Trends in U.S. Coastal Regions, 1970-1998

Addendum to the Proceedings, 'Trends and Future Challenges for U.S. National Ocean and Coastal Policy'

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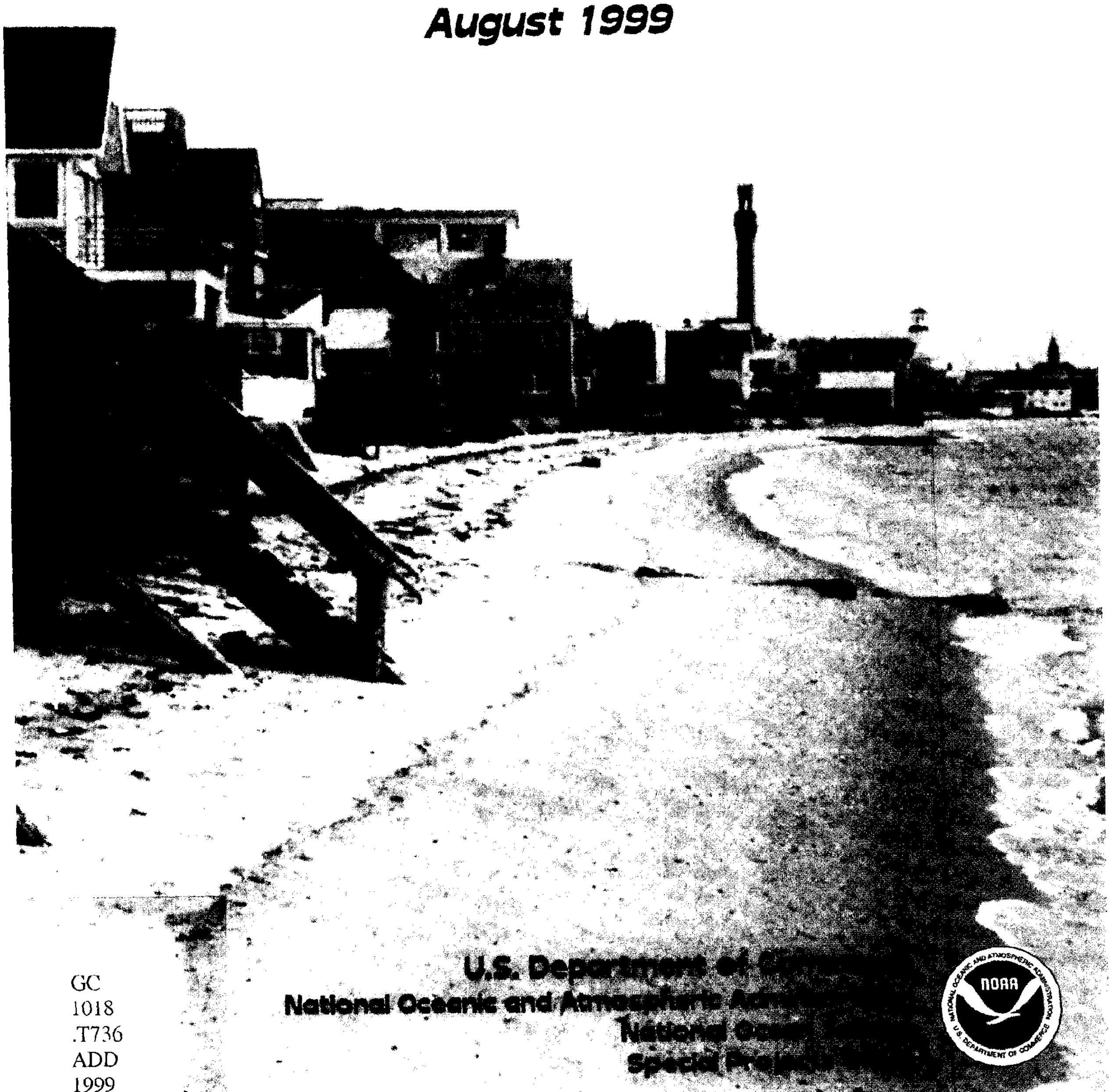

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About This Report

This report examines underlying and emerging trends that are shaping the coast, coastal resources and uses, and coastal management and policy. Past and projected trends are presented in population and settlement; economic activity; social values; resources; environmental quality; hazards; and governance and management. An effort is made to use enough contextual information so that the data convey a story about the present and future of the nation's coasts.

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For More Information

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Executive Summary

Coastal areas are invaluable for their economic vitality and biological diversity. At the same time, the coasts are under considerable pressure. This paper examines underlying and emerging trends that are shaping the coast, coastal resources and uses, and coastal management and policy. Present and projected trends are discussed in population and settlement; social values; economic activity; resources; environmental quality; hazards; and governance and management.

Coastal population and settlement. Population growth and its associated impacts may be the most critical issue confronting coastal managers and decision-makers. Coastal areas are crowded and becoming more so. About half the nation's population presently resides in the narrow fringe of coastal counties. From 1996-2015, the coastal population is projected to increase from 141 million to 166 million. Population growth and consequent increases in settlement densities bring jobs, create economic prosperity, add new industry, improve regional infrastructures, enhance educational opportunities, and increase tax revenues—but they also burden local environments. As coastal populations swell, the natural features that may have attracted people to the coast are lost or diminished. Population pressures lead to increased solid-waste production, higher volumes of urban runoff, losses of green space and wildlife habitat, declines in ambient water quality, and increased demands on wastewater treatment, potable water, and energy supplies. To control these kinds of impacts, states and localities have begun to channel public investment for infrastructure into areas that are best able to accommodate growth without deleterious environmental impacts.

Social trends. Thirty years ago, most Americans believed that resources were essentially infinite and could be exploited forever. Today, in contrast, marine and coastal resources are known to be finite, and capable of being harmed or lost by human activities. As shown by national polling data, the transition of the environment from an issue of limited concern to one of universal concern occurred years ago. Moreover, the public understands the ocean's importance to human health, and demonstrates a sense of responsibility to protect the ocean for present and future generations. Coincident with the evolution of public attitudes that favor ocean protection, nongovernmental organizations have risen to work with both landowners and government agencies to conserve and manage the environment, and they have considerable technical and managerial capabilities and resources.

Economic and resource trends. Marine-related economic activities in the coastal zone and coastal ocean account for up to two percent of the U.S. Gross National Product and are comparable in scope to other important sectors of the economy, such as agriculture. Recreation and tourism, waterborne commerce, energy and mineral production, and fisheries account for most economic activities along the coast.

- **Recreation and tourism**. Outdoor recreation and tourism are the most significant economic activities in the coastal zone, accounting for half or more of total ocean-related economic activity. Despite the diversity and scope of recreational activities—from birdwatching, to boating-based sports, to second-home developments—little information is available on coastal and marine recreation and tourism, its scope, importance, and impacts. Interestingly, the government plays an important role in providing the underlying conditions for marine recreation and tourism. These include (1) ensuring a clean environment, (2) assuring coastal access, and (3) promoting a safe operating environment. Given the economic importance of marine recreation and tourism, and the importance of the government role in providing the basic underlying conditions for these activities, much more could be done to understand, document, manage, and promote marine recreation.

- **Waterborne commerce.** U.S. waterborne foreign trade is projected to continue to grow at an average annual rate of 3.7 percent. Domestic waterborne trade is also growing, and becoming more diverse—the shifting of freight cargoes from ships to barges, and the growth in passenger traffic, especially ferries and day boats, are prominent domestic trends. The focus of all this activity is the major ports (about 145 of them), each of which handles more than 9 million metric tons of cargo annually. These ports need to keep pace with the growth in trade, and other changes in ships and shipping. U.S ports are affected by important changes in two areas: (1) the rapidly changing intermodal freight transportation market, which moves increasing amounts of cargo on ever more demanding schedules, and (2) the increasing number and complexity of environmental regulations that pertain to ports. The U.S. Department of transportation and other agencies have initiated a coordinated national effort to highlight trends, promote coordination at the national level, and encourage local solutions. This will help ensure adequate port infrastructure, including appropriate channel and berth depths, real-time navigation information, modern port facilities, and efficient intermodal connections.

- **Energy and minerals resources and production.** About 19 percent of the nation's produced oil comes from federal offshore lands. Moreover, revenues and royalties earned on this production are a significant source of revenue for the federal government. Heightening the importance of the oceans to the U.S. energy supply is the fact that about 50 percent of oil consumed is imported by ship, and the reliance on imported petroleum is slated to grow to 60 percent by 2010. An increasing fraction of domestic offshore oil and gas is being discovered and produced from wells drilled in deep water, especially in the Gulf of Mexico. Rapid and dramatic technology advances, coupled recently with relief from paying royalties on deepwater production, have combined to encourage the trend toward deep water production. Current models suggest that federal offshore lands contain 50 percent of the nation's remaining undiscovered oil and gas resources; offshore oil production rates are projected to increase by at least 10 percent between 1995 and 2000.

- **Fishery resources and food supply.** U.S. fishery landings have increased over the past 50 years, but have now reached the maximum capacity of our oceans and coastal waters to produce fish. While landings in Alaska have increased dramatically, they have declined in other regions for many species. In addition, for some marine species, recreational landings represent a significant and growing proportion of the catch. The challenge in fisheries management is to achieve sustainable fisheries over the long-term. To accomplish this, it is necessary to end overfishing and allow depleted stocks to rebuild.

  The acreage of designated shellfishing waters is at an all-time high. At the same time, health restrictions on these waters are at their lowest levels since 1980. Overall, the condition of shellfish harvest waters is improving.

  The degradation and loss of coastal habitats, with other factors such as overfishing, are constraining the contribution of fisheries to world dietary needs at a time when population growth and rising affluence are increasing the demand for food. Aquaculture holds some promise as an alternative to wild harvest, but has environmental problems of its own.

Environmental quality. Coastal oceans and estuaries are among the most productive and valuable natural systems. They are also among the most threatened. Environmental stressors include nutrient overenrichment, bacterial contamination, chemical pollution, oxygen depletion, oil and grease spills and contamination, and planned and unplanned habitat alterations. The importance and severity of these stressors varies from region to region and often is a consequence of human activity.

- **Point sources.** Point sources of pollution include discharges of municipal and industrial wastewater and dumping of materials into ocean waters. In general, the nation has made a massive and partially successful investment over the last generation to control point sources, and the environment has benefited as a result. Two of the outstanding successes include (1) more widespread wastewater treatment, and higher levels of treatment, across the nation, and (2) the elimination of most ocean dumping and greater control over the one major dumping activity that remains—the disposition of materials dredged from navigable waterways. The developments in wastewater treatment are mirrored and confirmed in environmental measurements that show long-term reduction of heavy metal and organic chemical pollution in the marine environment near urban areas, as well as improvements in other indicators of environmental quality. Ocean dumping of dredged material now is confined to clean materials placed in designated dump sites that are carefully monitored.

- **Nonpoint sources.** The remaining one- to two-thirds of pollutants contributing to the degradation of coastal and marine waters are from nonpoint sources, which include runoff and seepage from agricultural and urban areas, and air deposition onto land and into water. Seasonal eutrophication (oxygen depletion) of water bodies is an important manifestation of nonpoint pollution. The problem varies by region. The aggregate picture indicates an increase in the severity and extent of eutrophication in the future, with greater than 60 percent of the monitored estuaries expected to show worsening eutrophication symptoms. This is largely a consequence of the anticipated population growth in estuarine watersheds. Because of projected population increases, the need to limit nutrient inputs to estuaries must be emphasized further as we move into the next century.

- **Habitats.** Human activities have changed, degraded or destroyed coastal habitats, threatening many important species. Until recently, many coastal habitat resources were undervalued or not fully appreciated in terms of our dependence on them. Efforts have recently begun on every coast to identify the habitats essential for every life stage of every managed fish species. Once these essential habitats have been identified, measures can then be taken to protect them from direct damage, and from degradations such as nonpoint source pollution, eutrophication, and physical habitat loss resulting from coastal development.

Coastal hazards. Coastal storms damage property, take lives, and disrupt ecosystems as a result of high winds, storm surge, flooding, and shoreline erosion. The theory that global warming will make storms stronger and more frequent is under intense study; the data are incomplete about whether global warming will lead to more destructive coastal storms. It is known, however, that sea level is rising in many regions, and that global warming may speed this process. Global sea level is projected to rise on average about 5 mm/yr. A rise in sea level and increased storm frequencies could accelerate erosion and associated habitat loss, increase salinity, alter tidal ranges, change sediment and nutrient transport patterns, and increase coastal flooding.

The societal cost of coastal hazards is determined not only by the annual variability in their occurrence, but also by the increasing population at risk, the growing numbers and value of structures and businesses, and other manifestations of economic activity. Both population and wealth have increased greatly, and these changes have increased the exposure of the U.S. population to damages from coastal hazards.

When the losses from coastal storms are normalized to account for these changes, the extent of damages actually has decreased (on average) over the years. The explanation for this conundrum of greater potential for loss, but relatively fewer actual losses, lies in the success of major and long-term efforts to prepare and plan for coastal hazards, and to mitigate their effects. These efforts include (1) better predictions, forecasts and warnings that enable timely and targeted preparations and evacuations of high hazard areas, and (2) building codes that incorporate hazard-resistant construction standards, as well as guidelines for appropriate siting of structures in areas where they are less likely to suffer wind or water damage.

Governance and management. The great number of activities that occur in the coastal zone and in, on, and under the coastal ocean are governed by a complex and often fragmented framework of laws, regulations, and practices. Three fundamental trends are occurring to address this situation. First, on an international scale since 1973, the idea of the oceans as a "commons" has been supplanted by principles, codified in the Law of the Sea Convention, which (1) recognize the rights of nation-states to establish 200-mile exclusive economic zones over ocean resources and uses, and (2) authorize regional management arrangements for ocean uses. This trend has led to increases in resource utilization, such as fisheries development and offshore energy production. Second, federal environmental mandates have established special ocean and coastal management areas, and expanded the national capacity to plan for and manage the coastal zone. Third, integrated management approaches are coming into use that bring together diverse stakeholders to address the economic, environmental, and social demands placed on finite ocean and coastal resources.

Introduction

Coastal areas are invaluable for their economic vitality and biological diversity. At the same time, the coasts are under considerable pressure. More than half of the U.S. population lives and works in coastal regions. As coastal populations grow and associated economic development increases, many of the qualities and features of the coast are diminished. Coastal habitats are degraded or lost, harmful algae blooms proliferate, fisheries are overexploited, and seafood advisories increase. The natural processes of coastal ecosystems are being disrupted, and this, in turn, threatens the ecological and economic values of coastal areas. Figure 1 shows the gradual increase in U.S. coastal and noncoastal populations in recent decades.

A plethora of federal, state, and local management efforts address these issues. Nevertheless, there is a growing recognition that, because of the direct and indirect impacts of human activities, crisis conditions are emerging in many coastal areas. Regrettably, the environmental quality of coastal and marine areas and resources, and the economic value of vital ocean and coastal industries such as trade, tourism, and fishing, will be in jeopardy unless effective measures are taken soon to safeguard, protect, and restore our oceans and coastal areas.

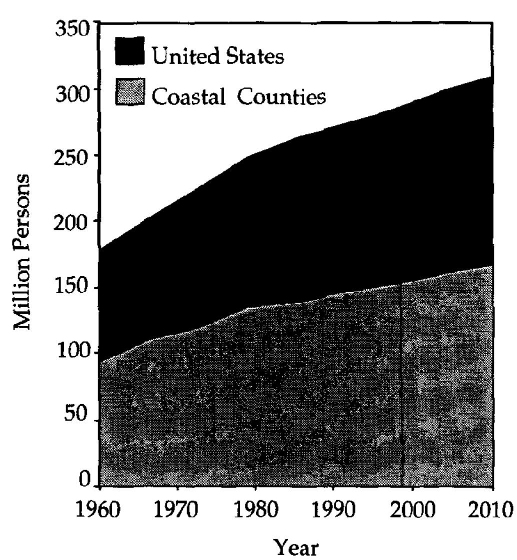
This paper examines underlying and emerging trends that are affecting coastal and marine resources and uses, and coastal management and policy. Trends (past and projected) are presented in population and settlement; economic activity; social values; resources; environmental quality; hazards; and governance and management. An effort is made to use enough contextual information so that the data convey a story about the present and possible future of the nation's coasts.

The report focuses on the coastal and ocean areas of the United States. Ocean areas represent waters extending from the shoreline to the limits of the Exclusive Economic Zone (200 nautical miles). The term coastal area, coastal region, or coastal zone generally refers to the land and waters included in the nation's coastal counties. Coastal counties are defined as those including at least 15 percent of their land area within a coastal watershed.

Pressure, State, Response Focus. A pressure, state, and response analytical framework is used in this paper. *Pressures* may result from: (1) human activities that stress the natural environment (e.g., population growth); or (2) natural changes that stress human activities (e.g., sea level rise). These pressures, together with societal actions (*responses*) to address the pressure or mitigate their impacts on society, determine the environment's *state* or condition. As an example, consider population growth, settlement, and economic development in the coastal zone. These activities bring demands for water, waste disposal and raw materials; they increase pollutant discharges to water and air, and change land uses, often degrading or fragmenting natural habitats. Without mitigation, these pressures can seriously compromise natural biophysical systems. The pressures that are examined in this paper include trends in population and settlement; economic activity; social values; and natural hazards in the coastal zone.

State is the quality or condition of the environment. It is the result of the combined effects of the pressures and societal attempts to reduce the effects of the pressures, i.e., responses. State relates to ecological processes or to a part or parts of ecological systems. In this report, the state of the coastal environment is summarized by examining trends in living and nonliving coastal resources, coastal environmental quality, and certain human settlement patterns that increase the potential for damages from coastal hazards.

Figure 1. *Past and projected population trends in U.S. and coastal counties, 1960-2010*



Sources: Bureau of the Census, 1998; National Planning Association, 1995

Responses are societal actions that improve environmental conditions or alleviate or eliminate environmental pressures. Societal actions include legislation, regulation, capital expenditures on infrastructure (e.g., waste treatment), research, financial incentives and disincentives, education, information gathering, and changes in personal habits or behaviors. Responses take place in many arenas, including national and state legislatures, government agencies at federal, state, and local levels, nonprofit organizations, private industry, international organizations, and even individual households. The governance and management section addresses trends in response efforts along the coast. Responses to pressures (e.g., societal responses to deteriorated water and air quality, resource depletion, coastal hazards) are also discussed.

The quantity and quality of the data used to develop this report vary according to each topic. Information documenting trends in economic activities, resource status and use, pollution impacts, and management is of varied quality and uneven in subject matter. It also is difficult to summarize trends on these topics in a limited space. However, actual trend information for coastal areas at the national scale is not readily available for many topics. As a result, some of the trend information included in this report applies to noncoastal areas as well. In addition, it is difficult to obtain projected data for topics other than population or activities that are directly impacted by population growth (e.g., projected municipal sewage treatment effluent).

Coastal Population and Settlement

Coastal areas are crowded and becoming more so every day. More than 141 million people—about 53 percent of the national total—reside along the narrow coastal fringes. Population growth in the 1990s has averaged about 1.1 million people per year. The population is projected to increase by about 24.7 million, reaching 166 million people by the year 2015. Most of this population growth will occur in the states of California, Florida, Texas, Washington, and Virginia. Together, California and Florida are expected to increase by 13 million people, more than half of the total increase in coastal population.

Hot Spots of Growth

Between 1997 and 2015, 10 counties in the aforementioned states are projected to account for about one-third of all anticipated coastal population growth. The largest population increases are expected in Los Angeles (1.6 million) and San Diego (1.2 million) counties in California, and Harris County (1.2 million) surrounding Houston, Texas.

Growth along the Southern California coast, from Santa Barbara to San Diego, has been rapid, averaging about 3,400 newcomers every week. The region's population increased from 11.6 million in 1970 to 18.7 million in 1997, and is projected to increase by 5.2 million people—reaching almost 24 million—by 2015. This region alone accounts for more than 13 percent of the nation's coastal population.

During the past several years, Florida's population has increased by about 4,400 people per week. Florida includes many of the nation's fastest-growing counties. Large numbers of people have settled in the Miami-Ft. Lauderdale metropolitan area, and also along Florida's southwest coast. Rapid population growth also has occurred since 1970 in vacation and retirement communities, especially along the state's western coast.

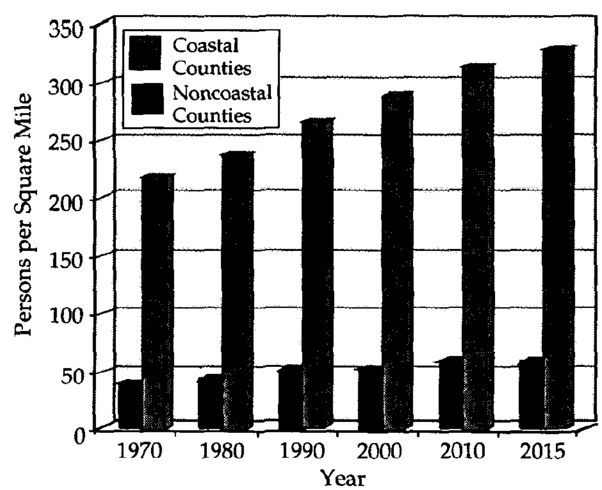
Coastal counties lead in many demographic indicators. During the last decade, 17 of the nation's 20 fastest-growing counties were located along the coast. Nineteen of the 20 most densely populated counties in the country are located along the coast. Coastal counties are also undergoing more development than noncoastal areas, accounting for 16 of the 20 counties with the largest number of new housing units under construction. Finally, coastal counties are among the nation's wealthiest; 18 of the 20 leading counties in per capita income are located along the coast (Bureau of the Census, 1994a).

This kind of growth brings jobs, creates economic prosperity, adds new industries, improves regional infrastructure, enhances educational opportunities, and increases tax revenues—but it also burdens the environment. As coastal populations swell, the natural features that may have attracted people to the coast are lost or diminished. Population pressures include increased solid waste production, higher volumes of urban nonpoint runoff, loss of green space and wildlife habitat, declines in ambient water quality, and increased demands on wastewater treatment, potable water, and energy supplies.

Settlement Patterns

The coast is becoming more crowded every year. Coastal areas are more densely populated than the rest of the Nation. In 1997, an average of 277 people inhabited every square mile of coastal land (excluding Alaska). This is three times the national average (91 persons per square mile). Since 1970, the coastal population density increased by about 62 persons for every square mile of coastal land (Figure 2).

Figure 2. *Past and projected population density in coastal and noncoastal counties, 1970-2015*



Sources: Bureau of the Census, 1998; National Planning Association, 1995

Fourteen of the 20 largest U.S. cities are located in the coastal zone. The population for seven of these cities exceeds one million people. In 1990, almost 113 million people—about 45 percent of the U.S. population—lived in urban areas along the coast. In many large cities, the most rapid growth is occurring in the outermost suburban areas. Rapid rates of growth have occurred in "exurban" counties such as Spotsylvania, VA; Manassas, VA; and Calvert, MD, located along the outer metropolitan fringe of Washington, DC. Dare, NC; Dorchester and Berkeley, SC; and Virginia Beach, VA, typify southeastern U.S. counties where rapid population growth is fueled by economic development and relocating retirees.

About 9,000 new, single-family homes are constructed along the coast every week (NOAA, 1992). Another 6,700 housing units in multi-unit buildings are also built every week. Single-family housing developments frequently include large homes on large lots. For example, almost one-third of all new home construction is for houses with more than 2,400 square feet of floor area (Bureau of the Census, 1994b). In addition, the median lot size in the U.S. is about 17,000 square feet (Culliton et. al., 1992).

Every day, about 1,300 acres of coastal lands are bulldozed under or paved over and converted to urban land. Currently, about 8 percent of all coastal lands are classified as urban. This is up from 3.5 percent in 1960. Urban lands account for about 41,175 square miles of coastal areas, up from 17,862 in 1960.

As urban areas have grown along the coast, agricultural land has diminished. Farmland has declined from 160,649 square miles in 1982 to 140,570 in 1992—a decrease of 20,079 square miles. This equates to an average loss of 0.7 acres of coastal farmland per minute. This valuable land that produces food and provides open space, wildlife habitat, and clean water is increasingly at risk. The competition for farmland—especially productive agricultural land—will intensify as the coastal population grows and technological innovations make it easier for people to live and work in more widely dispersed communities.

The increasingly complex mix of urban and rural land use also has natural resource impacts. Urbanization brings streets and rooftops that gather stormwater into drains and drainageways instead of filtering it naturally through the soil. Sprawl results in higher costs for paving and road maintenance, sewer and storm drain construction, water supply, and maintenance for localities (Thompson, 1993). Sprawl also overtakes farm and forestland and open space. It brings pollutants such as oil leaked from automobiles and chemicals leached from suburban lawns. Watersheds where the maintenance of healthy conditions formerly depended on agricultural land stewardship are often affected now by the actions of hundreds of small landowners, making the task of developing effective, cooperative efforts all the more difficult and necessary (USDA, 1996).

Housing Construction Trends

An average of 2,000 new homes were built along the U.S. coast every day during the past 25 years. The most dramatic growth since 1970 has occurred in Florida and California, where an estimated 7.6 million housing units were authorized for construction between 1970 and 1994. This represents 40 percent of all new housing construction along the coast. Single-family homes account for about 60 percent of all new housing along the coast. About 453,000 new single-family homes are constructed in coastal areas every year. Multi-unit dwellings (e.g., duplexes, condominiums, apartments) are built at the rate of 303,000 units per year.

The construction of single-family housing is more common along the Atlantic Coast and in the Great Lakes region than elsewhere. More than 62 percent of all new construction in these regions is for single-family dwellings. Multi-unit buildings are more predominant in the Pacific Region.

Seasonal Housing. Coastal areas are popular vacation and retirement destinations (Table 1). The growth in seasonal homes along the coast increased by more than 45 percent between 1960 and 1990. Seasonal housing is most heavily concentrated along the Northeast coast. In 1990, about 484,000 seasonal homes (e.g., single family, cottages, condominiums) were located along the northeastern seaboard. Barrier island developments are home to a large portion of this housing. More than one-fifth of these seasonal dwellings are concentrated along the New Jersey shore. Massachusetts (18 percent), New York (17 percent) and Maine (16 percent) also account for a large share of second homes situated along the Northeast Coast.

Table 1. Leading states in coastal county seasonal homes, 1990

State	Seasonal Homes
Florida	408,328
Michigan	213,214
New York	142,194
California	125,593
New Jersey	100,529
Massachusetts	88,642
Maine	78,062
Texas	53,662
Wisconsin	48,388

Source: Bureau of the Census, 1998

More than 63 percent of seasonal housing in the Southeast is located along the Florida coast. The area from West Palm Beach to Miami is one of the nation's leading tourist destinations, accounting for 41 percent of all seasonal homes between Virginia and the Florida Keys. North Carolina and South Carolina account for much of the remaining seasonal housing in the region.

In the Gulf of Mexico, western Florida accounts for almost 70 percent of all seasonal dwellings. Rapid development has occurred along the state's south-west coast in recent decades. Almost 14,000 new seasonal homes were constructed near Ft. Myers in the 1980s. Another 10,000 seasonal dwellings were constructed in the 1980s in Collier County, where beach resorts such as Marco Island and Naples are located.

Seasonal housing in Pacific coastal counties is most heavily concentrated in California. About 60 percent of all seasonal dwellings in the Pacific region are located in the state. San Diego and Los Angeles counties are home to most of the state's seaside second homes. In contrast, Washington accounts for about 19 percent of second homes in this region. Hawaii, a tourist mecca, surprisingly represents only six percent (12,876 units) of the regional total.

Michigan's extensive shoreline, rimming the Great Lakes, makes it the leader among Great Lakes states. It accounts for 56 percent of all coastal seasonal dwellings in the region, followed by New York (16 percent) and Wisconsin (13 percent).

The Smart Growth Movement: A Response to Population and Settlement Pressures

The population of coastal counties in Maryland grew from about 3.6 million in 1970 to almost 4.7 million in 1997–an increase of about 3,250 people per month. This growth has yet to abate; on the contrary, an increase of 750,000 people is projected for Maryland's coastal counties between now and 2015.

Such growth has had an enormous impact on the Chesapeake Bay, the largest estuarine system in the United States. The Bay's watershed, radically changed since the onset of European settlement three centuries ago, continues to undergo changes that reflect land use across this 64,000-square-mile expanse. Polluted runoff enters the bay from urban, suburban and agricultural lands. About 40 percent of the land is no longer in its natural state, and wetlands are still being lost at a rate of about eight acres per day (Chesapeake Bay Program, 1997 on-line).

Around the Chesapeake Bay, sprawl is quickly gobbling up open space and forested land. According to the Chesapeake Bay Foundation, more than 90,000 acres are consumed by sprawl each year in states bordering the Bay. Today, four to five times more land is used per person than was the case 40 years ago.

An ever expanding population has resulted in higher wastewater flows to the Bay. Through increased wastewater treatment and a ban of phosphorus-containing detergents, point sources of phosphorus have been reduced by 70 percent since a peak in the 1970s. Recently implemented controls of nitrogen are already reducing the levels of this pollutant entering the Bay from point sources, such as industrial facilities and municipal sewage treatment plants (Chesapeake Bay Program, 1997 on-line).

In 1997, the Maryland Legislature approved the "Smart Growth and Neighborhood Conservation Initiatives." The legislation earmarks state funding of infrastructure (e.g., roads, sewers, schools) for new development to "growth areas" along the Washington-Baltimore metropolitan corridor and to established cities and towns. Any development outside these growth areas would not receive state support (Sustainable Communities Network, 1997 on-line). A major objective of the legislation is to preserve Maryland's agricultural lands and green space. Without the legislation, it is feared that some half-million acres of open space and farm-land would be lost over the next 20 years (Sustainable Communities Network, 1997 on-line). This effort—focusing state funds for infrastructure on areas that can accommodate growth without deleterious environ-mental impacts—is a major accomplishment.

Social Trends

At the cusp of the millennium, change in every aspect of our lives is both the trend and the norm. Our society is becoming more diverse. Some people grow more isolated from the environment; others embrace the natural world. Complex technological systems (e.g., power grids, tankers, pipelines) are increasingly vital, but their reliability depends on the performance of people[1].

Thirty years ago, most Americans believed that resources were essentially infinite and could be exploited forever. Most also believed that a Nation that could send a man to the moon could, in a few short years, master any technological problem, including cleaning up river pollution and finding a cure for cancer. The government in that expansive era was viewed as the principal means for addressing social ills and promoting progress. Today, marine resources and coastal areas are recognized as finite resources, capable of being harmed or lost by human activities (The Heinz Center, 1998). A balance between use and conservation is sought. The principle of "sustainability"[2] is invoked and decision-makers are encouraged to apply the precautionary principle[3]. Managers seek to achieve their objectives through partnerships that build on public and private roles and capabilities, because solutions and innovations often require the participation of all stakeholders. Perhaps the most far-reaching change is that most Americans today, and most companies and units of government, characterize themselves as environmentalists.

Awareness about the Importance of Environmental Quality. A generation ago, the idea that the United States should make a substantial commitment to the environment was just beginning to come into focus as a result of myriad events and issues. Today, in contrast, Americans of all classes and social groups are deeply committed to a safe and healthy environment. All of the modern environmental legislation, and the sweeping federal role in protecting the environment, stem from this evolution in public awareness about the importance of environmental quality[4].

The transition of the environment from an issue of limited concern to one of widespread concern occurred years ago. Today, surveys show that most Americans have turned their attention elsewhere (Table 2). However, a "settled" issue like the environment can return to national prominence after untoward events or if people feel their political leaders are not mindful of their concerns. The "spike" of interest in the environment in 1990, as shown in the table, may be attributed to this phenomenon.

Table 2. The environment as a voting issue: Exit polls, 1982-1992

Year	Exit Pollster	Most Important Issues	Percentage
1982	CBS/NY Times	Unemployment	38
		Environment	3
1984	LA Times	Government Spending	22
		Environment	4
1988	CBS/NY Times	Helping Middle Class	25
		Environment	10
1990	Voter Research and Surveys	Education	26
		Environment	21
1992	Voter News Service	Economy/Jobs	12
		Environment	5

Source: Adapted from Ladd and Bowman, 1996

Interestingly, as the environment has declined in intensity as a national issue, it has become more potent politically at the state and local levels, where tangible choices must be made between competing interests. On the whole, however, pollsters find Americans' commitment to the environment to be broad-based, stable, and strong.

A 1996 poll gauged Americans' attitudes toward marine environmental issues (Spruill, 1997). It documented widespread recognition of the ocean's importance, concern about its health, and a sense of responsibility to protect the ocean for present and future generations. This strong concern for the ocean makes the coastal and marine environment "an issue waiting to be made."

Nongovernmental Organizations—Powerful New Stakeholders in Environmental Management. Environmental organizations have become a potent political force, perhaps the strongest single political force influencing coastal policy. As a point of reference, the number of U.S. nongovernmental organizations (NGOs) concerned with coastal natural resources and environmental issues rose from 192 in 1970 to 560 in 1997 (National Wildlife Federation, 1997, 1970). The rise in numbers and influence of the environmental advocacy community is one of the fascinating institutional developments in recent decades.

These predominantly private-sector interests are willing to work with both landowners and government agencies to conserve and manage the environment, and they have considerable technical and managerial capabilities and resources to offer. They focus public discourse and attention on issues of interest to them. Land trusts protect ecologically important lands by purchasing them; these activities are often undertaken in concert with public agencies as part of a regional strategy to protect the environment. Many NGOs provide additional research and monitoring resources, and help track conditions and issues. Occasionally, through adroit political and legal pressure, NGOs are instrumental in compelling industry or government agencies to favor environmental protection over other possible outcomes.

Economic and Resource Trends

Economic activities in the coastal zone and coastal ocean account for up to two percent of the U.S. Gross National Product and are comparable in scope to other important sectors of the economy, such as agriculture (Pontecorvo, 1989; Wilson and Wheeler, 1997). Recreation and tourism, waterborne commerce, energy and mineral production, and fisheries account for most of the economic activity in coastal areas.

Recreation and Tourism

Outdoor recreation and tourism are the most significant economic activities in the coastal zone. A study in California documented that tourism alone ($9.9 billion) accounted for more than half of the state's $17.3 billion ocean-related economic activity (Wilson and Wheeler, 1997). The proportion of the U.S. population that participates in at least one outdoor recreation activity has increased from 89 to 94.5 percent between 1982-1983 and 1994-1995 (Cordell et al., 1997). Miami Beach alone receives more visitors than any National Park. Coastal states in aggregate earn 85 percent of total tourist revenues (NOAA, 1998 on-line).

The number of recreational boats and participation rates in saltwater fishing are potential measures of recreational activity in the coastal zone. Since passage of the Coastal Zone Management Act in 1972, the number of recreational boats has nearly doubled to 16.5 million. Interestingly, the number of inboard boats, which are more likely to be found in saltwater, has tripled to 2.4 million.

Both the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) both compile information on saltwater fishing. The USFWS reports that the number of saltwater anglers increased significantly between 1970 and 1985, while expenditures on saltwater fishing more than doubled during the same time period (USFWS, 1997). NMFS reports that the estimated number of people participating in marine recreational fishing has leveled off in the past five years (increasing by only one percent since 1993) and now stands at over 12 million (NMFS, 1998). These sources notwithstanding, one cannot draw conclusions about outdoor marine recreation as a whole based on trends in one activity.

Estimates of recreational use in coastal areas indicate the following (NOAA, 1998 on-line):

- Saltwater fishing generates expenditures of over $5 billion annually; a total economic output of $15 billion; total earnings of over $4 billion; and over 200,000 jobs.
- More than 77 million Americans participate each year in recreational boating activities.
- The average American spends 10 recreational days on the coast each year.

Perhaps a more useful indicator of the overall trend in coastal and marine recreation is tourist visitation patterns. Foreign tourism is a critical component of the overall U.S. tourism picture. Total foreign visitation to the United States increased by 76 percent between 1985 and 1995 (from 25.8 million to 45.5 million) and in 1986, the United States was the world's most popular tourist destination (Miller and Auyong, 1991; Miller, 1993). More than 90 percent of visitation by foreign tourists takes place in states "where beaches are the leading tourist destination" (Houston, 1996).

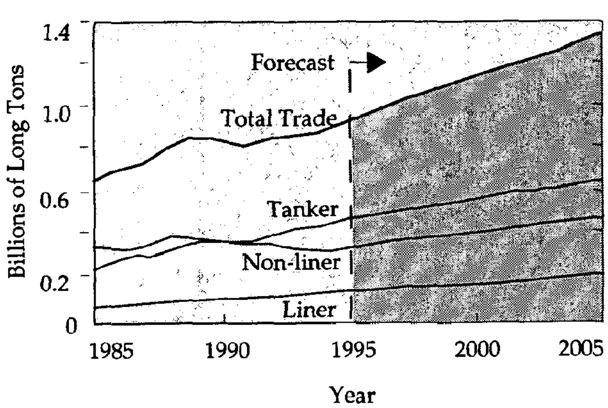
Non-use values. The non-use value of coastal resources can be significant. A non-use value is a measure of the intrinsic value of a resource (i.e., the value of the resource without any direct contact or interaction by humans). It is a measure of the value people place on a resource simply due to its existence in a certain condition (e.g., a protected beach or coral reef). It may also be a measure of the possible future use of the resource (beach or reef), or the assurance that the resource will be available in the future in a certain protected condition. Assuming a certain level of water quality, the Chesapeake Bay has a non-use value of $89 million (Bockstael et al., 1989). Thus, when non-use values are taken into account, the economic importance of oceans and coasts can be very great.

Importance of the Government's Role. The government plays an important role in providing the underlying conditions for coastal and marine recreation and tourism. These include (1) ensuring a clean environment, (2) assuring coastal access, and (3) promoting a safe operating environment. Given the economic importance of marine recreation and tourism, and the importance of the government role in providing the basic underlying conditions for these activities, much more could be done to understand, document, manage, and promote coastal and marine recreation.

Waterborne Commerce

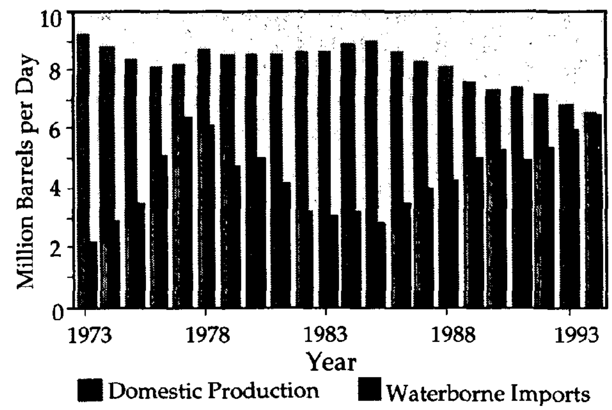
International Trade. International trade continues to be a major factor in worldwide economic growth. The United States now leads the world in the value of imports and exports. Moreover, U.S. waterborne foreign trade is projected to grow at an average annual rate of 3.7 percent (Figure 3). The value of exports and U.S. commodity imports was almost $1.2 trillion in 1994. Commodity exports rose from 5 percent of the gross domestic product in 1984 to 7.5 percent in 1994 (U.S. Bureau of the Census, 1995). Shipments of oil and petroleum products constitute a major component of U.S. trade. The U.S. imports

Figure 3. *Trend in U.S. waterborne commerce*



Source: National Research Council, 1996

Figure 4. *Waterborne crude oil imports and domestic crude oil production, 1973-1994*



Source: National Research Council, 1997a. Import data from U.S. Army Corps of Engineers, 1973-1994. Production data from Energy Information Administration, 1995

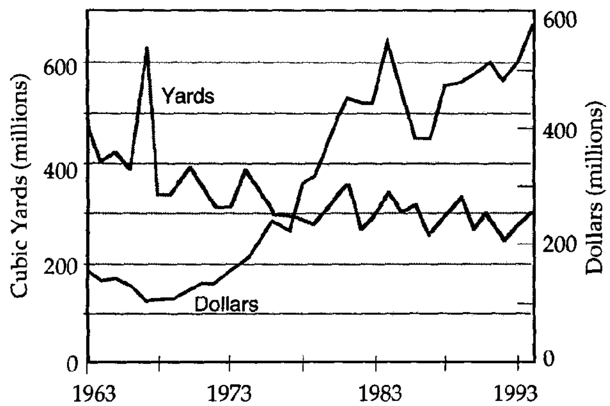
more than half of the oil it consumes, and imports are growing steadily (Figure 4) (American Petroleum Institute, 1996).

Foreign-flag vessels have largely carried the more than fourfold increase in U.S. waterborne international trade since World War II. In 1994, foreign flag vessels carried about 98 percent of U.S. foreign trade by tanker and 85 percent by cargo liner. To accommodate expanding trade, oceangoing ships have grown considerably in size, complexity, and speed. The increase in international waterborne trade and its growing importance to U.S. prosperity, as well as the demands posed by changes in world fleets, require that maritime transportation be highly efficient. As a result, waterways management is an increasingly important determinant of system efficiency.

Domestic Trade. The face of domestic marine transportation has changed as well (Marine Cabotage Task Force, 1997). Since 1965, large containerized cargo vessels have replaced breakbulk cargo vessels. In domestic shipping, barges have replaced traditional self-propelled ships as the vessel of choice. In the ore-carrying Great Lakes fleet, large, self-unloading vessels have replaced older, less-efficient vessels. Moreover, in many regions, passenger ferries and excursion boat services are growing.

Changes in Ports. The focus of all this activity is the port. The U.S. waterways transportation system includes about 145 ports that each handle more than 1 million metric tons of cargo annually. The top 10 ports handle a total of more than 900 million metric

Figure 5. Volume and costs of dredging by the U.S. Army Corps of Engineers and industry, 1963-1994



Note: Estimates do not include disposal costs and are current, not constant dollars.
Source: National Research Council, 1997b

tons annually. These ports need to keep pace with the growth in trade as well as other changes in ships and shipping. They also must continue to accommodate other users of the waterfront, and provide other benefits (e.g., recreational opportunities, marine habitat protection).

Despite their importance, many U.S. ports show signs of stress. A study by international tanker operators concluded, "It is an anomaly that tankers which approach U.S. terminals do so without the support of a modern vessel traffic system, often base their approach on 50-year-old charts, are instructed to approach the berth on less than adequate water draft, and finally moor at a berth which was designed to accommodate ships much smaller than a modern tanker" (Intertanko, 1996).

Ports are being affected by important changes in two areas (Bookman, 1996). The first is the rapidly changing intermodal freight transportation market, which moves increasing amounts of cargo on ever-more-demanding schedules. The survival of a general cargo port now depends on its capability to receive and transfer goods as quickly as possible. A 1991 survey found that half of public ports and two-thirds of container ports face growing problems providing seamless transportation links among waterways, highways, and railroads (National Research Council, 1993).

The second factor is the increasing number and complexity of environmental regulations that pertain to ports (National Research Council, 1997b), especially concerning the growing need to deepen and widen channels to accommodate the latest ships.

Interestingly, as documented in Figure 5, the volume of dredging fluctuates little from year to year. Similarly, there is abundant anecdotal evidence that obtaining approvals for dredging continues to be a complex and time-consuming process.

Toward a Safe and Efficient Maritime Transportation System. The requirement for a safe and efficient marine transportation system has recently garnered national attention. A coordinated national effort to highlight the trends and address the related issues is being led by the interagency Committee on Waterways Management (U.S. Coast Guard, in press). Policy coordination at the national level, combined with action at the local port level, can help ensure an adequate infrastructure, including appropriate channel and berth depths, real-time navigation information, modern port facilities, and efficient intermodal connections.

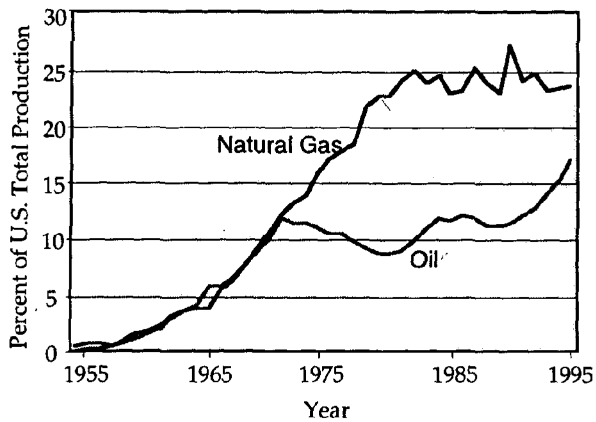
Energy and Minerals

About 50 percent of oil consumed by the United States in 1994 was imported. Current consumption suggests that by 2010, the U.S. will import over 60 percent of its oil and gas. This dependence on foreign oil is troublesome because, as experienced in the 1970s, the international oil market is subject to unpredictable price changes and disruptions. This makes the United States vulnerable to economic impacts by geopolitical developments and instability in world oil markets.

Oil and Gas Production. Almost one-fifth of the nation's produced oil comes from federal offshore lands (Minerals Management Service, 1997a) (Figure 6). Revenues and royalties earned from this production contribute significant funding to the federal government. In 1997, the government received $1.4 billion in bonuses, $68 million in rent, and $3.5 billion in royalties from offshore petroleum activities (Energy Information Administration, 1998). In addition, the offshore oil and gas industry employs tens of thousands. In the Gulf of Mexico and other regions, some 38,000 people are employed offshore on drilling rigs and platforms, and another 46,000 are employed in the industry onshore.

Energy production occurs offshore of Alaska, California, and in the Gulf of Mexico. In 1996, the Gulf of Mexico outer continental shelf (OCS) alone produced

Figure 6. Federal OCS oil and gas production, 1954-1995



Source: Minerals Management Service, 1997a

over 98 percent of the nation's OCS gas and over 85 percent of OCS oil (Minerals Management Service, 1997b). Similarly, the Gulf of Mexico OCS accounted for 79 percent of new oil field discoveries and 70 percent of new gas discoveries, reinforcing the Gulf's future as the nation's primary domestic oil and gas producer (Energy Information Administration, 1998).

Between 1995 and 1997, OCS oil production rose from 19 percent to 20 percent of U.S. total oil production. OCS gas production rose from 26 percent to 27 percent of U.S. total gas production between 1997 and 1998, an increase for the third consecutive year (Minerals Management Service, 1998 on-line). These recent offshore development trends may begin to reverse a long trend of decline in U.S. domestic petroleum production.

About 45.6 billion barrels of oil and 268 trillion cubic feet of natural gas are estimated to be on U.S. offshore federal lands. These are estimates of undiscovered resources that could be developed using conventional technology (Minerals Management Service, 1997a). By comparison, more than 416 million barrels of oil and 4.7 trillion cubic feet of natural gas were produced on the federal outer continental shelf (OCS) in 1995 (Minerals Management Service, 1997d).

Trends in Technology. U.S. offshore energy production is occurring in water depths exceeding one mile, far offshore in the Gulf of Mexico. Rapid and dramatic technological advances, recently coupled with relief from paying royalties on deepwater production, have combined to encourage the trend toward deep water. In 1965, the deepest well was in water 632 ft. deep. In 1996, the deepest well was in water 7,620 ft. deep. It is anticipated that production will extend to even greater depths in the next century. However, development of these resources will require advances in production technologies to address adverse oceanographic conditions, handle geohazards, and accommodate irregular ocean bottom relief that complicates pipelines and foundations (NOAA, 1998).

As a result of increasing technology and the need to reduce reliance on imports of oil and gas, U.S. drilling is showing a general increase in both exploratory and development wells. Although no exploratory wells were drilled on the Pacific OCS in 1997, other regions recorded a high level of exploration, combining for a national total of 353 exploratory wells, up from 327 wells in 1996. A 10-year record of 601 development oil wells was set in 1997; this was up from 562 wells in 1996 (Minerals Management Service, 1997c).

Three-dimensional seismic acquisition, modeling, and interpretation have greatly increased the efficiency of oil and gas exploration. This has resulted in the drilling of fewer exploratory wells and increased rates of discovery. In addition, renewed interest in deep water is being credited to technological advances and horizontal drilling. Improvements in technology allow companies to identify reservoirs in progressively deeper water. Extended reach or horizontal drilling allows for enhanced production, increased production in borderline fields, and additional protection in environmentally sensitive areas. It is estimated that one- to two-thirds of all new wells will be horizontally drilled over the next five years (NOAA, 1998).

Alternative Energy Resources. Recent research has shown that most continental margins contain vast reservoirs of gas concentrated in frozen, icelike gas hydrates within the top several hundred meters of sediment. These vast deposits of methane hydrates found in deeper oceanic areas are a promising, but challenging, new resource. A conservative estimate of methane gas in gas hydrate deposits is massive; it is believed to contain about twice the carbon held in all conventional fossil fuels on earth (NOAA, 1998).

In addition, technology exists for harnessing renewable and non-hydrocarbon energy resources from the oceans. These include the heat content (thermal gradient) in the world's oceans and the mechanical energy manifested by various ocean-water motions (e.g., surface waves, tides, and currents). While technologies to use these resources have been proven, the sources themselves have not yet proven to be economically viable, except in isolated, small applications (NOAA, 1998).

Sand and Gravel. Coastal and ocean areas contain vast deposits of sand and gravel. Portions of the nation's OCS, especially in the Northeast, contain abundant supplies of this resource. Sand and gravel used in construction and in most public works projects account for the largest tonnage of minerals produced from the ocean (NOAA, 1998). Nearshore and offshore sand and gravel supplies are also important sources used for beach nourishment projects along barrier island communities (National Research Council, 1995).

Other Minerals. Mineral deposits in U.S. waters (other than sand and gravel) include massive phosphate beds beneath the continental shelf from North Carolina to northern Florida; titanium-rich, heavy mineral sands off the East Coast from New Jersey to Florida, and off the West Coast from Oregon to northern California; gold-bearing sand and gravel deposits off Alaska; barite deposits off southern California; manganese nodules on the Blake Plateau off South Carolina and Georgia and off Hawaii in the Clipperton Fracture Zone; and cobalt and platinum-rich crusts off of Hawaii. Gold was recovered by dredging in state waters off Nome, Alaska, from 1986 to 1990 (NOAA, 1998).

Food Supply

The world population increases by about 80 million each year; this rate of growth is projected to continue for the next few decades. As population and affluence increase, so does the demand for food. A growing imbalance between population growth and food production may be one of the most important global issues in the next century. Coastal and ocean regions play important roles in food supply. Fisheries and marine aquaculture make obvious contributions, but there are more subtle relationships as well, such as the effects of farming practices on coastal habitats.

Trends in Farming Practices and Coastal Habitats. Traditionally, a growing demand for food was met by converting natural lands to arable lands. More recently, in this century, higher-yielding varieties of grains and other crops have been employed, along with increasing amounts of fertilizer, to steadily increase unit crop production and land productivity (Food and Agriculture Organization, 1998). Trends in animal production have favored factory-style production of meat animals—poultry, swine and beef—over free-range harvesting. This intensification of farming practices has affected coastal environments in three ways. First, ploughed lands tend to lose their topsoil unless careful conservation practices, such as forested riparian buffers, are employed. Over the years, huge amounts of sediment from farmlands have run off into America's rivers, estuaries, and coastal ocean. Second, fertilizers and pesticides applied in increasing amounts to both farmlands and suburban lands over many years end up in runoff, ultimately finding their way into rivers, estuaries, and coastal oceans, where their negative effects on marine habitats are being documented. Third, animal feedlots and plants produce concentrations of organic wastes, which, until recently, were not required to be strictly controlled. These wastes have contributed to widespread pollution and marine habitat degradation in several major estuaries. Many of the coastal environmental trends discussed in subsequent sections of this report have their origin, at least in part, in the intensification of farming practices.

Fisheries Trends and Food Production. Even as the global demand for food grows at a record pace, growth in the supply of food is slowing. Growth in the supply of food from fisheries is no exception. Worldwide, the 1990s have witnessed a leveling off of fisheries production for direct human consumption. This is due in no small part to overfishing and habitat degradation. The majority of economically valuable marine fisheries are now at or beyond their limits of sustainability (Food and Agriculture Organization, 1997). Because yields have leveled off, the annual addition of 2 million tons to the world's animal protein supply, which historically came from growth in the fish catch, must now come from fish farming, poultry production, or some other source.

The United States is fortunate in that it can afford the higher costs that are the consequence of resource scarcity. Moreover, faced with fisheries declines of its own, the U.S. depends increasingly on imports to meet domestic consumption. Much of the imported seafood, especially high-value edible products such as shrimp and salmon, come from marine aquaculture (National Marine Fisheries Service, 1996 on-line).

Trends in Marine Aquaculture. Marine aquaculture, the farming of marine finfish, shellfish, crustaceans and seaweed, as well as the ocean ranching of anadromous fish, is rapidly growing around the globe. In the United States, freshwater aquaculture is an expanding industry; however, marine aquaculture has yet to achieve economic success beyond a limited basis. Constraints to the industry have included conflicts concerning the use of coastal and ocean space, public concerns about the effects of aquaculture on water quality, and ecological concerns stemming from the potential for cultured animals to escape into wild populations. Poor water quality and high labor and land costs have also inhibited marine aquaculture in the United States (National Research Council, 1992; Goldburg and Triplett, 1997). However, because seafood consumption is increasing while yields from capture fishing are reaching the limits of sustainable returns, the opportunity exists for U.S. aquaculture to supply the growing demand, and for U.S. marine aquaculture to make a significant contribution.

Aquaculture production (freshwater as well as marine) now represents 20 percent of U.S. consumption, with production increasing at an average annual rate of 6.4 percent over the last decade (World Resources Institute et al., 1998; USDA, 1998; NMFS, 1997). About 10 percent of this production is marine aquaculture. The largest U.S. marine aquaculture production is in salmon, with 13,906 metric tons in 1996. This represents a doubling of production within a decade. The production of oysters, which were the mainstay of U.S. marine aquaculture in the 1980s, remained stable; the recent decline in harvest was probably due to environmental factors.

Living Marine Resources

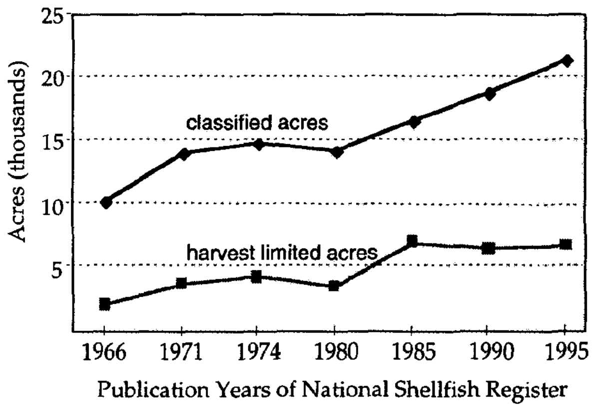
Fisheries. U.S. fishery landings have increased over the past 50 years, but have now reached the maximum capacity of our oceans and coastal waters to produce fish. Landings in Alaska have increased dramatically, while they have declined in other regions for many species. In any given region, commercial fisheries for "new" stocks have developed (Alaska walleye pollock), while others have declined (New England groundfish), and others have remained fairly stable (Gulf of Mexico menhaden). In addition, recreational fishing represents a significant portion of the landings for some marine species, such as striped bass in the Northeast, spotted seatrout in the Southeast, red drum in the Gulf of Mexico, and Pacific salmon on the West Coast. In a 1997 report to Congress on the status of U.S. Fisheries, using a methodology that recognized 737 marine species and stock groups, the National Marine Fisheries Service estimated that 86 species (12 percent) are overfished, 10 (1 percent) are approaching an overfished condition, 193 (26 percent) are not overfished, and 448 (61 percent) are of unknown status (NMFS, 1997 on-line). In order to achieve long-term potential yield, it is necessary to end overfishing and allow depleted stocks to rebuild.

Marine Mammals. Although marine mammals, including dozens of species of whales, dolphins, porpoises, seals, walruses, and manatees, are not harvested in U.S. waters, they are important components of coastal marine ecosystems. Of the 163 marine mammal stocks in U.S. waters, there is sufficient long-term population information to describe trends for only 55 (33 percent) of the stocks; the status of the remaining 108 (66 percent) stocks is unknown (NMFS, 1996). Of those for which information is available, eight (5 percent) are declining, 24 (15 percent) are known to be stable, and 23 (14 percent) are believed to be increasing. Fifty-four stocks of marine mammals are classified as "strategic" under the Marine Mammal Protection Act. These are of major concern because they are depleted, have excessive mortality, or are listed as endangered or threatened under the Endangered Species Act. A few species of major concern include the blue, fin, and sperm whales in both the Atlantic and Pacific Oceans, the northern right whale in the Atlantic, Steller sea lions in Alaskan waters, Hawaiian monk seals in Hawaii, and manatees in Florida.

Shellfish. The harvest of oysters, clams, and mussels along the coast of the United States is a tradition that can be traced back many centuries to the native Americans who first inhabited these shores. Hundreds of huge and long-forgotten middens, the waste heaps of oyster and clam shells that dot the coast, are testimony to the original abundance of these animals and their importance as a source of food. Today, most Americans consider shellfish more a delicacy than a staple. Nevertheless, the harvest, processing, distribution, and consumption of shellfish, particularly oysters, make up an important industry, supporting thousands of jobs and generating hundreds of millions of dollars for the nation's economy.

In 1995, over 24.8 million acres of marine and estuarine waters in the contiguous United States were classified as shellfish growing waters under a program to protect human health that is jointly administered by coastal states and the National Shellfish Sanitation Program (Figure 7). Of the 4,230 growing areas involved, 59 percent were approved for harvest; 17 percent were conditionally approved, restricted or conditionally restricted; and only 11 percent were prohibited–the lowest percentage on record for this category (NOAA, 1997). The 1995 commercial harvest from these waters totaled 77

Figure 7. Classified growing waters of the contiguous United States, 1966-1995



Source: NOAA, 1998 p

million pounds of oysters, clams and mussels worth approximately $200 million at dockside (NOAA, 1997).

Environmental Quality

Coastal and ocean waters are among the most productive and valuable natural systems on Earth. They are also among the most threatened. Many of the nation's coastal areas are under increasing pressures from population growth and related development. The pressures from growth include increased solid waste production, higher volumes of urban nonpoint runoff, loss of green space and wildlife habitat, declines in ambient water quality, and increased demands on wastewater treatment, potable water, and energy supplies. These pressures adversely affect the quality of coastal and marine waters and associated habitat.

Water Quality.Several key issues are associated with coastal water quality. These include the status of nutrient levels and the extent of contamination by pathogens, chemicals, oil, debris, and litter. These have been priority issues for coastal managers in recent decades, and are likely to be the focus of coastal water quality management efforts in the foreseeable future.

Nutrients. Nutrients are essential for healthy aquatic communities. In excess levels (especially nitrogen and phosphorus compounds), however, they can overstimulate the growth of aquatic weeds and algae (Figure 8). Excessive growth of these organisms can, in turn, clog navigable waters, interfere with swimming and boating, outcompete native submerged aquatic vegetation (SAV), and with excessive decomposition, lead to oxygen depletion. The resulting harmful algal blooms can cause fish kills or manatee deaths, and in some instances, may threaten human health.

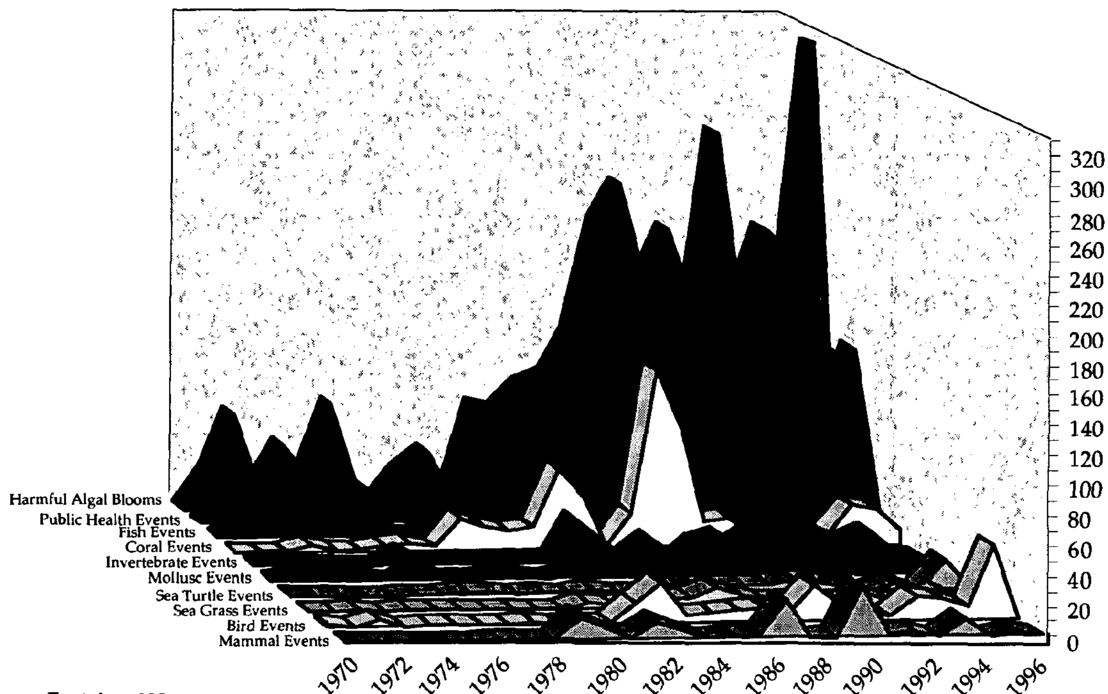
In the summer of 1997, newspaper headlines focused on an area of nutrient overenrichment and oxygen depletion, known as the "Dead Zone," that seasonally covers approximately 7,000 square miles of the Gulf of Mexico near the mouth of the Mississippi River. Runoff from agriculture, including farmland areas in the upper Midwest, is believed to be the primary culprit. In the Chesapeake Bay region that same summer, the Governor of Maryland closed fisheries and warned citizens about seafood safety because of a bloom of the toxic species *Pfiesteria piscicida*. In this instance, the likely cause was the inadequate handling of agricultural wastes, primarily from poultry.

Since the end of the 1940s, population growth, increased fertilizer use, animal husbandry, and changes in land use have contributed to increased nutrient inputs to coastal waters. It has been estimated that 40 percent of estuarine and coastal waters are not "fishable or swimmable," primarily because of nutrients and bacteria from urban and agricultural runoff and municipal wastewater discharges (U.S. EPA, 1996 on-line). Recent studies have shown that air deposition of nitrogen is also a significant contributor to nutrient overenrichment of some coastal and marine waters.

Pathogens. Viruses, bacteria, and protozoa can cause diseases in plants, people, and other animals. In humans, illnesses range from typhoid and dysentery to minor respiratory and skin diseases (U.S. EPA, 1996 on-line). These organisms may enter waters through a number of routes, including inadequately treated sewage, stormwater drains, septic systems, runoff from livestock operations, and overboard sewage discharge from recreational boats. In excess, they contribute to closures of shellfish beds and swimming areas, fish kills, and seafood consumption warnings. The good news is that approved shellfish harvest waters are at an all-time high, and overall, the condition of shellfish harvesting waters in the United States is improving (NOAA, 1997).

During 1996, there were at least 2,596 individual closings and advisories for ocean, bay, and Great Lakes swimming beaches due to bacterial contamination. Over 80 percent of the beach closings and

Figure 8. Major marine ecological disturbances, 1970-1996



Source: Epstein, 1998

advisories that year were based on monitoring that detected bacteria levels exceeding beach water-quality standards. The number of beach closings due to pathogen contamination continues to decrease as a number of metropolitan areas upgrade their sewer systems and separate their storm drains and sewer systems (NOAA, 1998).

Toxic Chemicals. Toxic organic chemicals are synthetic compounds that contain carbon, such as polychlorinated biphenyls (PCBs), dioxins, and the pesticide DDT. These synthesized compounds often persist and accumulate in the environment because they do not readily break down in natural ecosystems. Many of these compounds cause cancer in people and birth defects in birds and fish.

Since 1940, more than 70,000 synthetic chemicals have been introduced into the marine environment. There impacts are widespread and varied, such as the Mobile Delta, where excessive levels of mercury in finfish resulted in the closing of some fishing areas in the early 1970s and again in the early 1990s (U.S. EPA, 1997). Efforts to reduce chemical loadings to marine waters have had some success. Away from the influence of urban sources, offshore monitoring of toxic chemicals has shown a decline in the concentrations of chemicals which have been banned from use in the U.S. (NOAA, 1997a). Meanwhile, reported releases of toxic chemicals to surface waters decreased by 4.1 million pounds (a reduction of more than 10 percent) from 1994 to 1995 (U.S. EPA, 1997b). This reduction is a reflection of changes in industrial practices (e.g., source reduction, installation of pollution control equipment, increased recycling and reuse of waste as raw materials, production changes, and fewer one-time release events) (NOAA, 1998).

Over the last decade, the chemical contamination of aquatic sediments has been recognized as a serious problem in U.S. coastal waters. "Hot spots" of toxic chemicals have been shown to alter and reduce bottom-dwelling organisms, to interfere with cellular and physiological processes, and to cause disease in fish. Most "hot spots" are found in areas of high vessel traffic, industrial activities, or poor flushing, and are often located near urban centers (USEPA, 1994). Other adverse economic impacts of contaminated sediments include delays and rising costs to maintain dredging in navigational waterways. This is due to the potential danger of resuspending toxic chemicals in the water column, and the need to find acceptable disposal sites for dredged sediments (NOAA, 1998).

Oil Contamination. In 1996, approximately 4,200 oil spills occurred in coastal areas and in the open ocean and nearshore. Spill sources range from minor marina activities to one-time releases from tankers (U.S. Department of Transportation, 1995), with major tanker spills accounting for only 5 percent of the volume of oil spills. Fixed facilities and offshore exploration and production platforms contribute 15 million gallons of oil pollution to the world's ocean bodies each year. In contrast, 363 million gallons of oil per year reaches the ocean in runoff from land and municipal and industrial wastes. In fact, the yearly road runoff from a city of five million could contain as much oil as one large tanker spill (Ocean Planet, 1995). Natural oil seeps discharge 62 million gallons of oil into marine waters each year. Effects on organisms from oil spills can be acute, such as fish kills from initial contact with the toxic fractions of petroleum, or subtle, such as chronic effects on reproduction that become evident as toxic chemicals concentrate through the food web of an ecosystem. Effects on human populations are realized through economic losses, such as those associated with the loss of tourism or a fishery. Particularly susceptible to injury from releases of oil are exposed shorelines, shallow reef environments, estuaries, mangrove forests, and wetlands (U.S. EPA, 1993).

The volume of oil spilled in the United States has declined steadily over the past two decades. Although large, uncontained spills occur rarely, the public remains concerned about them. Nevertheless, the data show a gradual decline in the volumes spilled. The U.S. Coast Guard reports that 15.2 million gallons were spilled in 1973, declining to 2.1 million gallons in 1993 (USCG, 1998). The trend in the number of oil spills, however, shows 9,014 spills reported in 1973, peaking at 10,644 in 1979, reaching a low of 4,841 in 1987, and climbing to 8,972 in 1993. This trend, however, may be the result of increased vigilance and reporting (USCG, 1998).

Marine Debris and Litter. Some 267 species of marine organisms are known to ingest or become entangled in marine debris that cause injury and sometimes death (Marine Mammal Commission, 1995). Coastal communities can lose millions of dollars in annual tourism revenue, experience declines in commercial and recreational fish stocks, incur damages to vessels, and see declines in property values as a result of marine debris. Coastal communities in New Jersey spend $1.5 million each year to remove debris from beaches and coastal waters to prevent a repetition of the 1987 and 1988 beach seasons, when $2 billion in tourist revenue was lost as a result of debris washing ashore.

Similarly, lost or neglected fishing gear also contributes to the depletion of commercial fisheries. While numbers for the United States are unavailable, Japan estimates that in 1992, the Japanese fishing industry spent $4.1 billion dollars in boat repairs resulting from damage caused by marine debris. Sources of marine debris include vessels and beachgoers, but recent studies show that 80 percent is likely to be from indirect sources such as street litter, improperly sealed waste receptacles, landfills, and from combined sewer overflow events. An international treaty (Annex V of MARPOL) banning the dumping of plastics from ships and regulating other garbage discharges has been in place since 1988, and improvements are being made to reduce marine debris from ships.

Point Sources of Pollution

Point sources[5] include discharges of municipal and industrial wastewater via pipelines, releases from vessels, and the dumping of materials, such as dredged sediments, into coastal and ocean waters. In the United States, more than 2,000 sewage treatment plants, municipalities, and industrial facilities discharge effluents into estuarine and coastal waters. Every year, approximately 2.3 trillion gallons of effluent are discharged into coastal and marine waters from sewage treatment facilities. While most of this sewage meets secondary treatment standards prior to disposal, nutrients and pathogens from such discharges can contribute to the degradation of local marine ecosystems, creating "dead zones" and forcing the closure of shellfish beds and swimming areas. Nutrient loading also can significantly degrade coral reefs and other coastal ecosystems.

Municipal wastewater treatment plants are the major point source of pollution in coastal areas where the population is significantly increasing. As a result of major public and private investments over many years, there is a long-term trend toward higher levels of wastewater treatment. The number of facilities in coastal counties providing less than secondary treatment declined by 80 percent between 1986 (409 facilities) and 1996 (85 facilities), while the number of facilities providing secondary treatment or better increased by 4 percent (3,233 facilities to 3,346 facilities). The number of facilities providing less than secondary treatment is projected to decline by 56 percent between 1996 and 2016 (85 facilities to 37 facilities), while the number of facilities providing secondary or more advanced treatment is projected to increase by 16 percent (3,346 facilities to 3,967 facilities).

The trends towards more widespread wastewater treatment and higher levels of treatment are reflected in environmental measurements of biochemical oxygen demand (BOD_5), an indicator of pollution. Coastal monitoring across the Nation demonstrated that there was an average 19 percent decline in BOD_5 from 1990 to 1997 (U.S. EPA, 1998). Similarly, a 20 percent decline in BOD_5 from 1986 to 1996 was found in coastal counties (Pacheco, 1999 pers. comm).

More than 2.8 billion gallons of industrial wastewater per day are discharged directly into U.S. ocean waters (U.S. EPA, 1994). Many of the chemicals discharged into marine waters can be toxic even in minute concentrations, and can compromise the water column, contaminate sediments, and concentrate in marine organisms. Exposure to these chemicals and metals can pose risks of acute or chronic toxicity to marine organisms. In addition, the risks to predators and humans rise when toxins become concentrated through the food chain. In some locations, thermal pollution from electric generating plants has been shown to stress marine organisms by raising the ambient temperature of the water.

Operating vessels sometimes directly discharge oil, sewage, garbage, and nonindigenous species into marine waters. Some pollutants enter coastal and marine waters from direct discharges (e.g., sewage from vessel toilets, ballast water exchange), while others may be a result of leaching (e.g., anti-fouling agents, paints). Once discharged, pathogens in sewage can impact drinking water intakes (e.g., in the Great Lakes), and result in closings of shellfishing and swimming areas. At the same time, discharged nutrients can increase eutrophication levels.

Oil and other chemical contaminants washed or discharged into the ocean may become suspended in the water column, ultimately settling in sediments and accumulating in marine organisms. Discharged garbage adversely affects marine life (by entanglement or ingestion), and can also cause vessel damage by getting tangled in propellers or sucked into engine intake valves. The potential negative consequences of nonindigenous species carried in ships' ballast water are an increasing concern across the Nation.

In U.S. coastal and ocean waters, dredged material is the primary waste transported and directly disposed. Disposal of dredged material can increase suspended solids in the water column and smother benthic organisms. If the sediments are contaminated, the potential exists for acute or chronic toxicity to develop in marine organisms and become a risk to human health (U.S. EPA, 1991). The U.S. disposes of approximately 300 million cubic yards of dredged material each year from inland and coastal waters, only 60 million cubic yards (20 percent) of which are dumped in open ocean waters. Materials disposed of at ocean dump sites have to meet established water quality and sediment quality criteria.

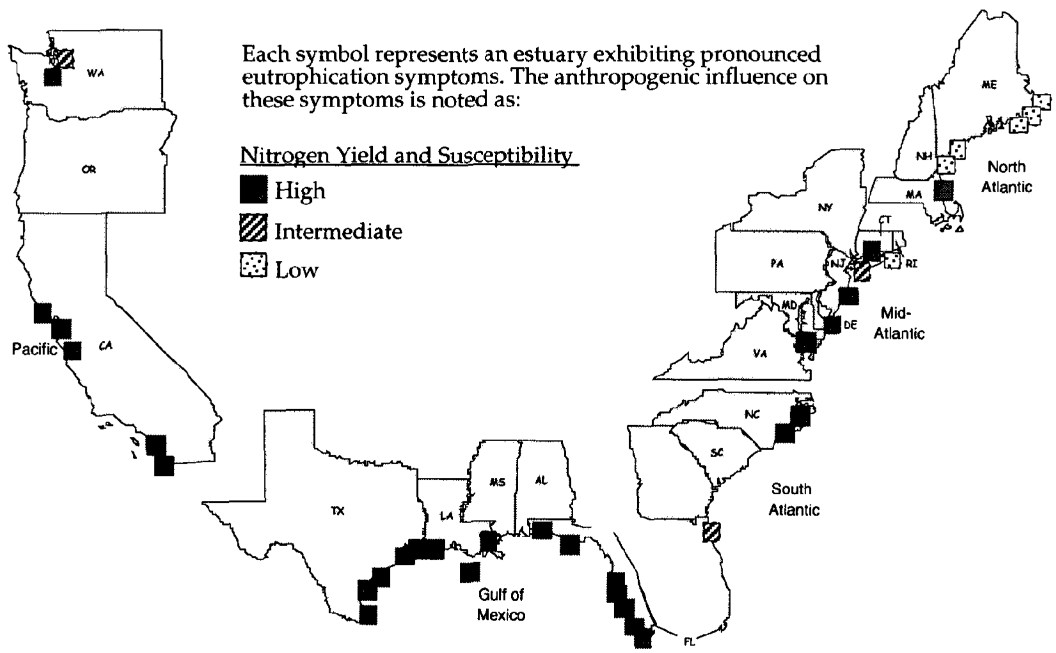
Nonpoint Sources of Pollution

One- to two-thirds of pollutants contributing to the degradation of coastal and marine waters are from nonpoint sources, and include sediments, organic materials, nutrients, pathogens, and toxic chemical compounds. The problem is difficult to address because it includes runoff and seepage from agricultural and urban areas, air deposition onto land and water, and multiple methods of transport. Nationwide, it has been estimated that nonpoint sources account for more than half of the suspended solids, nutrients, fecal coliform, and metals entering coastal waters each year. Runoff from nonurban areas, sewage spills and overflows, urban stormwater runoff, and combined sewer overflows are often responsible for seafood advisories and shellfish-bed and beach closings.

Estuarine Eutrophication. Estuarine eutrophication is an issue of critical concern to coastal managers. Although it is a natural process, human activities can accelerate eutrophication by increasing the levels of nutrients and organic substances entering estuaries. Agricultural runoff, urban runoff, leaking septic systems, and sewage discharges are the primary sources of nutrients that enter coastal waters. These substances can overstimulate the growth of algae and aquatic plants, creating conditions that interfere with recreational uses, and the health and diversity of native fish, plant, and animal populations (CEQ, 1998).

Algal blooms result from increased nutrient concentrations and often lead to indirect effects such as increases in turbidity and decreases in dissolved oxygen concentrations. Algal blooms sometimes have additional impacts, such as the loss of recreational opportunities, reduced aesthetics, declines in commercial fisheries, and loss of habitat. Perhaps the greatest concern at present is the apparent increasing occurrence of red tide algal species, such as *Pfiesteria piscicida*, that can kill fish and that also have major implications on human health, both by direct contact in estuarine waters and through bioaccumulation in fish tissues.

Figure 9. Estuaries exhibiting anthropogenic eutrophication effects



Source: NOAA, 1998

Eutrophication-related problems occur in many of our nation's estuaries, mostly during the summer months. The problem varies by region. For example, extreme levels of chlorophyll *a*, a measure of algal biomass, have been observed in Mid-Atlantic, Gulf of Mexico, and South Atlantic estuaries. Hypoxia and anoxia, conditions of low dissolved oxygen, are most widespread in the Gulf region, where over 80 percent of estuaries are depleted of dissolved oxygen. Toxic algal blooms occur in nearly half of the Nation's estuaries, with the greatest number of occurrences observed in the Gulf of Mexico, North Atlantic, and Pacific Coast estuaries.

Reports of worsening trends in concentration, spatial coverage, or frequency of occurrence of toxic blooms, hypoxia events and nitrogen are about equal to improving trends on a national basis. For trends in SAV coverage, however, the number of estuaries reporting worsening conditions is three times as great as those reporting improvements. The overall trend in eutrophic conditions, which integrates trends in several indicator parameters, shows that conditions in 14 percent of U.S. estuaries have improved since 1970 while 31 percent of the estuaries studied reported that conditions have worsened. For 55 percent of the estuaries studied, conditions have not changed or there was insufficient information for trend evaluation. Regionally, there is a fairly even distribution of reported improvements, while the greatest number of estuaries for which conditions have worsened are in the Gulf of Mexico. Figure 9 shows the locations of estuaries with high levels of eutrophic symptoms that can be linked to human activities.

Future Trends. The aggregate picture indicates an increase in the severity and extent of eutrophication in the future, with greater than 60 percent of currently monitored estuaries expected to show worsening symptoms of eutrophication. Future trends are dependent on the levels of municipal waste treatment, the effectiveness of stormwater management in newly developed areas, the extent and practice of agricultural activities, and trends in transportation (e.g., vehicle emissions). It is important to note that nutrient reduction strategies have helped to reverse or halt eutrophication events in Maryland's Patuxent River and Florida's Tampa and Sarasota bays. Because of projected population increases, however, the need to limit nutrient inputs to estuaries must be more emphasized as the Nation moves into the next century.

Habitats

Coastal areas, including mangrove swamps, wetlands, estuaries, seagrass beds, and coral reefs, provide critical habitat, including essential spawning and nursery areas, for living marine resources. Wetlands serve as filters for land-based contaminants, and together with coral reefs, buffer against storm surges and help prevent coastal erosion.

Human activities have changed, degraded, or destroyed coastal habitats, threatening many species of economic and recreational importance. Continued population growth and associated development pressures along the coasts reduce the quantity and quality of the nation's habitat resources. Until recently, many coastal habitat resources have been undervalued or not fully appreciated in terms of people's dependence on them.

Habitat Loss. Coastal habitats critical to healthy ecosystems are being lost and degraded at a rapid pace. While the rates and reasons differ from one habitat type to another, the pressures all stem from anthropogenic activity, and the consequences are always deleterious to the environment.

Wetlands. More than one-third of the nation's threatened and endangered species live only in wetlands, and more than half use wetlands at some point in their lives (U.S. EPA, 1998 on-line). In the Southeast, over 90 percent of the commercial catch and 50 percent of the recreational catch are of fish and shellfish dependent on wetlands. Still, years of continued degradation, or their conversion to cropland or developed land, have resulted in wetland losses, particularly coastal wetlands. Wetlands are among the most highly altered ecosystems worldwide. Table 3 summarizes total wetland losses by type since the mid-1950s. The period from the mid-1970s to mid-1980s saw the greatest wetland losses; since then, the rate of loss has decreased.

Coastal wetlands (both tidal and nontidal) have been destroyed by direct (e.g., draining, dredging, land fill, spoil disposal) and indirect (e.g., sediment diversion, hydrologic alteration) human impacts associated with development, resource extraction, and agricultural activities (NOAA, 1998). Coastal wetlands are stressed by nonpoint source pollution and are at risk from demands for housing, roads, and recreation facilities, as well as by commerce and industry. Natural processes, such as erosion and subsidence also contribute to wetlands losses.

Table 3. *Trends in U.S. wetland acreage*

	Million Acres			
Wetlands Type	mid-1950s	mid-1970s	mid-1980s	mid-1990s
Estuarine	5.59	5.53	5.10	5.09
Fresh Water				
Marshes	33.07	24.31	25.88	25.01
Shrub	11.00	15.51	15.60	17.07
Forested	55.09	55.15	50.39	47.93
Other	2.70	5.35	5.14	5.79
Total Acreage*	107.45	105.85	102.12	100.91

**Note: Totals may not agree with sum of components due to independent rounds.*

Source: President's Council on Environmental Quality, 1998

Almost half of the estimated total acreage of U.S. coastal wetlands was lost by the mid-1970s. Losses in Louisiana exceed those in any other state, averaging 24,000 acres annually for the period from 1978 to 1990. The average annual wetland loss is estimated to be from 70,000 to 90,000 acres on nonfederal lands. Coastal wetlands continue to decrease in area, although the rate of loss has declined over time. About 89 percent of national wetland losses from the mid-1970s to the mid-1980s occurred in the Southeast (Boylan and MacLean, 1997).

Seagrasses. Historically, severe losses of seagrasses have occurred as a result of water quality issues, a problem that cannot be rectified solely by replanting. Seagrass losses in estuaries and nearshore waters are due primarily to excessive nutrient loadings and sedimentation. Direct damage from vessels (mooring scars, propeller scars, vessel wakes) has also harmed seagrass beds. Fishery harvest methods can also result in devastating losses to seagrass beds. Bottom trawling operations, in particular, turn over and disrupt significant amounts of bottom habitat (Dayton, 1998). This loss of seagrass causes undesirable and often irreversible conditions. The ramifications of these losses include increased shoreline erosion, water column turbidity, and degraded water quality. The permanent loss of seagrass beds eliminates most associated habitat functions that support other living marine resources.

Significant losses of seagrasses have occurred in the Chesapeake Bay and in the Gulf of Mexico. Over 50 percent of the historical seagrass cover has been lost in Tampa Bay, 76 percent in Mississippi Sound, and 90 percent in Galveston Bay. Gulf of Mexico losses are related to population growth and the accompanying declines in water quality. Seagrass losses have also occurred in Puget Sound and San Francisco Bay.

Extensive damage to seagrass beds from propeller scarring has been reported in Florida coastal waters, particularly in the Florida Keys National Marine Sanctuary.

Coral Reefs. Coral reefs are considered to be the world's most diverse marine ecosystems, home to hundreds of thousands marine species. The United States has approximately 16,879 square kilometers of coral reefs that harbor about 550 commercially valuable species (NOAA, 1998). Threats to coral reefs have increased over the last 20 years and have resulted in global declines. Although actual data are not available, it is estimated that approximately 58 percent of the world's coral reefs are at risk from human activities; about 27 percent of these are at high risk. Ten percent of the world's reefs are severely damaged, with the expectation is that this number will increase to 30 percent over the next two decades (NOAA, 1998).

Overfishing and destructive fishing practices, along with coastal development, land-based pollution from deforestation, agriculture and marine spills and pollution, pose the greatest threats to reefs. Changes in species composition result from overfishing and may ultimately result in ecosystem changes. Coral diseases have increased dramatically. Even recreation, if not regulated, causes damage to coral reefs (World Resources Institute et al., 1998). Although it is not a problem in the United States, the growing international trade in harvested corals and coral species contributes to the degradation and destruction of corals worldwide.

Habitat Regulation and Restoration. To date, most habitat restoration activities have focused primarily on wetlands. Several states have enacted laws to regulate activities in wetlands, and local jurisdictions have adopted wetland protection ordinances or have changed the development permit process to foster protection of these habitats. Most coastal states have significantly reduced losses of coastal wetlands. Some states and local governments have also established nonregulatory programs to help protect wetlands. Federal programs focus on regulation (section 404 of the Clean Water Act), economic incentives and disincentives (tax deductions for selling or donating wetlands to a qualified organization), and acquisition (establishing national wildlife refuges). In most instances, the restoration of seagrass beds and coral reefs have lagged behind wetland restoration projects.

In 1996, regional fishery management councils were directed to identify and protect essential fish habitat. Efforts are now under way on every coast to identify the habitats that are essential for every all life stages of all managed fish species. Once these habitats have been identified, the regional councils can act directly to minimize the negative effects of fishing. The councils can also call attention to, and influence, other important factors such as nonpoint source pollution, eutrophication, and physical habitat loss resulting from coastal development or other activities.

Habitat Alterations as the Result of Unintentional Introductions of Non-Indigenous Species. Marine flora and fauna are entering and taking hold in new environments, often disturbing or displacing native species, at an increasing rate as a direct result of human activity, especially global shipping (National Research Council, 1996). While many introduced species do not establish themselves or have a major impact, some do have detrimental effects on the ecosystem and human society, including the economy, recreation and health (NOAA, 1994).

Species enter new environments by many vectors. One important pathway is transport by ship, in ballast water, in sediment on the ship, or on the ship's hull or cargo (National Research Council, 1996). The frequency of unintentional introductions by ship of harmful species has increased, in part as a consequence of rapid growth in global transportation systems, which link continents ever more tightly and thus increase the chances that an entrained organism may survive a sea voyage and live to reproduce in a new environment.

International efforts are under way to reduce the threat of unintentional introductions of species. However, most control measures remain voluntary or only partially effective. The sad fact is that many nonindigenous species have already become established, with deleterious consequences, and more will become established, altering coastal and marine habitats in undesirable ways in the future.

Coastal Hazards

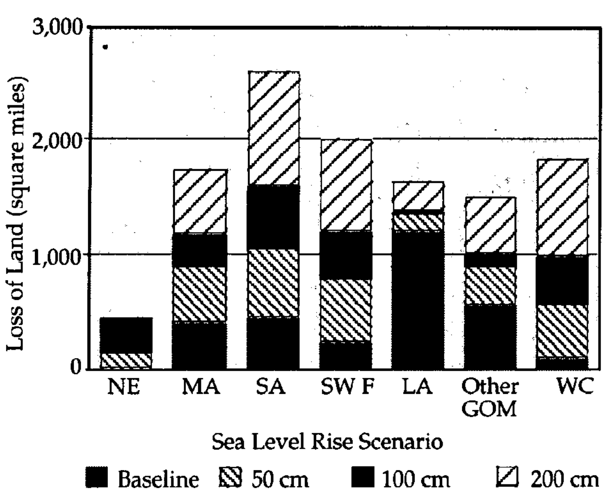
Coastal storms damage property, take lives, and disrupt ecosystems as a result of high winds, storm surge, flooding, and shoreline erosion. Coastal locations are also exposed to long-term hazards such as chronic coastal erosion, potential sea-level rise, and global climate change. The costs of these events to society are climbing both nationwide and worldwide as coastal settlements place more people and property at risk. Moreover, the frequency, magnitude, and consequences of coastal hazards may change in the future as changes occur in the global climate.

Natural hazards currently cause about $50 billion in damages each year in the U.S. (NOAA, 1998a). Losses in 1970 were about $4.5 billion[6]. Of about $500 billion in disaster-related losses between 1975 and 1994, 80 percent were weather-related. Given the significant costs of catastrophic weather events, the focus has shifted in recent years to reducing losses through advances in weather prediction, regional planning, and emergency preparedness.

Trends in the Frequency and Magnitude of Coastal Hazards. The theory that global warming will make storms stronger and more frequent is under intense study. The Earth's average surface temperature has risen approximately 0.6°C (1°F) in the last century, and the nine warmest years have all occurred since 1980 (Titus and Narayanan, 1995). If computer model predictions of warming are correct, under some scenarios, a 50 percent increase could occur in the destructive potential of large storms. There are also arguments, however, to the idea that a warmer atmosphere will result in more destructive storms. In short, the data are incomplete as to whether global warming will lead to more destructive coastal storms.

One thing is certain—relative sea level is rising in many regions, and global warming may speed this process. Along much of the U.S. coast, sea level is

__Figure 10.__ Dry land loss by 2100 without shore protection



Note: NE-Northeast; MA-Middle Atlantic; SA-South Atlantic; SWF-Southwest Florida; LA-Louisiana; Other GOM-Other Gulf of Mexico; WC-West Coast.

Source: Titus et al., 1991

rising 2.5 to 3.0 mm every year (10-12 inches per century). The Intergovernmental Panel on Climate Change has forecasted a rise in global sea level of 5mm per year. This totals either 20, 49 or 86 cm by the year 2100, within the range of uncertainty (Bijlsma, 1996). A rise in sea level could increase storm frequencies and associated storm surges, which in turn, could accelerate erosion and associated habitat loss; increase salinity in estuaries and freshwater aquifers; alter tidal ranges in rivers and bays; change sediment and nutrient transport, and also the pattern of chemical and microbiological contamination, in coastal areas; and increase coastal flooding. Particularly at risk are saltwater marshes, coastal wetlands, coral reefs, coral atolls, and river deltas (Figure 10). In the worst scenarios, the number of homes in the coastal floodplain vulnerable to coastal hazards would more than double (NOAA, 1998b).

Increasing Potential for Loss. The societal cost of coastal hazards is determined not only by annual variabilities in their occurrence, but also by the increasing population at risk and the growing numbers and value of structures, businesses, and other manifestations of economic activity in coastal areas. Coastal populations, societal expectations, economic activities and personal consumption all have increased greatly in the past decades. Together, these changes have increased the exposure of the total U.S. population to damages from coastal hazards.

Prior to 1989, no single event caused insured losses in excess of $1 billion. Since 1989, losses from several coastal storms have exceeded this figure (Institute for Business and Home Safety, 1998)[7]. The largest of these catastrophes was Hurricane Andrew, with estimated insured losses of $15.5 billion.

In the wake of the annual onslaught of news coverage of storms, other hazard-related disasters and their costly results, many people have concluded that coastal storms are becoming more frequent and devastating. However, careful analysis of climate data and loss records shows that more frequent or more intense storms are not necessarily the cause, or at least the sole cause, of increasing damages. Rather, there is more at risk today (Pielke and Landsea, 1998). Three factors account for the increasing potential for loss: (1) adjustments to the value of the dollar largely as the result of inflation, (2) increasing population and growing settlement densities in coastal areas, and (3) the nation's personal wealth, which has increased dramatically over the years. All of these factors combine to increase the exposure to,

Table 4. Estimated U.S. losses associated with hurricane activity (in 1995 dollars)

Years	Number of Hurricanes with Losses Valued at Greater than a Billion Dollars			
	Greater than $1	Greater than $5	Greater than $10	Per Year
1925-1929	2	2	2	17.7
1930s	4	1	1	2.6
1940s	8	4	2	5.6
1950s	4	2	2	3.7
1960s	6	5	3	5.2
1970s	5	2	1	2.7
1980s	3	2	1	2.2
1990-1995	4	1	1	6.6

Source: Pielke and Landsea, 1998

and the consequent property losses from, coastal hazards.

When the loss record is normalized to correct for these underlying changes, the picture is very different (Pielke and Landsea, 1998). Instead of increases in losses, normalized damages actually decreased in the 1970s and 1980s; nor are losses in the 1990s unprecedented (Table 4). Pielke and Landsea conclude that "All else being equal, each year the U.S. has at least a 1 in 6 chance of experiencing losses related to hurricanes of at least $10 billion (in normalized 1995 dollars)."

Thus, long-term efforts to prepare and plan for coastal hazards, and to mitigate their effects, are necessary to save lives and to prevent or mitigate the ever-increasing potential for property losses in coastal areas.

More Effective Prediction, Preparedness, and Response. Experience has shown that the property damage and loss of life from coastal hazards, including storms and erosion, can be minimized through planning and mitigation. Better predictions, forecasts, and warnings provide timely and targeted evacuations of high hazard areas. Forecasters can now predict climate changes for up to a year, and weather for a week or more. These advances have come about as the result of major long-term investments in the science of numerical weather prediction. The improved skill and lead-time of today's forecasts save hundreds of millions of dollars a year in the United States.

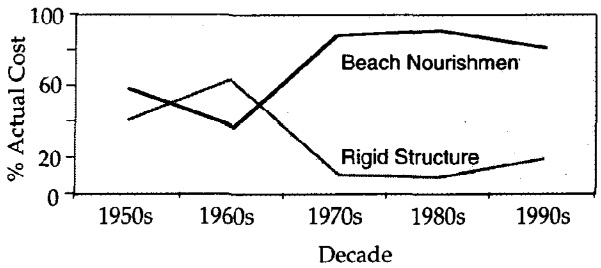
Advances in climate prediction and weather forecasting are particularly useful to the agriculture, transportation, energy, and water resource sectors of the economy. They also make possible advance warnings of violent weather that can provide valuable time for evacuations and preparedness activities. Today, about 90 percent of severe weather events can be predicted with confidence; in areas where the most advanced technology and methods are not yet in use, the prediction rate is 60 percent. Meteorologists can now make 48-hour predictions of temperature and precipitation with the same confidence they brought to 12- to 24-hour forecasts 20 years ago. Similar advances in coastal storm tracking and advance warnings enable more timely preparations and coordinated evacuations.

Building codes that incorporate hazard-resistant construction standards have proven very effective in reducing the cost of disasters, as has the appropriate siting of structures in areas where they are less likely to suffer wind and water damage or be affected by coastal erosion. From September 21-30, 1998, Hurricane Georges left a trail of destruction in the Caribbean region and across the U.S. Gulf Coast. Damage reports from various locations along the hurricane's path told an interesting story about the degree to which deaths and property losses from coastal storms can be prevented by preparedness and mitigation. The Virgin Islands reported no deaths and little major damage. With recent hurricanes in 1989 and 1995 on everyone's mind, the islanders followed evacuation and preparedness orders; many structures had been rebuilt or upgraded to the latest building codes. In contrast, Puerto Rico, only a short distance away, incurred at least $2 billion in damages. Puerto Rico had not suffered a "direct hit" in recent years, and the island was less prepared than its nearby neighbor.

Managing Coastal Erosion. The nation's shorelines, especially the sandy types that extend for 2,700 miles from the coast of Maine to Texas, are vulnerable to coastal hazards. Sand is carried by water and wind between offshore bars and the beach, across the dunes, through coastal inlets, and throughout the entire littoral zone. Complicating the picture is the projected rise in sea level over the long term (Bijlsma, 1996).

The impacts of rising sea level include inundation, flooding, erosion, and saline intrusion into coastal aquifers. Clearly, an environment so dynamic, and threats so dramatic, pose unique problems for those who live or build in these areas. Structures built too close to the shoreline are often threatened by erosion. The degree of protection, management, or human intervention that may be needed to counter coastal

Figure 11. The shift from fixed structures to beach restoration and nourishment to manage erosion



Source: Hillyer, 1996

erosion depends on the nature of the shoreline and the prevailing uses of the adjacent area. For developed communities with water-dependent economic activities such as harbors and resorts, the strategy of choice is usually to protect the existing infrastructure and maintain the beaches. For eroding shorelines that are less developed, the decision becomes more difficult (National Research Council, 1985). The choice is either to stabilize the shoreline at some environmental and economic cost, or to retreat from the shoreline and let nature takes its course, also at some environmental and economic cost. When the shoreline is to be protected, the choice is often between hard stabilization (e.g., groins and jetties) and soft stabilization techniques (e.g., beach nourishment).

The differences between types of shorelines and erosion situations often make it necessary to consider a variety of shoreline protection measures (National Research Council, 1995). Nevertheless, a clear shift from hard protective structures to beach nourishment techniques has occurred in engineering practices for shoreline stabilization (Figure 11). On the whole, beach nourishment is considered less disruptive to the environment, but projects require periodic maintenance to maintain their effectiveness (National Research Council, 1995).

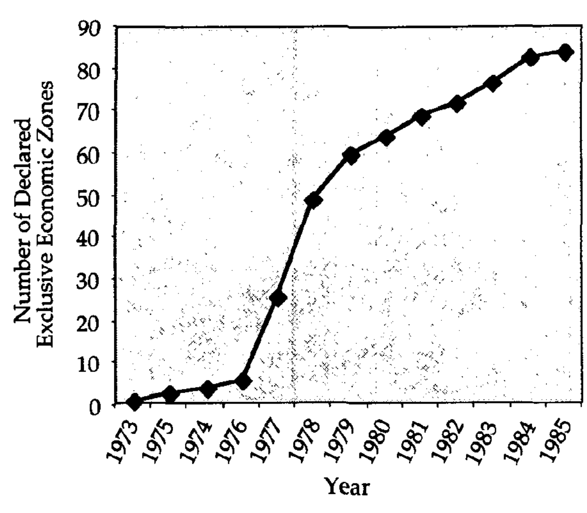
Despite the demonstrated success of planning, preparedness, and mitigation, many coastal property owners do not obtain insurance coverage for damages from coastal hazards, especially flooding and chronic erosion (Miletti, 1997), or take necessary and appropriate mitigation measures. Property owners in high-risk areas tend to turn to federal disaster relief programs, shifting the burden to taxpayers. Education and public awareness of coastal hazards, their costs, and the societal advantages of mitigation may help to alleviate this situation, and, ultimately, reduce the cost of coastal hazards to society.

Governance and Management

The great number of activities that occur in the coastal zone and ocean are governed by a complex and often fragmented framework of laws, regulations, and practices at the federal, state, and local levels (National Research Council, 1997). The resources affected are diverse, as are the resource users, and management efforts struggle with diverse goals that sometimes are incompatible. Single-purpose legislation that serves specific goals well has also produced separate management regimes that require a great deal of coordination. Moreover, while private ownership predominates on land, large areas of marine resources are in the public domain.

Three fundamental trends are occurring in coastal and ocean area governance and management. First, on an international scale since 1973, the idea of the oceans as a "commons" whose resources and space are open to all has been supplanted by new principles codified in the Law of the Sea Convention, which (1) recognize the rights of nation-states to establish 200-mile exclusive economic zones over ocean resources and uses, and (2) authorizes regional management arrangements for ocean uses, such as international fisheries management and environmental protection. Second, federal environmental mandates have established special ocean and coastal management areas, and have increased the national capacity to plan for and manage the coastal zone. Third, integrated management approaches are

Figure 12. Establishment of Exclusive Economic Zones



Source: Smith, 1986

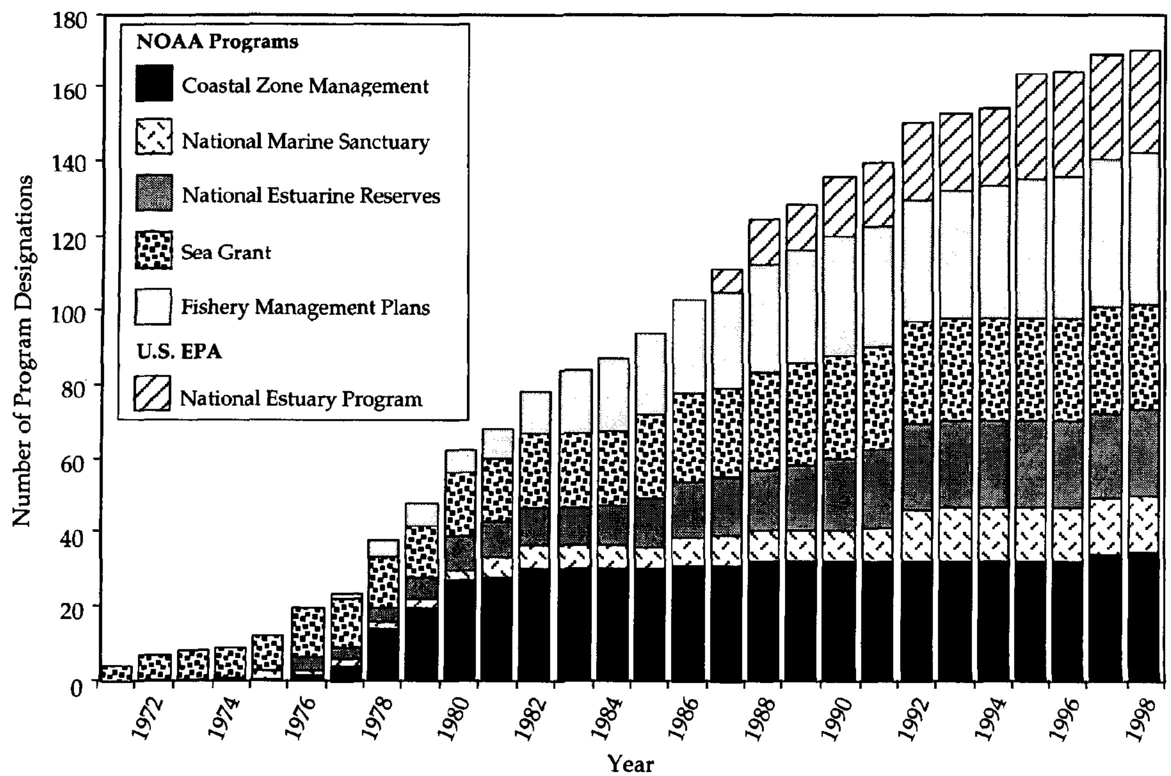
coming into use that bring together diverse stakeholders to address economic, environmental, and social demands placed on finite ocean and coastal resources.

International Developments. United Nations deliberations on the Law of the Sea led most nations in the 1970s and 1980s to establish zones of exclusive economic jurisdiction over ocean areas and resources that extend offshore for 200 miles (Figure 12). This trend has continued in the 1990s, and has led to increases in resource utilization, such as fisheries development and offshore energy production.

The other major international development during this era was the establishment of regional or use-focused entities that have planning, management, and enforcement authorities (Van Dyke, 1998). In a remarkable display of the "greening" of international diplomacy, the London Convention has been greatly strengthened to control ocean dumping. An international convention was recently negotiated to address the management of cross-jurisdictional and migratory fish stocks. Measures also have been taken to promote fishing vessels' compliance with international conservation and management efforts on the high seas. Steps have been taken to more effectively address the marine transport of radioactive and hazardous cargoes. Land-based sources of marine pollution, conservation of marine mammals, high seas fishing practices, and management of Antarctic fisheries have all received significant international attention. Clearly, under the framework of the international Law of the Sea, there is a growing worldwide capacity to reach and implement important agreements on difficult ocean resource and management issues.

Growth in National Mandates and Capability for Managing Oceans and Coasts. As a matter of national policy, states have the primary responsibility for setting comprehensive policies and managing their coastal zones[8]. The influence of states on their coastal zones and the adjacent coastal ocean, and their capacity to manage these areas, have grown over the course of many years (Hershman, 1996). This is, in part, a consequence of the growing number of federal mandates to manage the oceans. These mandates have generally been accompanied by funding to implement them, which, in turn, has resulted in increased federal, state, and local capacities to manage coastal zones, ocean areas, and their uses. Figure 13 provides a cumulative look at the growth, over time, of some federally chartered

Figure 13. *Growth in federally approved coastal and ocean planning and management programs, 1974-1989*[9]



coastal and coastal ocean planning and management programs. It indicates that long-term growth has occurred in national mandates for managing the oceans and coasts, and also, by extension, the capacity of states and others to implement those mandates.

Along with the growing mandates for managing oceans and coasts, the national awareness of the need for management, and the technical capability to accomplish management tasks have also grown. Widespread public awareness of coastal issues, their complexity and responses to them has become an important factor in stewardship of the coastal zone. A recent review conducted by the National Sea Grant Program and other agencies found that informal marine education has been extensive and growing in the US for many years (NOAA, 1998). Major developments have included growth in the extent and quality of media coverage of marine and coastal issues, and proliferation of aquaria and other institutions that feature public displays and learning about oceans and coasts. Another bright spot is the maintenance and growth, over many years of high quality graduate marine and coastal education programs that have produced adequate numbers of trained professionals to meet national needs (Journal of Marine Education, 1998).

Other advances in the capability to achieve management objectives have come about as the result of investments in and applications of technology. Remote sensing, imaging technology and "smart" instruments have brought new data and ways to present and analyze new information. Modeling and simulation have become important aide to consensus building and decision-making. Marine biotechnology advances, in addition to leading to tremendous new economic opportunities are also leading to new indicators and tools that can help protect the environment (Biotechnology Research Subcommittee, 1995; Zilinskas and Colwell, 1995). Communications and information technology advances have helped managers reach out to new constituencies and bring in new ideas.

Growing Reliance on Integrated Management. Managing the oceans and coasts is an interdisciplinary endeavor requiring integrated approaches. This is because a broad spectrum of issues must be considered to manage resources, safeguard ecosystem health and biodiversity, and allow economic uses that conflict minimally with one another, and that cause minimal harm to the environment. Slowly but surely, integrated approaches to management are emerging to meet these demands. They generally involve (1) a regional or ecosystem focus, (2) accurate information on the state of the environment (that can only come from significant investments in science and monitoring), and (3) collaboration between government agencies, varying levels of government, and private-sector interests. Examples of successful, innovative, integrated ocean and coastal management efforts abound in every coastal region. A few examples include inshore lobster fisheries in the Gulf of Maine; estuarine protection in South Carolina; innovative environmental planning and management in the Florida Keys; and restoration and protection of urbanized estuaries in California.

Still, formidable obstacles remain. They include bureaucratic obstacles in the form of agencies that seek to protect their "turf," economic issues posed by stakeholders who want to advance their own financial interests, and legal concerns of constituencies that want to achieve their goals through legislative action. Political obstacles occur where jurisdictional boundaries do not coincide with natural, ecological boundaries. Nevertheless, a well developed marine area governance and management system is evolving in response to the experience being gained across the Nation. Innovative partnerships are also harnessing the expertise and resources of private industry and nonprofit organizations. These constituencies, often the target of government regulation in the past, are introducing innovations into systems that have been largely dominated by insiders accustomed to traditional, hierarchical management approaches (National Research Council, 1997).

Concluding Observations

One topic runs like an undercurrent throughout this report—increasing population and its associated developments, requirements, and burdens. Population growth and associated increases in consumption drive changes in settlement and pollution patterns. They stimulate the demand for marine recreation, world trade, and oil and gas. They are the catalyst for intensified farming practices and the overexploitation of fisheries. Human activities and consumption lie behind the loss and degradation of marine habitats. Even where the environment is cleaned or protected in coastal and nearshore areas, the press of people threatens to overturn progress. Even natural disasters and changes to shorelines are of concern primarily because people stand or build in harm's way. If population control is "the issue" for the 21st century, then it was "the issue" in the 20th and 19th centuries as well. Fortunately, society has consistently risen to the challenge, initially through the promotion of public health, then through the control of pestilence and disease, and more recently by revolutionizing food production. Perhaps the ultimate challenge will be to learn how to live in harmony with the Earth.

Trends point toward outcomes; however, missing is any meaningful sense of direction concerning what conditions will prevail in the future. That is because future conditions are not completely, mechanistically driven. To the contrary, an informed citizenry's political choices drive management efforts to socially desirable ends. In other words, the future is in our hands. The debate should focus on goals for the future and how to achieve them. Information about present and projected trends merely informs the dialogue.

Goals can be set to favor the economy, the environment, or to find an acceptable balance somewhere in the middle. Unfortunately, policies and choices that favor population growth or resource exploitation often harm the environment and, ultimately, retard economic growth and harm public welfare. Similarly, policies that favor the environment work to the detriment of society because of the harsh social costs of artificially limited opportunities. As a result there really is only one socially acceptable outcome—to achieve an appropriate balance between economic development and protecting and preserving the environment. The key is to ensure that a healthy coastal and marine environment is available for future generations.

End Notes

1. Who would ever have imagined 30 years ago that a two-digit date code for computer systems, which were just coming into widespread use, would threaten to disrupt every quarter of society, from banking to electric power to transportation, just a few years later, as the calendar date switched from 1999 to 2000?

2. Sustainable development has been characterized as meeting the needs of the present without compromising the ability to meet the needs of the future.

3. The precautionary principle calls for conservative action in the face of uncertainty.

4. Wilderness Act (1964), National Environmental Policy Act (1970), Clean Air Act (1970), Coastal Zone Management Act (1972), Clean Water Act (1972) Marine Mammal Protection Act (1972) Marine Protection, Research and Sanctuaries Act (1972), Endangered Species Act (1973), Port and Tanker Safety Act (1974), Fishery Conservation and Management Act (1976), Outer Continental Shelf Lands Act Amendments (1978).

5. "The term 'point source' means any discernible, confined, and discrete conveyance, including, but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include agricultural stormwater discharges and return flows from agriculture." Clean Water Act, Section 502(14)

6. These figures are for all disasters and are only direct costs. They do not include indirect losses, such as lost business.

7. Hurricane Hugo in 1989, Hurricanes Andrew and Iniki in 1992, Hurricane Opal in 1995, and Hurricane Fran in 1996.

8. Even so, about 21 percent of coastal lands are owned or managed directly by the federal government.

9. The data are a raw compilation of federal program approval actions.

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