaching

Coral bleaching provides a direct indicator of the condition of coral reefs. Reef-building corals contain microscopic algae (zooxanthellae) living within their tissues in a mutually dependent partnership. This partnership breaks down when corals are stressed, and one of the most common causes of such stress is exposure to higher-than-normal temperatures. When this happens, corals lose the algae from their tissues and become a vivid white color, as if they had been bleached. Although corals may recover from such an event, they may die if the cause of bleaching reaches particularly high levels or persists for a long period. Temperatures just 1-2°C higher than average in the warm season are sufficient to cause bleaching.

Before 1979, there were no records of mass-bleaching of entire reef systems, but that changed in the last 2 decades. In 1987, 1991, and 1996, mass-bleaching was observed in 6 of the 10 major coral reef provinces of the world. The most recent and widespread bleaching event occurred from late 1997 until mid-1998, during one of the largest El Niño events of this century. Bleaching was recorded in all 10 provinces (Hoegh-Guldberg 1999:8). Coral death reached more than 90 percent in some locations; fortunately, many reefs have since recovered (Salm and Clark 2000:8). Experts believe high water temperatures caused the coral bleaching. There is no way of knowing whether human-induced climate change had any bearing, but researchers believe that the elevated sea temperatures associated with climate change could have this same detrimental effect.

Management Efforts

Evidence of the declining condition of coastal biodiversity has stimulated a number of actions by local communities, NGOs, and national governments to slow the rate of loss of particular habitats and to protect the species that remain. Although PAGE researchers did not attempt to survey the entire array of response measures, one important response has been the rapid growth in the number of marine protected areas. To date, more than 3,600 marine protected areas have been designated throughout the world (WCMC 2000). Even so, the total area under protection still falls well short of the minimum area that many marine scientists believe is necessary for the conservation of marine biodiversity.

The Bottom Line for Biodiversity. The variety of coastal habitats—from coral reefs to kelp beds—gives coastal ecosystems a wide array of species and complex communities. However, many indicators show a significant decline in this biodiversity. Degradation and area loss affect all major habitat types such as mangroves, seagrasses, coral reefs, and coastal wetlands. Invasive species have made significant inroads in many marine environments, especially near ports and other highly trafficked areas. Heavily exploited fish species such as cod and haddock have recently been listed as threatened species. Disease incidence among marine mammals and coral reefs has risen dramatically, as have coral bleaching events. Overall, the capacity of marine ecosystems to support their normal biodiversity has been greatly diminished.

SHORELINE PROTECTION

The economic and human costs of coastal storm damage are growing as more people expand into coastal settlements and put lives and property at risk. Economic losses in Europe from floods and landslides between 1990 and 1996 were four times greater than the losses suffered in the 1980s and more than twelve times those of the 1960s (EEA 1998:274). From 1988 to 1999, the United States sustained 38 weather-related disasters causing damage that reached or exceeded $1 billion each, for a total cost in excess of $170 billion (NCDC 2000). In both Europe and the United States, many of these weather-related natural disasters involved flooding in coastal areas or, in the case of the United States, hurricane impacts in coastal regions. Worldwide, more than 40 million people per year are currently at risk of flooding due to storm surges (IPCC 1996:292).

Healthy coastal ecosystems cannot completely protect communities from the impacts of storms and floods, but they do play an important role in stabilizing shorelines and buffering coastal development from the impact of storms, wind, and waves. For example, Sri Lanka spent US$30 million on revetments, groins, and breakwaters in response to severe coastal erosion that occurred in areas where coral reefs were heavily mined (Berg et al. 1998:630). Japan spent roughly 4.5 trillion yen (US$41 billion) on shoreline protection projects from 1970 to 1998 (Japanese Ministry of Commerce 1998).

For many countries, protection of coastal ecosystems is likely to be one of the most cost-effective means of protecting coastal development from the impact of storms and floods. Clearly, with the substantial loss in extent of various coastal ecosystems, the ability to provide this service of shoreline protection has significantly diminished in most nations.

The Bottom Line for Shoreline Protection. There is no doubt that the dramatic loss of coastal habitats around the world has diminished the capacity of coastal ecosystems to protect human settlements from storms. There are few estimates of how great the economic cost of the loss of this service might be, but losses from storm damage already cost billions of dollars annually. With intensive development of the world's coasts proceeding rapidly, the value of the coastal protection service will undoubtedly rise quickly, too.

COASTAL TOURISM AND RECREATION

Travel and tourism, encompassing transport, accommodation, catering, recreation, and services for travelers, is the world's largest industry and the fastest growing sector of the global economy. The World Travel and Tourism Council projected travel and tourism would generate US$3.5 trillion and account for more than 200 million jobs in 1999–about 8 percent of all jobs worldwide (WTTC 1999). In most countries, coastal tourism is the largest sector of this industry and in a number of countries, particularly small island developing states tourism contributes a significant and growing portion to GDP and foreign exchange. Travel and tourism in coastal zones can promote both conservation and economic development, if properly managed.

Most statistics related to tourism are aggregated by country, and agencies and organizations compiling statistics typically do not distinguish inland from coastal tourism. With this in mind, PAGE researchers chose the Caribbean–where the vast majority of tourism is coastal or marine in nature–to assess the condition of coastal ecosystems with regard to their potential to support the recreation and tourism industry.

In 1998, travel and tourism in the Caribbean accounted for more than US$28 billion or about 25 percent of the region's total GDP. The industry provided more than 2.9 million jobs in 1998 (more than 25 percent of all employment), with projections in excess of 3.3 million jobs by 2005 (WTTC/WETA 1998). The number of tourists arriving in the Caribbean is growing rapidly. Over the next decade, tourist arrivals are expected to increase by 36 percent (Caribbean Tourism Organization 1997).

Ecotourism

Different types of tourism differ in their benefits to local economies as well as in their environmental impacts. In the Caribbean, for example, most of the prosperous hotels are large resorts; nature-based tourism (ecotourism) is a small niche market. Worldwide, relatively few local communities have realized significant benefits yet from nature-based tourism on their own lands or in nearby protected areas. The participation of local communities in nature tourism has been constrained by a lack of relevant knowledge and experience, lack of access to capital for investment, inability to compete with well-established commercial operations, and simple lack of ownership rights over the tourism destinations (Wells 1997:iv).

Protected areas often supply the most valuable part of the nature tourism experience, but capture little of the economic value of tourism in return (Wells 1997:iv). Although many governments have successfully increased tourist numbers by marketing their country's nature tourism destinations, most have not invested sufficiently in managing those natural assets or in building the infrastructure needed to support nature tourism. Thus sensitive sites of ecological or cultural value have been exposed to risk of degradation by unregulated tourism development, too many visitors, and the impact of rapid immigration linked to new jobs and business opportunities (Wells 1997:iv–v) (see Box 1.15 Ecotourism, pp. 34-35).

Tourism Related Pressures

Tourism has a tremendous potential to bring economic prosperity and development, including environmental improvements, to the destinations in which it operates. However, poorly planned and managed tourism can harm the very resources on which it is based. Adverse impacts of tourism in the Caribbean include scarring mountain faces with condominium and road construction; filling wetlands and removing mangrove forests for resort construction; losing beach area and lagoons to pollution and to sand mining, dredging, and sewage dumping; and damaging coral reefs with anchoring, sedimentation, and marina development (UNEP/CEP 1994). A 1996 Island Resources Foundation study found that tourism was a major contributor to sewage and solid waste pollution in virtually every country in the Caribbean, as well as the prime contributor to coastal erosion and sedimentation (IRF 1996). Since the success of tourism in the Caribbean has been built on the appeal of excellent beaches and a high-class marine environment suitable for a range of outdoor activities, this inattention to the harmful impacts of tourism itself directly threatens the industry's growth in the region.

? **The Bottom Line for Tourism and Recreation.** Information is not available to accurately judge whether the capacity of coastal ecosystems to support tourism is being diminished at a global scale. However, in some areas, such as parts of the Caribbean region, there is clear evidence of degradation. Nonetheless, this industry has the potential—and indeed incentive—to bring long-term sustainable benefits to coastal communities without degrading the resource on which it depends.