CHAPTER SIX

River's End

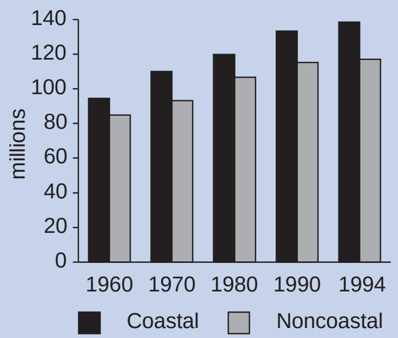
The meeting of rivers with coastal estuaries and the sea marks the end of a journey, yet in American history these locations also mark a beginning—the earliest settlements at the beginning of the nation's history. Some of these settlements grew to become the nation's largest cities. The ports of Boston, New York, Philadelphia, New Orleans and others have rich histories as centers of waterborne commerce.

Today, America's coastal areas support the country's major population centers, much industrial activity, burgeoning retirement and "second home" communities, and popular tourist attractions. Population growth and development pressures in coastal areas often lead to changing and sometimes conflicting land uses; pressures and demands for infrastructure and services; increased pollutant discharges from point and nonpoint sources; and diminution of coastal habitats and aquatic resources. (For a definition of coastal area, see Part III, Table 1.7.)

The coastal regions of the U.S. represent only about one fourth of total U.S. land area, yet the Bureau of the Census estimates that in 1994 roughly 53 percent of the total U.S. population—nearly 140 million people—were living within coastal areas (Figure 6.1). Coastal corridor densities range from 69 people per square mile along the Pacific coast to over 410 people per square mile along the Atlantic coast (Figure 6.2). The U.S. coastal population increased by about 44 million people from 1960 to 1994, slightly more than half the total U.S. population increase . In several small New England states, the entire state population lives within the coastal zone (Figure 6.3).

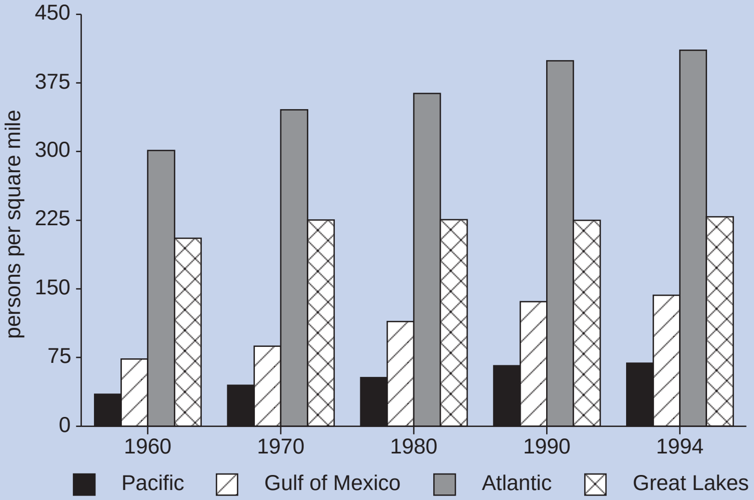
Population growth, both the traditional expansion from cities characteristic of the Northeastern and Mid-Atlantic areas and the suburban sprawl common in the South and Gulf of Mexico, will continue.

Figure 6.1 U.S. Population by Coastal and Noncoastal Place of Residence, 1960-1994



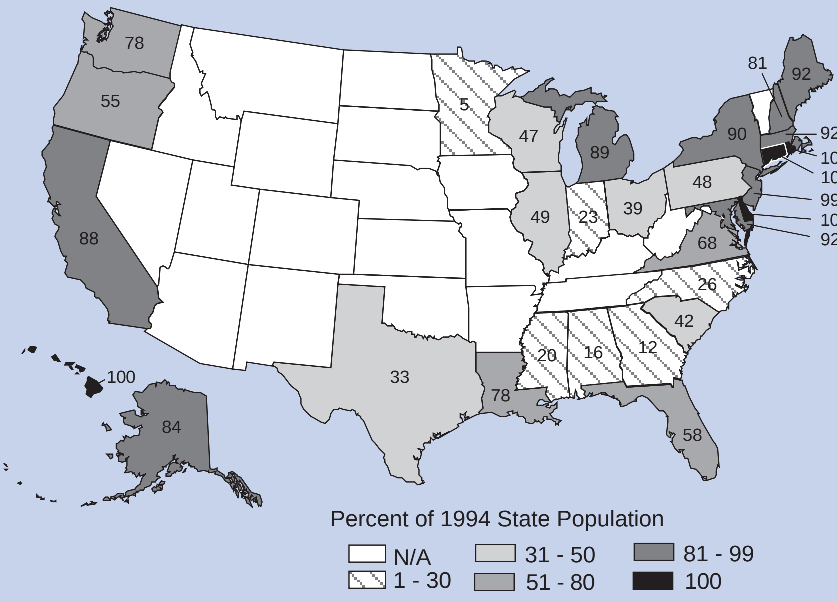
Source: See Part III, Table 1.7.

Figure 6.2 U.S. Coastal Population Density, 1960-1994



Source: See Part III, Table 1.7.

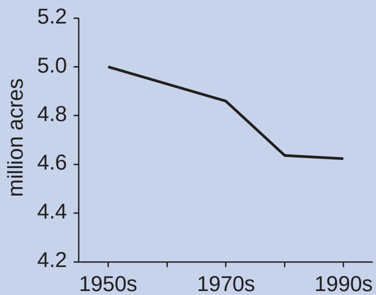
Figure 6.3 Percentage of State Population Living in the Coastal Zone, 1994



Source: U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States* (GPO, Washington, DC, 1997), data from the 1990 Census of Population and Housing, and updates by agency.

Note: N/A = Not applicable.

Figure 6.4 U.S. Coastal Vegetated Wetlands, 1950s to 1990s



Source: Dahl, T.E. et. al., *Status and Trends of Wetlands in the Conterminous United States, 1980s to 1990s* (DOI, FWS, Washington, DC, Draft).

In eastern Florida alone, population per shoreline mile is expected to increase nearly 30 percent by 2010.

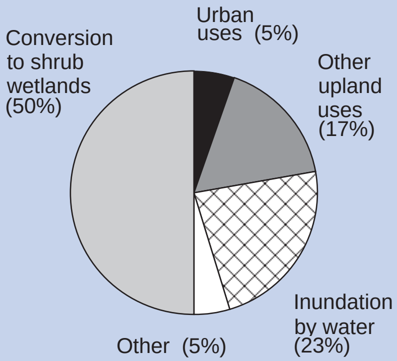
According to a recent study by the National Wetlands Inventory, coastal wetlands continue to decrease in area, although the rate of decline has slowed considerably from earlier periods (Figure 6.4). Urban development, residential and recreational development in rural areas, silvaculture, and erosion were responsible for the losses (Figure 6.5). These losses are particularly significant because of the vital role these coastal habitats play in supporting productive fish and shellfish resources (Box 6.1).

Wetlands losses in Louisiana—estimated at about 24,000 acres annually in the 1978-90 period—are the largest of any state and accounted for two thirds of the nation's total loss in this period. Much of the loss is due to altered hydrology stemming from navigation, flood control, and mineral extraction and transport projects. In the northern Gulf of Mexico, losses of seagrass have also been extensive over the last five decades—from 20 to 100 percent for most estuaries—largely because of coastal population growth and accompanying deterioration of water quality.

Some portion of wetland and seagrass bed losses are attributable to natural processes such as hurricanes and coastal storms. Rising sea level and coastal subsidence—natural processes that are probably accelerated by human activities—are also causing coastal habitat losses. For example, more than half of the coastal marsh acreage lost in Texas between 1955 and 1992 was due to land subsidence and submergence (drowning), which resulted from withdrawal of underground water, oil, and gas (Figure 6.6).

In Boston Harbor, eelgrass beds were abundant just before the turn of the century, but by 1990 only a few beds remained in the remotest parts of the harbor. Probable causes of the decline

Figure 6.5 Loss of U.S. Coastal Marshes by Cause, 1985-1995



Source: FWS, *Status and Trends of Wetlands in the Conterminous United States, 1980s to 1990s.*
Note: Total loss = 32,000 acres.

Box 6.1
Fish and Shellfish Conditions

In 1996, 2,193 fish consumption advisories were reported by states to EPA (Box Figure 6.1). The number of advisories rose by 453 in 1996, representing a 26 percent increase over 1995. The number of waterbodies under advisory represents 15 percent of the Nation's total lake acres and 5 percent of the Nation's total river miles. In addition, 100 percent of the Great Lakes waters and their connecting waters and a large portion of the Nation's coastal waters were also under advisory. States typically issue five major types of advisories and bans to protect both the general population and specific subpopulations (usually pregnant women, nursing mothers, and young children). All types of advisories increased in number from 1993 to 1996. Box Figure 6.2 shows the number of advisories in the United States for four major contaminants (mercury, PCBs, chlordane, and DDT).

In its National Status and Trends Program, the National Oceanic and Atmospheric Administration (NOAA) measures trace metals and synthetic organic compounds at about 100 sites nationwide and contaminants in mussel and oyster tissues and coastal sediments at about 240 sites nationwide. Not surprisingly, both projects have found that the highest concentrations are near urban and industrial areas. The highest concentrations of chemicals in fish livers are near urbanized areas in the Northeast (New York City, Boston, and Baltimore) and the West (San Diego, Los Angeles, and Seattle). The highest concentrations of organic contaminants in molluscan tissues are at urban sites near Boston, New York City, Mobile, San Diego, San Francisco, and Los Angeles.

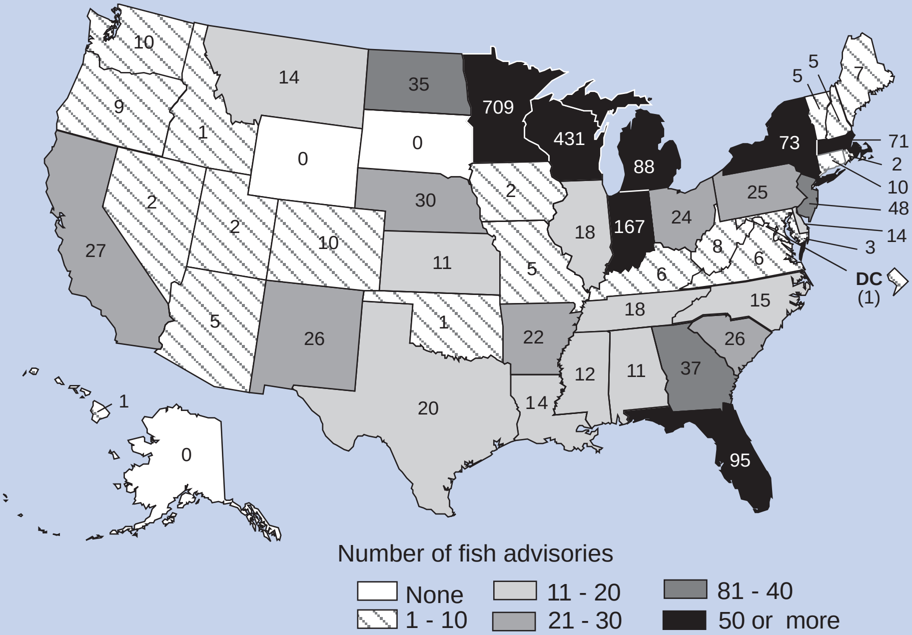
Based on acute toxicity measurements, about 10 percent of the nation's coastal regions are environmentally degraded. The extent of environmental degradation ranges from none in generally pristine environments such as Apalachicola Bay in Florida to 85 percent in the relatively small but heavily contaminated Newark Bay. Approximately 50 percent of coastal regions show adverse biological responses to environmental contaminants.

In its National Shellfish Register of Classified Growing Waters, NOAA conducts surveys of shellfish-growing waters in 122 estuarine and 98 non-estuarine areas (4,230 individual shellfish growing areas) in 21 coastal states. Shellfish-growing areas are classified as approved or "harvest-limited" (including areas that are either conditionally approved, restricted, conditionally restricted, or prohibited).

Over the period from the first report in 1966 to the latest report in 1995, the acreage of classified shellfish-growing waters has increased more than twofold, from 10 million to over 24 million acres. The increase is due primarily to a rise in the number of states classifying non-estuarine waters. The total area of approved waters is at an all-time high of 14.8 million acres (59 percent of all classified waters) (Box Figure 6.3). There were only 2.8 million acres of prohibited waters (13 percent of all classified waters). This is the lowest total of prohibited waters since the 1966 report, and the first time that the percentage of prohibited waters has been below 20 percent.

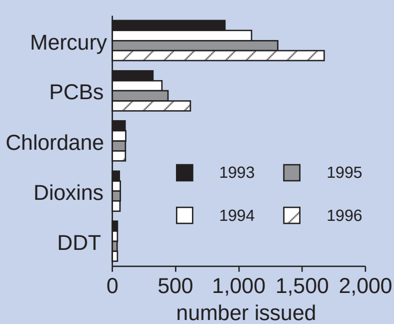
include decreased water clarity, the growth of algae on eelgrass leaves, and disease. With the expected improvements in water clarity, decreased nitrogen, and reduced algae expected in the harbor in the next few years, eelgrass beds could recover. But the recovery is likely to take decades unless artificial transplanting programs are implemented in the harbor.

Box Figure 6.1 Number of Fish Consumption Advisories Issued by State, 1996



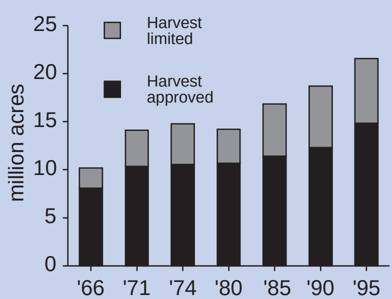
Source: U.S. Environmental Protection Agency, Office of Water, *Update: National Listing of Fish and Wildlife Consumption Advisories*, Fact Sheet (EPA, OW, Washington, DC, 1997).

Box Figure 6.2 Fish Consumption Advisories, 1993-1996



Source: U.S. Environmental Protection Agency, Office of Water, *Update: National Listing of Fish and Wildlife Consumption Advisories*, Fact Sheet (EPA, OW, Washington, DC, 1997).

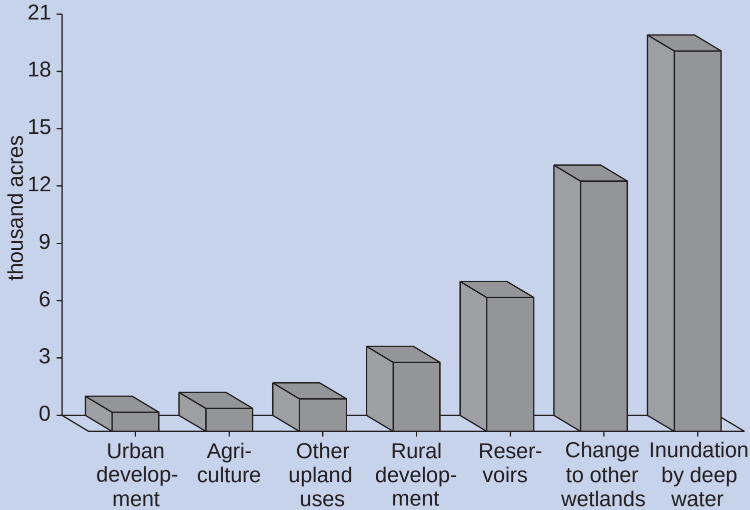
Box Figure 6.3 Classified U.S. Shellfish Waters, 1966-1995



Source: National Oceanic and Atmospheric Administration, *The 1995 National Shellfish Register of Classified Growing Waters* (NOAA, Silver Spring, MD, 1997).

Note: Harvest limited = sum of conditionally approved, restricted, conditionally restricted, and prohibited.

Figure 6.6 Loss of Coastal Marshes in Texas by Cause, 1955 to 1992



Source: Moulton, D.W. et. al., *Texas Coastal Wetlands: Status and Trends, Mid-1950s to Early 1990s* (DOI, FWS, Albuquerque, NM, 1997).

Note: Total loss = 47,500 acres.

COASTAL DEVELOPMENT PRESSURES

Between 1970 and 1989, almost half of all U.S. building construction occurred in coastal regions (Figure 6.7). Florida and California far outpaced other states in all types of coastal construction (Figure 6.8).

Until recently, coastal development has been relatively uncontrolled. For example, many communities permitted coastal wetlands to be filled for housing developments and their waters to be directed into channels. Local governments often overlooked master land-use plans in making decisions on zoning, building permits, and public works projects. In Florida's metropolitan Dade County, which includes Miami, county commissions developed a sewer plan for the entire county as early as 1961, yet the county continued to allow septic tanks and the kind of urban sprawl that the master plan regarded as undesirable until the mid- to-late 1960s.

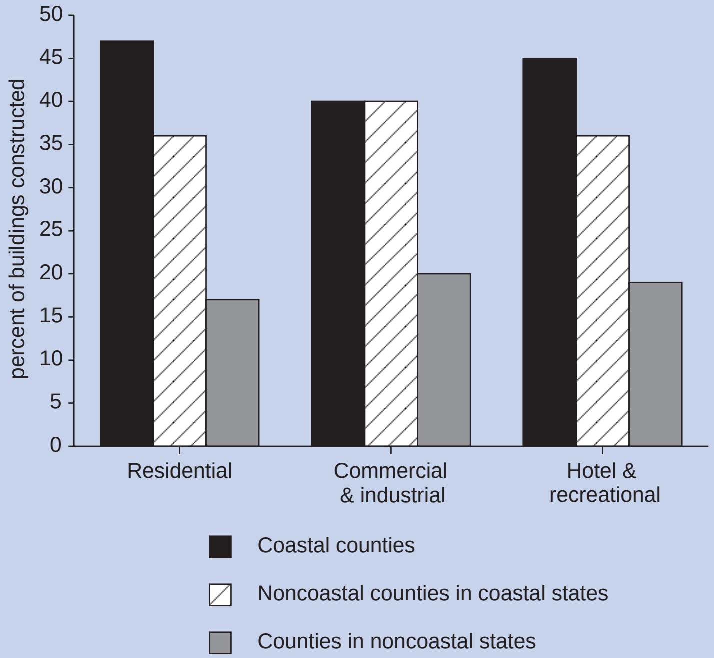
By the mid-1970s, local support was building for controlling growth and keeping development from exceeding the carrying capacity of natural systems. In Dade County, for example, local conservationists protested a proposal to build a new town with as many as 250,000 people along south Biscayne Bay. The plan ultimately approved by the county limited population to 51,000 and excluded all development along the Bay except for a marina.

Florida's massive growth in the 1970s and 1980s finally led the state to adopt a comprehensive growth management system in 1984-86. It required development to proceed on a "pay-as-you-go" basis, which meant building infrastructure to support new development. The state government also attempted to combat urban sprawl, developing policies that promoted redevelopment and the use of existing urban infrastructure.

Similar pressures were building in other states. For example, Maryland enacted the Chesapeake Bay Critical Area Protection Law, which limits development in areas within 1,000 feet of tidal waters or 1,000 feet from the landward side of tidal wetlands. Maryland's new "Smart Growth" law, which is described in Chapter Five, also helps protect undeveloped coastal areas.

At the national level, Congress recognized the need to balance protection of estuarine health with economic growth by establishing the National Estuary Program (NEP) as part of the 1987 amendments to the Clean Water Act. The Environmental Protection Agency oversees

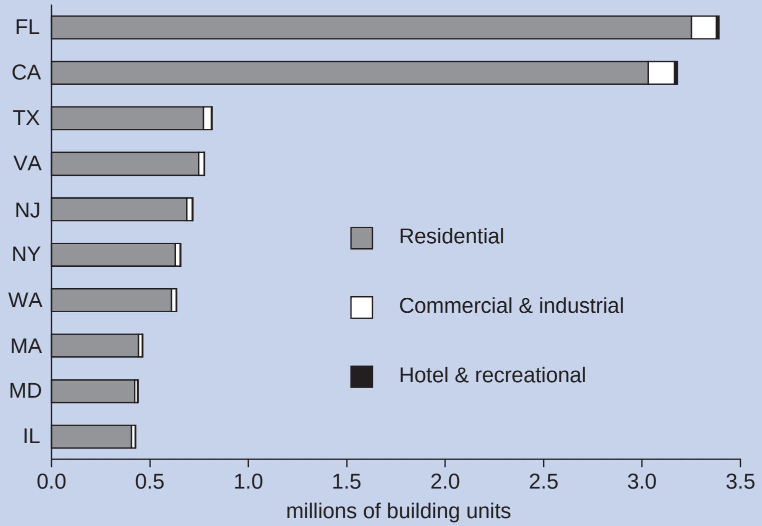
Figure 6.7 Distribution of Building Construction in Coastal and Noncoastal Counties by Type, 1970-1989



Source: Culliton, T.J. et. al., *Building Along America's Coast: 20 Years of Building Permits, 1970-89* (DOC, NOAA, Rockville, MD, 1992).

Note: Percentages are based on the following totals: residential, 29,742,682 units; commercial and industrial, 1,557,660 units; and hotel and recreational, 148,142 units.

Figure 6.8 Ten Leading States in Coastal Construction Authorized by Permit, 1979-1989



Source: Culliton, T.J. et. al., *Building Along America's Coast: 20 Years of Building Permits, 1970-89* (DOC, NOAA, Rockville, MD, 1992).

the NEP, which currently includes 28 estuaries around the country. Each estuary program involves building a partnership between government agencies and the citizens and businesses in the estuarine watershed. These partnerships develop and implement management plans for protecting and restoring the estuaries, while taking into consideration economic and recreational demands. The NEP serves as a model for all coastal watersheds and for coastal communities taking a partnership approach to managing their estuarine resources.

Development on coastal barrier islands—the long, narrow spits of beach that lie along much of the east coast—has slowed significantly in recent years, in part because of a major change in federal policy.

By 1980, half of the nation's 280 coastal barrier islands were at least partially developed, 70 heavily so. Barrier island structures were often badly damaged by hurricanes and other storms, and then rebuilt. Between 1978 and 1987, about $1 billion, much of it in federal funds, went to reconstructing previously damaged areas. This unproductive cycle has slowed since 1982, when Congress agreed to eliminate federal subsidies perpetuating this destruction-reconstruction cycle. While the Coastal Barrier Resources Act (COBRA) does not bar private development, withdrawal of the subsidies makes development much less likely.

Box 6.2
Water Quality in Coasts and Estuaries

Of the 72 percent of the nation's estuarine waters surveyed, EPA's 1996 *National Water Quality Inventory* found that 58 percent were fully supporting their designated uses, 38 percent were impaired, and 4 percent were threatened (Box Figure 6.4). The most widespread causes of impairment were nutrients and bacteria, which affected about half of the impaired area (Box Figure 6.5). Oxygen depletion from organic wastes, habitat alteration, oil and grease, toxic chemicals, and metals also were significant environmental problems. Urban runoff, including CSOs, discharge from municipal and industrial sewage treatment plants, and agricultural runoff were significant sources of pollution (Box Figure 6.6).

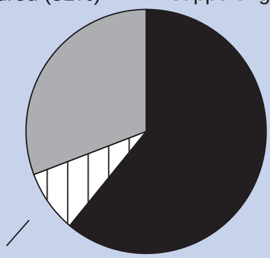
Long-term survey data by the U.S. Geological Survey show that coastal erosion is affecting each of the 30 coastal states. About 80 percent of U.S. coastal barrier islands are undergoing net long-term erosion at rates ranging from less than 3.3 feet to as much as 65 feet per year. Natural processes such as storms may be the precipitating cause of this erosion, but human activities such as mineral extraction, commercial and residential development, shoreline barrier construction, beach nourishment, and dredging are recognized as having major effects on shoreline stability. Rising sea level is also implicated in the erosion of barrier islands.

COASTAL WATER QUALITY

Water quality continues to affect the safety and utility of the nation's ocean, bay, and Great Lakes beach water (Box 6.2). In 1996, according to a survey conducted by the Natural Resources Defense Council, there were at least 2,596 individual closings and advisories, 16 extended closings that lasted 6-12 weeks, and 20 "permanent" closings that lasted over 12 weeks.

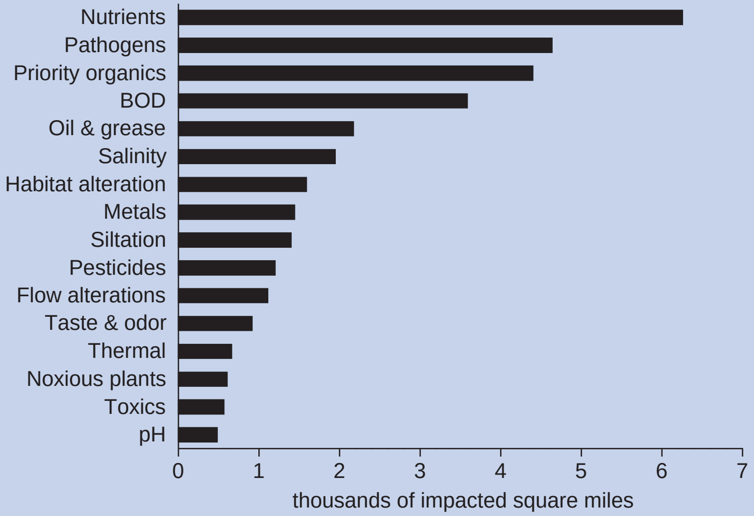
Roughly 83 percent of 1996 beach closings and advisories were based on detected bacteria levels exceeding beach water quality standards. An estimated 13 percent were in response to a known pollution event and 4 percent were precautionary closures resulting from rain that carried pollution to swimming waters. (Pollution events are often triggered by heavy rains that accompany hurricanes

Box Figure 6.4 Overall Use Support in U.S. Estuaries, 1996



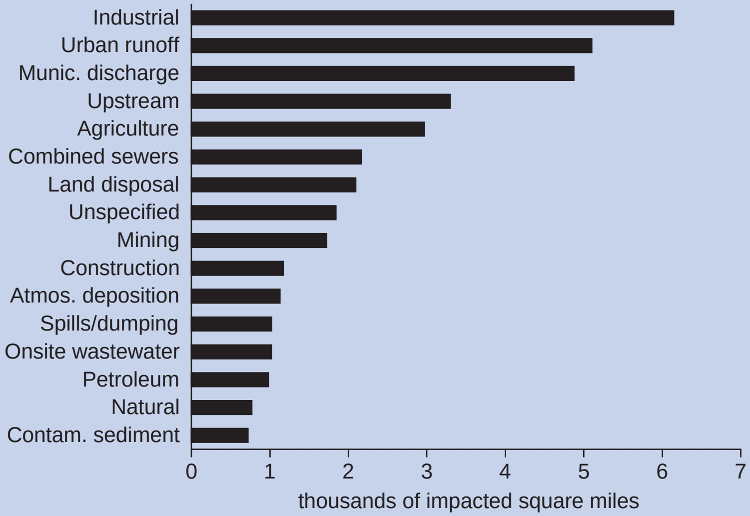
Source: See Part III, Table 6.4.
Note: Based on an assessment of 23,921 square miles or 60 percent of U.S. estuarine waterbody area.

Box Figure 6.5 Leading Causes of Impairment in U.S. Estuaries, 1996



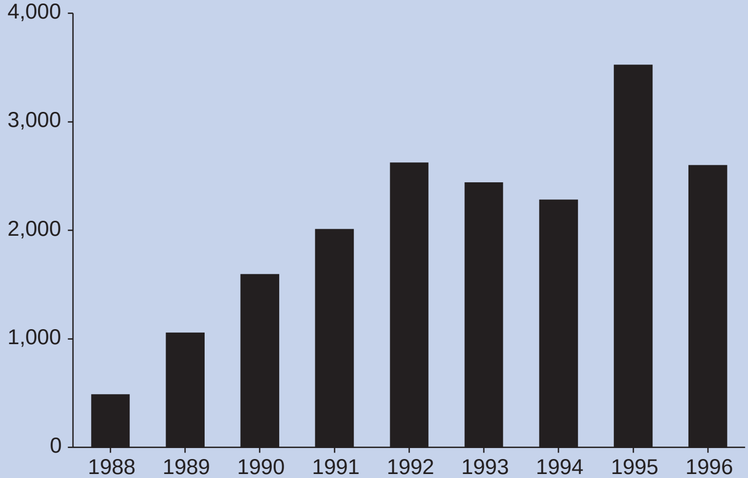
Source: U.S. Environmental Protection Agency, Office of Water, *National Water Quality Inventory: 1996 Report to Congress*, Table C4 (EPA, OW, Washington, DC, 1998).

Box Figure 6.6 Leading Sources of Pollution in U.S. Estuaries, 1996



Source: U.S. Environmental Protection Agency, Office of Water, *National Water Quality Inventory: 1996 Report to Congress*, Table C5 (EPA, OW, Washington, DC, 1998).

Figure 6.9 Number of U.S. Coastal Beach Advisories and Closings, 1988-1996



Source: Natural Resources Defense Council, *Testing the Waters 1997: How Does Your Vacation Beach Rate?* (NRDC, New York, NY, 1997).

Note: NRDC counts every day of an advisory/closure as one "beach closing." Does not include permanent or extended advisories/closures. Because of inconsistencies in monitoring and closing practices among states and over time, it is difficult to make comparisons between states or to assess trends.

and other storms, causing contaminated runoff.)

The number of beach closings in 1996 (Figures 6.9 and 6.10) was actually down from 1995, because of reduced hurricane activity in Florida and fewer heavy storms in California. The 1996 level of closings was comparable to the 1992-94 period. The major pollution sources in 1996 were polluted runoff from non-urban areas, sewer spills and overflows, urban stormwater runoff, and combined sewer overflows.

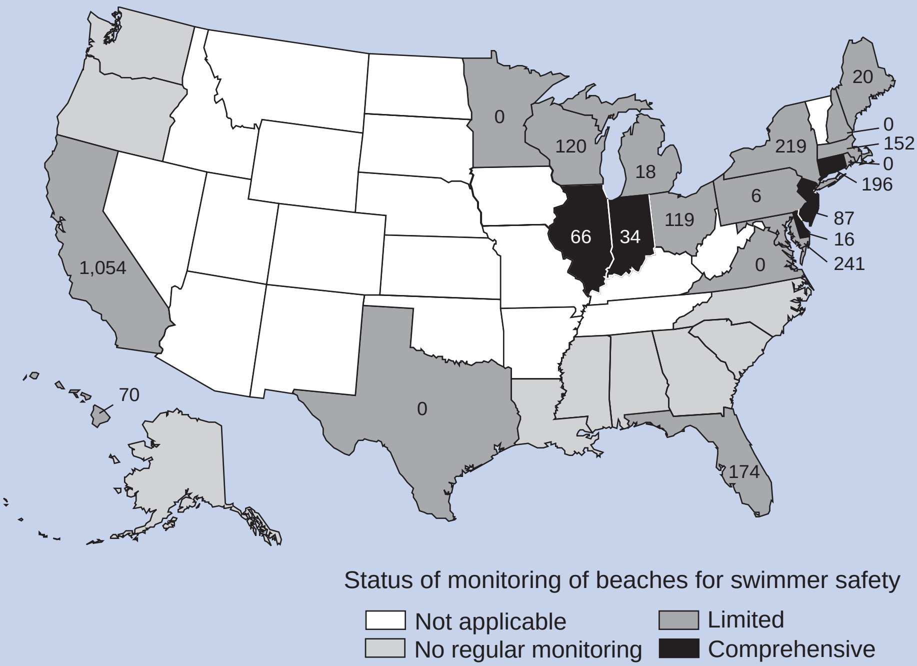
Nonindigenous Invasive Species

The introduction of nonindigenous aquatic species affects almost all of our nation's coastal, estuarine, and inland waters. These nonindigenous species have had severe local ecological and economic impacts in many areas. For example, according to the Great Lakes Sea Grant Network, facilities in the Great Lakes spent $120 million over six years (1989-94) for monitoring and control of the zebra mussel.

Though predation and competition, introduced species have contributed to the regional eradication of some native species and dramatic reductions in others. The continuous arrival of exotic species may make an estuary's ecosystem fundamentally unmanageable by continually changing the flora and fauna.

For example, there is documented evidence that 212 exotic species are established in the San Francisco Estuary.

Figure 6.10 U.S. Coastal Beach Advisories and Closings by State, 1996



Source: Natural Resources Defense Council, *Testing the Waters 1997: How Does Your Vacation Beach Rate?* (NRDC, New York, NY, 1997).

Another 40 exotic species were discovered too recently to know if they are established, while an additional 123 established species are considered potentially exotic. Aside from numbers, these species are dominant in many of the Estuary's habitats. Overall, the average rate of invasion since 1850 has been one new exotic species established every 36 weeks, but the rate has increased to at least one new species every 24 weeks since 1970.

The establishment and spread of nonindigenous species has led to increasing restrictions on water diversions, levee maintenance, and other activities in and near the San Francisco Estuary. Introduced organisms contribute to the fouling of hulls on boats and ships, which can reduce vessels' speed and increase fuel consumption by 15 to 50 percent. The state of California has recently been spending about $400,000 per year to control exotic plants in the San Francisco Estuary and Delta, and over $1 million to keep exotic fish from reaching the Delta. All of these activities (anti-hull fouling, exotic plant and exotic fish controls) require releasing substantial quantities of chemicals into the environment.

Under the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990, Congress established an Interagency Aquatic Nuisance Task Force to develop a coordinated federal program to prevent and control nonindigenous nuisance species. The Task Force was expanded to include state and regional representatives. The National Invasive Species Act of 1996 authorized further efforts to control and mitigate the impact of nonindigenous species. Control and mitigation approaches under development include national guidelines for ship ballast water management, development of state control plans, and public education and outreach.

Harmful Algal Blooms

Harmful algal blooms (HABs) have increased in frequency and severity in U.S. coastal areas over the past several decades. The most recent and visible examples are outbreaks of fish lesions and fish kills in estuaries of several Middle Atlantic and South Atlantic states and recent red tides and mass fish kills off the Texas coast.

The events on the East Coast are attributable to several toxic dinoflagellates, including *Pfiesteria piscicida*. Although this organism is similar to the toxic dinoflagellates that cause red tides, *Pfiesteria* in its non-toxic form is a single-celled predator that exists harmlessly in river sediment as either cysts or amoebae. In slow-moving, warm, brackish, nutrient-rich water, fish excretions are thought to trigger a transformation of the non-toxic *Pfiesteria* cysts into toxic dinoflagellate cells with whip-like tails. The dinoflagellates produce several toxins, which create lesions on fish in confined settings and also affect the immune system, liver, kidneys, and nervous system of trapped fish populations. Lab tests have shown that a *Pfiesteria* attack can kill healthy fish in less than 10 minutes.

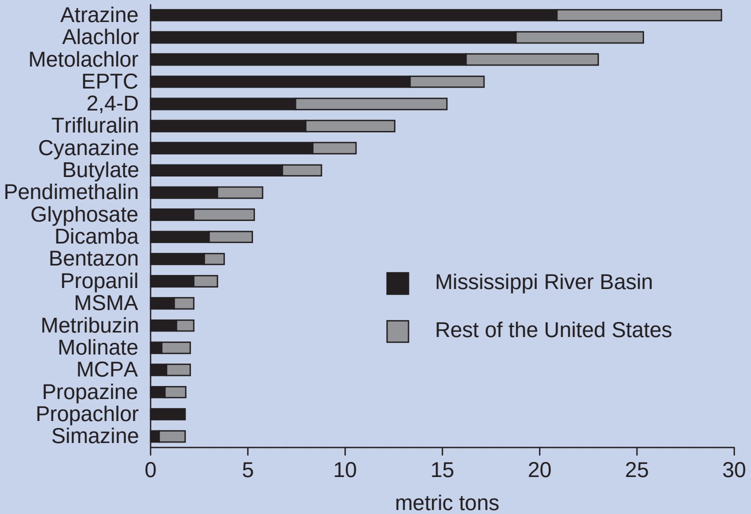
Pfiesteria were first observed in North Carolina, but have since been found as far north as the Indian River in Delaware and as far west as Mobile Bay. It has been shown that the *Pfiesteria* neurotoxin affects lab workers, fishers, swimmers, and other recreational users of nearshore marine and riverine waters during toxic episodes. Exposure may result in short-term memory loss, dizziness, muscular aches, vomiting, abdominal pain, and respiratory ailments.

An August 1997 *Pfiesteria* fish kill in the Pocomoke River in Maryland apparently caused serious health problems in 13 individuals. Ten of these people showed confusion and minor memory problems. Four of seven people who underwent a sophisticated brain scan test showed a particular abnormality of the brain, apparently caused by exposure to *Pfiesteria*.

The accumulation of dying fish and concerns for public health led Maryland Gov. Parris N. Glendening to close an eight-mile section of the Pocomoke in August, marking the first time that a state government has declared that the organism presented a risk to people in a natural environment. Subsequently, two other Eastern Shore rivers were closed.

Since 1993, federal agencies, including NOAA, EPA, DOI, and the National

Figure 6.11 Estimated Annual Herbicide Use in the Mississippi River Basin and Rest of the United States, 1987-1989



Source: Meade, R.H. (ed.), *Contaminants in the Mississippi River, 1987-92*, U.S. Geological Survey Circular 1133 (USGS, Reston, VA, 1995).

Science Foundation, have had in place a national plan of research, modeling, and management for HABs and their impacts. ECOHAB (*Ecology and Oceanography of Harmful Algal Blooms*), an interagency program established in 1996, is designed to provide specific information on the linkages between environmental conditions favoring optimal growth and toxicity of several noxious species, which is critical to the development of predictive models to forecast bloom events.

ECOHAB is supporting nine research projects on harmful algal blooms, including *Gymnodinium breve*, *Alexandrium tamarense*, *Aureococcus anophagefferens*, and *Pseudo-nitzschia*. Additional projects are currently being selected and will expand to other species, including *Pfiesteria*.

Pollutant Transport

Since 1975, the U.S. Geological Survey and others have studied pesticide concentrations in streams draining agricultural basins in a 10-state region of the Midwest. The studies reveal that rivers can transport environmental pollutants hundreds and even thousands of miles downriver to the river's terminus and into an estuary.

For example, take the case of atrazine, one of the most commonly used herbicides for weed control in corn and sorghum production (Figure 6.11). Most streams contain water with high concentrations of atrazine for several weeks to several months following the application of pesticides to farmlands. Concentrations generally are largest and may briefly exceed health-based limits for drinking water (3 micrograms per liter) during runoff from the first storms after application. Concentrations decrease during later runoff events.

The widespread occurrence of atrazine in these medium-sized streams raised questions about the magnitude and transport of atrazine down the large rivers that drain the basin. In the spring of 1991, USGS sampled for atrazine and four other herbicides in the Mississippi River and several of its major tributaries. Atrazine exceeded the maximum contaminant level in 27 percent of the samples, including a sample at Baton Rouge that was hundreds of miles from the major source of atrazine in the Midwest. Load calculations indicated that about 37 percent of the atrazine discharged from the Mississippi River into the Gulf of Mexico entered the river from streams draining Iowa and Illinois.

The second largest source was the Missouri River basin, which contributed about 25 percent of the atrazine entering the Gulf (Table 6.1). Although the annual mass transport appears to be large for several pesticides, it represents only a small fraction, generally less than 3 percent, of the pesticide mass applied annually to cropland in the basin. Temporal variations in the concentrations of herbicides in the Mississippi River reflect two factors: (1) the application of the herbicides on croplands, and (2) the rainfall and runoff events that follow the applications. It was anticipated that higher streamflows during the great flood of 1993 would dilute concentrations of herbicides that are usually flushed into streams in the spring and summer. Instead, concentrations and daily loads were higher than those measured in the previous years (Figure 6.12), probably because the intense and sustained rainfall fell shortly after planting in many areas and near the time when the most concentrated amounts of herbicides were on the soil. The total load of atrazine discharged to the Gulf of Mexico from April through August 1993 (1.2 million pounds, or 2.3 percent of the total

Pollution threatens valuable crops such as Gulf shrimp.

Photo Credit: S.C. Delaney/EPA

Table 6.1 Estimated Loads of Selected Pesticides Transported by the Mississippi River and Major Tributaries, April 1991 through March 1992

Pesticide	Illinois River	Missouri River	Ohio River	Mississippi River Above Missouri River[1]	Mississippi River at Thebes, IL[2]	Mississippi River Below Ohio River[3]	Mississippi River at Baton Rouge, LA[4]
				thousand kilograms			
Alachlor	8.79	7.87	4.97	35.00	42.90	47.90	33.70
Atrazine[5]	40.00	76.80	70.40	144.00	221.00	291.00	365.70
Butylate	0.21	0.31	1.17	0.96	1.27	2.44	na
Carbofuran	0.36	1.19	0.30	1.81	3.00	3.30	na
Cyanazine	19.80	31.30	13.40	81.70	113.00	126.00	127.00
EPTC	0.52	0.11	0.13	0.83	0.93	1.06	na
Metolachlor	18.90	24.70	20.20	62.50	87.20	107.00	123.00
Metribuzin	0.60	1.42	0.55	3.09	4.51	5.06	6.81
Prometon	0.51	0.43	0.82	0.77	1.20	2.02	na
Simazine	0.86	1.09	9.37	3.25	4.34	13.70	12.50

Source: Goolsby, D.A. and W.E. Pereiri, "Pesticides in the Mississippi River," in R.H. Meade (ed.), *Contaminants in the Mississippi River, 1987-92*, U.S. Geological Survey Circular 1133 (USGS, Reston, VA, 1995).

Notes: [1]Calculated from load in Mississippi River at Thebes, IL, minus load from Missouri River. [2]Above confluence with Ohio River. [3]Below confluence with Ohio River, calculated from load in Mississippi River at Thebes, IL, plus load in Ohio River. [4]Approximate transport from Mississippi River Basin to Gulf of Mexico, includes diversion into Atchafalaya River but not the contributions from the Red River. [5]Atrazine plus metabolites. na = no load estimate available.

amount applied annually to cropland in the Mississippi basin) was about 80 percent larger than the load for the same period in 1991 and 235 percent larger than in 1992.

The story is similar for the discharge of nitrogen from interior basins to the Gulf of Mexico. Excess nitrogen from a diversity of sources—fertilizers, animal manure, decaying plants, municipal and domestic wastes, and atmospheric deposition—enters the Gulf from the entire Mississippi watershed (Figure 6.13). These nutrients nourish an algae bloom. When the algae die, they drop to the bottom and decompose, a process that takes so much oxygen from the water that other marine organisms—fish, shellfish, and other bottom-dwellers—either die or move out of the zone. This deadly "hypoxic" zone, which forms each spring and summer off the coast of Louisiana, now covers an area of about 7,000 square miles (Figure 6.14), roughly the size of New Jersey. Smaller dead zones also have appeared in recent years in Chesapeake Bay, Florida Bay, and North Carolina's Pamlico and Albemarle sounds.

Much of the nitrate-nitrogen concentration entering the Gulf comes from sources a thousand miles upstream. Studies indicate that the principal regions contributing to the nitrogen load are the Upper Mississippi (31 percent), Lower Mississippi (23 percent), Ohio (22 percent), and Missouri (11 percent) river watersheds.

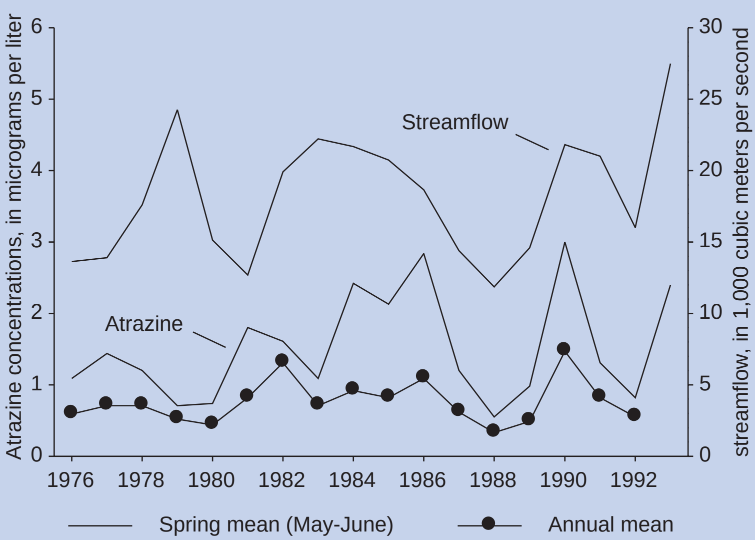
The victims of this pollution are Gulf fishermen, who are forced to avoid the dead zone area, fishing either closer to shore or traveling long distances into the Gulf. The economic impact of the dead zone problem is not precisely known, but marine fisheries contribute more than $1 billion a year to Louisiana's economy.

In mid-1997, the federal government created a federal task force on the dead zone problem and launched an 18-month multidisciplinary assessment that will explore the causes of the problem and possible solutions.

URBAN POLLUTION: THE CASE OF BOSTON HARBOR

The effort to control pollution in Boston Harbor provides an example of many of the problems facing the nation's older port cities: a watershed with many political jurisdictions and sources of pollution, old or out-of-date wastewater treatment equipment, and limited financial resources. As a result of these and other

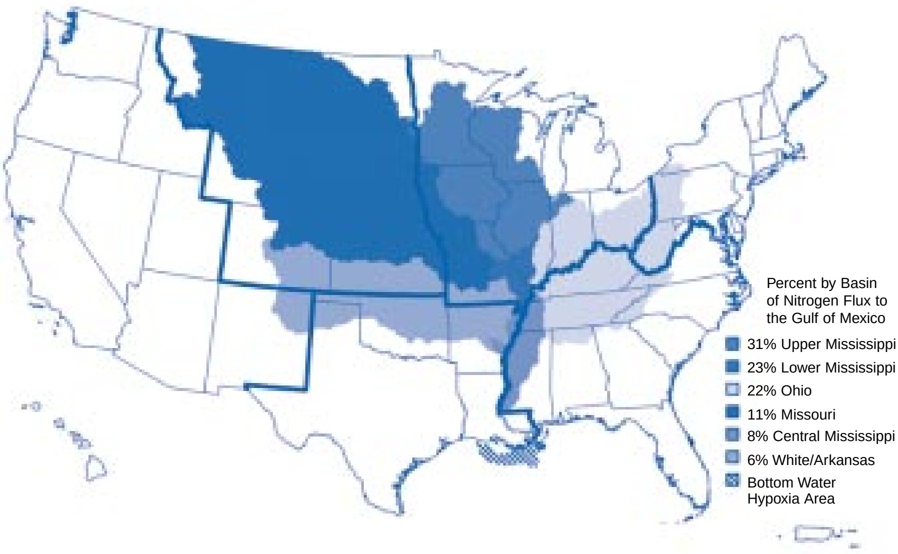
Figure 6.12 Atrazine Concentrations in the Mississippi River at Vicksburg, MS, 1976-1993



Sources: Goolsby, D.A. et al., *Occurrence and Transport of Agricultural Chemicals in the Mississippi River Basin, July Through August 1993*, U.S. Geological Survey Circular 1120-C (USGS, Reston, VA, 1993). Meade, R.H. (ed.), *Contaminants in the Mississippi River, 1987-92*, U.S. Geological Survey Circular 1133 (USGS, Reston, VA, 1995).

Notes: Data for 1993 are for July through August at Baton Rouge, LA. Earlier data on atrazine concentrations from this station are approximately equivalent to those from the Vicksburg, MS, station.

Figure 6.13 Nitrogen Flux to the Gulf of Mexico from the Interior Basins

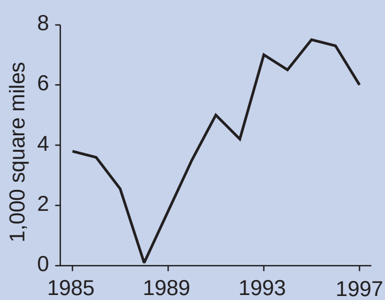


Source: USDA/NRCS based on data from R.B. Alexander, R.A. Smith, and G.E. Schwartz (USGS) and N.N. Rabalais, R.E. Turner and W.J. Wiseman, Jr. (Louisiana Universities Marine Consortium) #RWH.1606,1996.

factors, Boston Harbor in the mid-1980s was a severely degraded ecosystem.

The Boston Harbor project resulted in part from a 1985 court ruling that wastewater discharges into Boston Harbor from the Deer Island wastewater treatment plant violated the Clean Water Act. In response to this ruling and other pressures, the Massachusetts Water Resources Authority (MWRA) led a comprehensive effort to reduce pollution and restore the harbor ecosystem. The $3.7 billion project includes construction of primary and secondary wastewater treatment facilities, odor control facilities, a disinfection facility, new sludge digesters, an effluent outfall tunnel, a tunnel connecting Nut Island and Deer Island (site of existing treatment facilities), and new and rehabilitated pumping stations.

Figure 6.14 Estimated Size of the Dead Zone in the Gulf of Mexico, 1985-1997



Source: Rabalais, N.N. et. al., Louisiana Universities Marine Consortium, Hypoxia Monitoring Data.

Mobilizing the Watershed

The MWRA recognized that their effort would have to include the entire watershed. MWRA's water and sewer systems serve more than 2 million state residents as well as industries and businesses in 61 cities and towns. The system imports hundreds of millions of gallons of water per day to the Boston Harbor watersheds from several sources in western and central Massachusetts that would otherwise naturally drain to Long Island Sound via the Connecticut River, or to the Gulf of Maine via the Merrimack River. Much of the imported water eventually becomes household and industrial wastewater that is transported through a network of local sewers and interceptors (large regional sewers) to the Deer Island and Nut Island plants. The wastewater also includes runoff, rainwater, and snowmelt that is carried from parts of Boston, Cambridge, Somerville, and Chelsea. Together these flows make up the 370 million gallons of sewage collected for treatment on an average day.

Approaching the cleanup problem on a watershed basis meant understanding the various sources of pollution in the watershed and the differences among watersheds. For example:

- As the Charles River reaches the urban communities along its route to the harbor, high bacteria counts impair its use. Raw sewage from combined sewer overflows and contaminated storm drains adversely affect the Charles River basin, the Back Bay fens, and the Muddy River.
- Past industrial pollution in the upstream portion of the Neponset River watershed has resulted in high levels of toxic contamination, while sewage discharge from downstream combined sewer overflows remains a problem for both the river and the beaches along Dorchester Bay.
- In the Mystic River watershed, pollution from oil port operations in the Chelsea and Island End rivers adversely affects the health of marine animals and the biodiversity of the bottom-dwelling community.

The CSO Problem. Within the watershed, there were some 81 combined sewer overflows (CSOs) carrying both sewage and stormwater runoff. These antiquated systems were designed so that, if stormwater overflow is more than the system can handle, a mixture of stormwater and raw sewage overflows into the receiving body of water rather than backing up into the streets.

In 1990, MWRA developed a CSO Facilities Plan that would have built miles of deep rock tunnels to store combined sewage that would otherwise overflow during storms. In dry weather, the stored combined sewage would be pumped to the treatment plant. After gathering more sewage flow data, however, MWRA officials learned that both the volume and the environmental effects of combined sewage had been overestimated and that the costly tunnel system might not be necessary.

A new CSO plan was developed that looked at the relative impacts of various pollution sources. The primary problem was the risk to public health from sewage-borne pathogens (disease-causing bacteria and viruses), which make swimming and shellfishing unsafe, so the plan put special emphasis on eliminating CSOs near beaches and clam flats. By separating sewers or by relocating the CSOs to other, less sensitive areas, beaches in East Boston and South Boston and shellfish beds in the Neponset River estuary could be better protected.

In areas where CSOs appear to be a much less significant source of pollution than other sources, a more modest level of CSO control will be applied. For example, even with CSO disinfection in the Charles River, swimming in the Charles River basin will remain a health risk unless other sources of pathogens are controlled as well.

Larger, more complex projects will be implemented and ultimately owned and operated by MWRA, while local communities will be responsible for projects involving improvements to their pipes and to their CSO outfalls. More flow will be treated by CSO treatment facilities, and some overflows will be prevented by enlarging sewers or building small storage facilities. Larger sewer separation projects will extend over a number of years.

After the CSO plan is fully implemented, there will still be some occasional overflows in some areas (less than four times per year on average), but the volume discharged will be greatly reduced. Wherever the potential for large CSO discharge remains, including the Charles River basin, Fort Point Channel, and the Reserved Channel, the discharge will be disinfected.

Improvements to the system already are evident. Since CSO discharge volume depends to a large extent on rainfall in any given year, the fact that CSO discharge volume declined in 1994 compared to 1990—even though there was more precipitation in 1994—is a promising sign of progress. MWRA officials attribute the progress to completion of a number of small-scale sewer system improvement projects, improved efforts to clean sewers and maintain regulators and tide gates, and recent operational improvements at MWRA's "headworks" facilities, which remove rags, grit, and large objects from sewage before it enters the treatment plants.

MWRA also has started several other projects within the watershed:

- Interceptor construction and replacement projects will increase the capacity of old interceptors and prevent untreated sewage from entering the rivers and groundwater.
- Pollution prevention programs are helping industries, municipalities, businesses, and residential neighborhoods decrease the amounts of toxic metals and other contaminants that enter the region's sewers.
- An infiltration/inflow assistance program provides over $20 million to MWRA communities for projects to reduce stormwater and groundwater flow into the sewage collection and treatment system. Under the leadership of the Massachusetts State Water Resources Authority and others, a comprehensive effort is underway to

reduce pollution and restore the harbor ecosystem.

Modernizing Treatment

One of the biggest challenges facing the authority was the condition of the Deer Island and Nut Island sewage treatment plants, two old primary treatment plants that could not meet federal and state standards. These plants were given interim standards until the new, federally mandated secondary treatment plant at Deer Island was completed.

During the construction period, the old plants at Deer Island and Nut Island had to continue operating. At Deer Island, this meant keeping the old plant running while building the new one around it. At Nut Island, the old plant had to be kept running until completion of the new Nut Island-to-Deer Island tunnel.

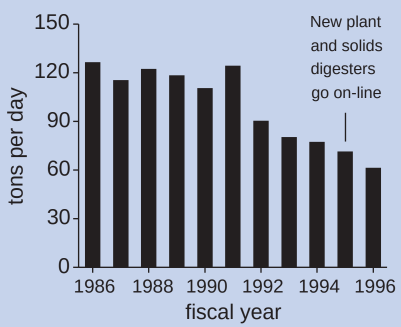
During this period, MWRA installed a computerized tracking system in the early 1990s and began to substantially step up its follow-up and enforcement actions against industries that did not meet their discharge permit requirements.

On January 20, 1995, MWRA started up the new Deer Island primary treatment plant. The new facility will treat sewage from both the North and South systems, and the Nut Island plant will be decommissioned. Sewage flows from the South System will be sent to Deer Island through a new inter-island tunnel. The new Deer Island facility will ultimately provide both primary and secondary treatment for both systems.

Through all six stages of the treatment process, the new plant provides substantial improvements:

- Ten new pumps have been installed to improve movement of wastewater from the 43 sewer communities. The old pumps frequently broke down, causing sewage to back up and overflow into the harbor.
- New vortex grit chambers—the largest of their kind in the United States—will improve removal of heavy particles like sand and coffee grounds.
- Larger settling tanks in the new plant have dramatically increased the plant's ability to remove solids and scum from wastewater. In FY 1996, Deer Island's solids discharge into Boston Harbor dropped to 61 tons per day, down from 71 tons per day in the previous year and less than half the 1986 level.
- Digesters break down solids collected during the treatment process, destroying pathogens and producing methane gas to help heat and power the plant. The plant's new digesters allow better mixing, improve production of methane, and minimize maintenance problems that troubled the old plant.
- Effective disinfection depends upon how long harmful bacteria in wastewater are exposed to sodium hypochlorite before discharge. The new plant has improved the disinfection process by doubling the contact time from 15 minutes to 30 minutes, providing more effective bacteria kill and using less sodium hypochlorite in the process.
- In the old plant, gases and odors escaped freely into the atmosphere. In

Figure 6.15 Solids Input to Boston Harbor from Deer Island Treatment Plant, 1986-1996



Source: Massachusetts Water Resources Authority, *The State of Boston Harbor 1995: The New Treatment Plant Makes Its Mark* (MWRA, Boston, MA, 1996).
Note: Sludge discharges ended in December 1991. This also contributed to observed improvements.

the new plant, the primary settling tanks are covered so that gases are trapped until they are treated with chemicals that remove the odors.

When the secondary treatment facilities became operational at the end of 1996, still more solids were removed during the wastewater treatment process (Figure 6.15).

A new effluent outfall tunnel, to be completed in 1998, will be the largest such tunnel in the world. This 24-foot-diameter tunnel, lying 300 feet below the ocean floor, will carry treated effluent 9.5 miles into Massachusetts Bay, where 55 diffusers—resembling giant sprinkler heads—will disperse the discharge into the deep waters of Massachusetts Bay. Many federal agencies, including NOAA and the National Marine Fisheries Service, worked with state, local, and other federal agencies on the development of the outfall and on ways to minimize any adverse effects on the marine environment.

MWRA officials are confident that the new outfall will significantly lessen the impact on the Bay ecosystem, since the secondary effluent to be discharged into the Bay will be much cleaner than the primary effluent and sludge that was discharged into the harbor until 1991. Furthermore, the discharge site in the Bay was selected because it provides for much greater dilution than would be possible in the shallow waters of Broad Sound or Boston Harbor.

A computer model predicts that the effluent will have only limited impacts near the outfall and virtually no effect on Cape Cod Bay. Chlorophyll-a, a measure of algal blooms, will increase only in the immediate outfall area, and will decline significantly in Boston Harbor. The deposition of organic matter on the sediments that can reduce bottom dissolved oxygen (DO) will be dramatically reduced in both the harbor and the bay. Bottom DO will improve because primary effluent, with a higher oxygen demand than secondary effluent, will no longer be flowing from the harbor into the bay.

MWRA's NPDES permit will incorporate stringent limits and testing requirements for Deer Island effluent discharges. In addition, MWRA plans to provide an intensive monitoring program for the outfall.

The large investment in improving Boston Harbor's water quality is already showing results. Beach postings have declined dramatically since the mid-1980s, bottom-dwelling animal communities have increased in abundance and diversity; flounder caught in Boston Harbor are now safe for human consumption, and PCB and mercury levels in flounder fillets are now well below FDA limits.

Despite this progress, there is a concern that the outfall will negatively impact the resources of Stellwagen Basin and Stellwagen Bank, a National Marine Sanctuary, which is an important feeding ground for marine mammals such as the endangered humpback and right whales. The Outfall Monitoring Task Force needs to continue to monitor the health of the ecological community by assessing species abundance and diversity in Stellwagen Basin, in Cape Cod Bay, and near the outfall.

PROTECTING SOUTH FLORIDA'S ENVIRONMENT

In the past 150 years, large water control projects have transformed the Everglades ecosystem from a vast subtropical wetland into a multiple-use, human-dominated system with some natural remnants. Each phase of this transformation has been marked by a series of crises—both cause and effect of the changes. (See Chapter One for a brief history of the South Florida ecosystem.)

The effort to restore the South Florida ecosystem began in 1983, when the state announced a "Save Our Everglades" campaign. The campaign goal was to restore key hydrologic functions of the original natural system.

After much study and evaluation, the state in 1990 adopted a plan developed by the South Florida Water Management District that would restore 40 miles of the original Kissimmee River ecosystem, 43 miles of river, and 26,500 acres of wetlands. In 1992, Congress authorized the Corps of Engineers to enter into a 50/50 cost-share arrangement with the state to begin work on the $400-million project. The plan also led to federal legislation to expand Everglades National Park into Northeast Shark Slough. Land acquisition in the park expansion area is proceeding, as well as construction modifications to re-water the area.

To help control runoff from farming into Lake Okeechobee, the state focused on reducing dairy farming on lands draining into the lake and on instituting best management practices on remaining farms. Efforts to protect the Water Conservation Areas have focused on regulations and treatment of agricultural discharges and on land acquisition in the conservation areas. Extensive federal, state, and local land acquisition has also been the focus at Big Cypress National Preserve and in protecting the Florida panther; about 150,000 acres of panther habitat have been acquired, including Florida Panther National Wildlife Refuge.

Notwithstanding these efforts, by 1988 the evidence was clear that agricultural pollution, especially phosphorus, was damaging Everglades National Park and the Loxahatchee National Wildlife Refuge. The federal government filed suit against the state of Florida for failing to enforce its own water quality laws.

In 1991, the state settled the litigation and agreed on a plan to remove 80 percent of the phosphorus flowing into the Everglades from the Everglades Agricultural Area, by improving agricultural practices and constructing filtration marshes called Stormwater Treatment Areas. The settlement agreement also required expanded research and monitoring, compliance by 2002 with all water quality standards in water delivered to the park and refuge, adoption of strict phosphorus limits for water in the park and refuge, and a new water delivery schedule aimed at maintaining the flora and fauna of the park and refuge.

The settlement was adopted by the federal court as a consent decree in 1992, but it was subsequently tied up by 36 federal and state lawsuits. In July 1993, after nine months of negotiations, the parties agreed to a Statement of Principles. The agreement provides for a $465 million system of Stormwater Treatment Areas (about 35,000 acres of filtration marshes to cleanse great volumes of water and improve water quantity, distribution, and timing benefits for the Everglades) and on-farm best management practices.

Key features of the plan were adopted by the Florida legislature in April 1994. The state is to construct five Stormwater Treatment Areas by 2003 and the Corps of Engineers must build one by 2002. The state is required to pay roughly 42 percent of the cost of the plan, while farmers will pay 50 percent and the federal government will pay 8 percent. Stormwater Treatment Areas are to be permitted and regulated by the Florida Department of Environmental Protection, the Corps, and EPA. Agricultural discharge is to be regulated by the South Florida Water Management District through permits that will impose best management practices to reduce phosphorus loads. In addition, the state is required to conduct an extensive research and monitoring program for the Everglades.

To improve interagency coordination, the Department of the Interior in June 1993 convened a South Florida Ecosystem Restoration Task Force, composed of federal agencies (the Corps of Engineers, EPA, NOAA, the Department of Justice, USDA's Natural Resources Conservation Service, and Interior's National Park Service, Fish and Wildlife Service, U.S. Geological Survey, and Bureau of Indian Affairs) who are responsible for restoring and maintaining the integrity of the South Florida ecosystem. In 1994, Governor Lawton Chiles also established a Commission for a Sustainable South Florida, which now includes 48 members from state, tribal, and local governments, business and public interest groups, along with five nonvoting members from the federal government. Like the federal group, the commission's primary mandate is to improve coordination among the many interests involved in the Everglades restoration effort.

According to a case study prepared for the Interagency Ecosystem Management Task Force, the effort to improve joint planning and coordination and to implement an ecosystem approach faces many constraints. For example, federal agencies have traditionally planned their budgets independently. Currently, most agencies are working together on projects, but the traditional budgeting process still often remains an impediment to allocating funds to support the integrated priority needs of the ecosystem. A related barrier is that no federal agency has been assigned to coordinate the ecosystem approach for the region.

The case study also noted that there are a number of constraints to effective communication and the more flexible approach characterized by "adaptive management," in which activities are modified based on new information that emerges as the consequences of current projects become clear. The Administration has worked to remove many of these barriers. For example:

- The Federal Advisory Committee Act (FACA) places restrictions on the ability of federal agencies to solicit advice from nonfederal parties without having to go through a cumbersome chartering process. In the past, the South Florida Ecosystem Restoration Task Force operated under FACA and had no nonfederal members and no ongoing, systematic contact with nonfederal government parties. In 1997, the task force was re-established and reorganized (under provisions of the 1996 Water Resources Development Act exempting it from FACA) to include nonfederal members. The task force now includes representatives from the state, the South Florida Water Management District, local government, and the Miccosukee and Seminole Indian tribes.
- The laws and regulations governing initiation of Corps projects result in a lengthy, rigid, and complicated process that often makes projects susceptible to derailment or makes them difficult to modify after completion. The Corps has established new procedures to streamline the review process.
- The Endangered Species Act and other laws emphasize both the protection of ecosystems and of individual species. The current emphasis on the ecosystem approach and on multispecies recovery will be used to reconcile cases like that of the Cape Sable seaside sparrow and the snail kite in South Florida, where the law's emphasis on individual species also pertains.

On a variety of fronts, progress to restore the system is well underway:

- Stormwater Treatment Area 6 was completed in October 1997, which will allow natural processes to reduce nutrient runoff from the Everglades Agricultural Area.
- Modification of Canal 111 began in 1996, which will maintain flood protection and restore more natural flows into the Everglades.
- About 85 percent (80,000 acres) of the lands necessary to restore the Kissimmee River have been purchased, with the goal of restoring the river and 27,000 acres of wetlands by 2009, while maintaining flood protection.
- About 61,000 acres have been added to Everglades National Park, and an additional 48,000 acres will be acquired to help restore the natural flow of water to the Everglades.
- Nutrient runoff from the Everglades Agricultural Area was reduced significantly between 1995 and 1997.

- About 90,000 acres were cleared of introduced melaleuca plants as part of the expansion of the exotic species control program.

Cumulative Effects: From the Everglades to Florida Bay and the Keys

The decline in freshwater flow that afflicts the Everglades also seems to be having an impact on the marine ecosystem of Florida Bay, and problems in Florida Bay may in turn threaten the Florida Keys National Marine Sanctuary. The sanctuary includes the entire 220-mile length of the Florida Keys and some 2,800 square nautical miles of nearshore waters. The sanctuary has some spectacular marine environments, including seagrass meadows, mangrove islands, and extensive living coral reefs.

The development of the sanctuary has been widely praised as an exemplary effort to use the ecosystem approach and to include a wide array of interests in planning and decisionmaking.

A partnership of federal, state, and local agencies was created for planning and management, and representatives of local interests—citizens, scientists, environmentalists, and business leaders—are participating. A Citizens' Advisory Committee reviews major documents produced by government agencies, including NOAA's Comprehensive Management Plan and the Water Quality Protection Program developed by EPA and the state.

Florida Bay has experienced severe water quality and ecological problems in recent years. Since 1987, a massive seagrass die-off has denuded thousands of acres of sediments. The seagrass die-off and resulting sediment resuspension and nutrient release were a major cause of massive phytoplankton blooms that have affected the bay. In turn, sponge die-offs caused by phytoplankton blooms created further impacts on juvenile spiny lobsters, which reside by day under sponges for protection from predation. Recent wet weather cycles have reversed some of these trends in Florida Bay and provide hope that the restoration plan will be successful.

Water quality and natural resources in Florida Bay are tightly linked to those of the marine sanctuary. According to some coral experts, for example, Florida Bay water may be contributing to coral declines in the sanctuary.

Land-based sources in the Everglades and Florida Keys are contributing to the area's water quality problems. The Bay drains much of the adjacent Everglades, receiving freshwater flows from the agricultural areas, marshes, and canals. According to EPA estimates, domestic wastewater discharges from land-based sources account for about 70 percent of the wastewater/stormwater nutrient loadings in the sanctuary area. Domestic wastewater facilities in the Keys include about 30,000 regulated on-site sewage disposal systems, 10,000 unregulated cesspits, over 200 small package plants, and two municipal wastewater treatment plants in Key West and the Key Colony Beach.

The Water Quality Protection Program (WQPP) developed by EPA and the Florida Department of Environmental Protection was developed with the help of a wide array of institutions and interested citizens in the Keys ecosystem.

Using federal and state funds, EPA and the state have initiated a comprehensive water quality monitoring and research program to protect the sanctuary area—the State/Federal Management Plan for the Florida Keys National Marine Sanctuary, which was adopted in January 1996. The protection program recommends a long list of actions to reduce pollution from domestic wastewater and stormwater sources, including establishing and implementing inspection and enforcement programs to eliminate all cesspits and enforce existing standards for all on-site disposal systems and package plants.

The program recommends restoration of the historical freshwater flow to Florida Bay and coordination by Everglades and South Florida officials to ensure that water quality management plans support water quality goals for the sanctuary.

Federal and state funds are also supporting an intensive research and modeling program in Florida Bay. This program is organized and coordinated under a federal-state Program Management Committee, which sets research priorities, reviews project results, and recommends activities to address information gaps. The objectives of the interagency program are to characterize existing environmental conditions in the Bay, monitor changes in the system, and apply this knowledge to predicting the potential implications of various Everglades restoration scenarios to Florida Bay and the Keys. The resulting models and information are very important to the Interagency Ecosystem Restoration Task Force because restoration decisions made for the Everglades could significantly affect Florida Bay and the Keys.

COASTAL WETLANDS

The Gulf of Mexico, South Atlantic coast, Great Lakes, ocean coastlines, and some rivers contain major concentrations of coastal wetlands, which are among the earth's richest and most productive habitats. Coastal wetlands, which form transitional areas between permanently flooded freshwater and marine aquatic environments and well-drained uplands, provide a variety of important ecological functions. They act as nurseries and temporary shelter to many species, including many endangered species and commercially important species such as flounder, menhaden, shrimp, oysters, and clams. Nearly all waterfowl, wading birds, and shorebirds migrating along the North American flyways find abundant food, rest stops, and nesting areas in the marshes and mudflats of coastal estuaries.

Coastal wetlands are critical to many economically important fisheries. In the Southeast, 94 percent of the commercial catch and over 50 percent of the recreational harvest are fish and shellfish that depend on the estuary-coastal wetlands system. In 1996, the dockside value of fish landed in the United States was $3.6 billion. The industry employs hundreds

Intense demand for development puts pressure on coastal wetlands like this one on Chesapeake Bay.

Photo Credit:
S.C. Delaney/EPA

of thousands of people, and consumers spend over $41 billion annually on fisheries products. An estimated 71 percent of this value is derived from fish species that during their life cycles depend directly or indirectly on coastal wetlands.

Both human activities and natural events threaten coastal wetlands. People dredge and fill areas, extract resources, introduce non-native species, contaminate stormwater runoff, and construct features that reduce tidal flows or freshwater inflows. Oil and gas activities withdraw resources, resulting in subsidence. Nature alters the coast through storms, saltwater intrusion caused by sea level change and land subsidence, and the normal succession of coastal wetlands into coastal uplands.

Louisiana's Coastal Wetlands

Almost 40 percent of all coastal marshes in the United States are in Louisiana, an area of about 2.5 million acres of fresh, intermediate, brackish, and saline marshes, and about 637,000 acres of forested wetlands. These wetlands are of immense economic value, supporting a commercial harvest of fish and shellfish with a market value of almost $1 billion annually, an estimated $250 million per year in income from ecotourism, and another $50 million from recreation.

The loss of the region's coastal wetlands reflects long-term impacts of development since the 19th Century. The construction of flood protection levees and navigation improvements along the Mississippi River ensured that most sediment bypassed the areas where it would naturally build and nourish wetlands during flood and nonflood period. Active channels such as Bayou Lafourche were blocked at the confluence with the Mississippi, cutting off vast wetland areas of the Delta from their life-sustaining supply of freshwater and transported sediment. Jetties and deep navigation channels at the mouths of tributaries direct sediments away from the Delta and into deeper waters of the Gulf of Mexico. Sediment deposits no longer compensate for the effects of natural coastal subsidence.

Coastal wetlands are increasingly submerged, killing many wetland plants and causing changes in vegetation. Channels dredged for navigation or oil and gas exploration also are causing infusions of saltwater into normally fresh or brackish wetlands. In other areas, urbanization, highways, and spoil banks from channel dredging disrupt natural drainage and sediment distribution.

The net result has been the functional and physical loss of hundreds of thousands of acres of wetlands as natural vegetation dies and sediment erodes away. Estimates in the 1960s placed annual losses at 39-42 square miles annually. Current losses are now estimated at about 25-35 square miles per year. Only a small fraction of annual losses stems from new development. Permits for new development were taking about 3,000 acres annually around 1980, but are now taking less than 200 acres. Most current losses are the legacy of earlier modifications that disrupted the natural processes.

The state has been working for over two decades to prevent further losses on barrier islands and wetlands. In 1989, Louisiana voters approved, by a 3-to-1 margin, a constitutional amendment establishing a trust fund to generate about $25 million per year for restoration activities.

In 1990, Congress passed and the President signed the Coastal Wetland Planning, Protection, and Restoration Act (CWPPRA). The act established a six-member Louisiana Coastal Wetlands Conservation and Restoration Task Force, with representatives from the state and five federal agencies: Interior, Commerce, Agriculture, EPA, and the Corps of Engineers. (Several other similar restoration programs are underway in other states.)

The task force has provided an effective forum for discussions among federal and state agencies on developing a restoration plan. In particular, the act led to integration of the traditionally independent planning and execution of budgets by federal agencies with an interest in the issue.

With the help of several technical committees and groups, the task force succeeded in developing a Louisiana Coastal Wetlands Restoration Plan. A work group prepared lists of priority projects and developed plans for monitoring project effectiveness. The Corps estimates that about 211,000 acres of wetlands would be restored under the plan.

Funds for implementing the plan have approached $40 million annually, with costs shared by state (25 percent) and federal (75 percent) governments. One of the strengths of the plan is that the budget includes funds for 20 years of monitoring. This should enable the state and the task force to make necessary adjustments to projects and planning.

Some 80 percent of the coast is privately owned, and the state estimates that real-estate-related activities take about one third of the total effort required prior to implementation of a project. State and federal agencies are actively working with private landowners to resolve conflicts. The Louisiana Department of Natural Resources has created a real estate section to help speed up the process. The department is also negotiating a settlement with the Louisiana Land and Exploration Company concerning mineral rights when new land is created during restoration of the Isles Dernieres chain of barrier islands. Constitutional amendments are before the state legislature that would resolve important land rights and oyster lease issues.

Highways and Wetlands

Many post-war highway and road projects, as well as earlier rail lines, were built in coastal wetland environments that at the time were considered of little value. In many cases, these projects substantially altered tidal flows and degraded coastal wetlands.

The rehabilitation of these highways presents a new opportunity to correct some of the environmental mistakes of the past. For example, designing culverts that more closely approximate tidal flows and constructing larger channels in and around transportation facilities could significantly help restore the productivity of damaged salt marshes.

Coastal America, a federal interagency partnership on coastal issues involving about a dozen federal agencies, recently studied transportation-related wetland restoration opportunities in Connecticut and Cape Cod. The Connecticut study focused on sites where the dominant species was the common reed (*Phragmites australis*), a highly invasive plant that dominates disturbed and tidally restricted areas.

The studies found that high marshes dominated by *Phragmites australis* are well-suited for restoration by increased saline flushing. Higher salinities can help more desirable and productive salt marsh vegetation drive out *Phragmites*. As the Phragmites plants disappear with an increase in salinity, native salt marsh plants will often recolonize spontaneously, thus precluding the need for expensive and difficult planting and transplanting projects.

The study issued a few cautionary notes about such restoration projects. For example, increased salinity conditions could subject shellfish beds to greater predation and/or a proliferation of protozoan diseases.

Using the results of the Coastal America study, the Connecticut Department of Environmental Protection applied for federal funding under the Intermodal Surface Transportation Act (ISTEA) for the restoration of Sybil Creek and Mill

Meadows salt marshes. This project represents the first commitment of ISTEA funding for salt marsh restoration in the nation.

Coastal America also has supported a variety of other wetland restoration projects around the country. For example:

- At the Roosevelt Roads Naval Station along the eastern coast of Puerto Rico, a proposed project would restore tidal flushing to about 1,000 acres of mangrove forest. In the late 1940s, construction of a two-mile road blocked four natural channels and stopped tidal exchange along the eastern boundary of the forest. The project includes demolition of existing causeways, construction of a new causeway with bridges to allow greater tidal flow and saltwater exchange, and the clearing of damaged and fallen mangroves restricting existing culverts. The Puerto Rico Trust will be involved in the planting of new mangroves in areas that were severely damaged.
- In the Sacramento Delta in San Francisco Bay, a proposed project would restore about 1,300 acres of wetlands around Prospect Island. The project will breach a levee and restore full tidal action to the site. Partners in this $5 million project include the Corps of Engineers, the Bureau of Reclamation, the Fish and Wildlife Service, and the CalFed Bay-Delta Program. Construction is scheduled to begin in 1998.

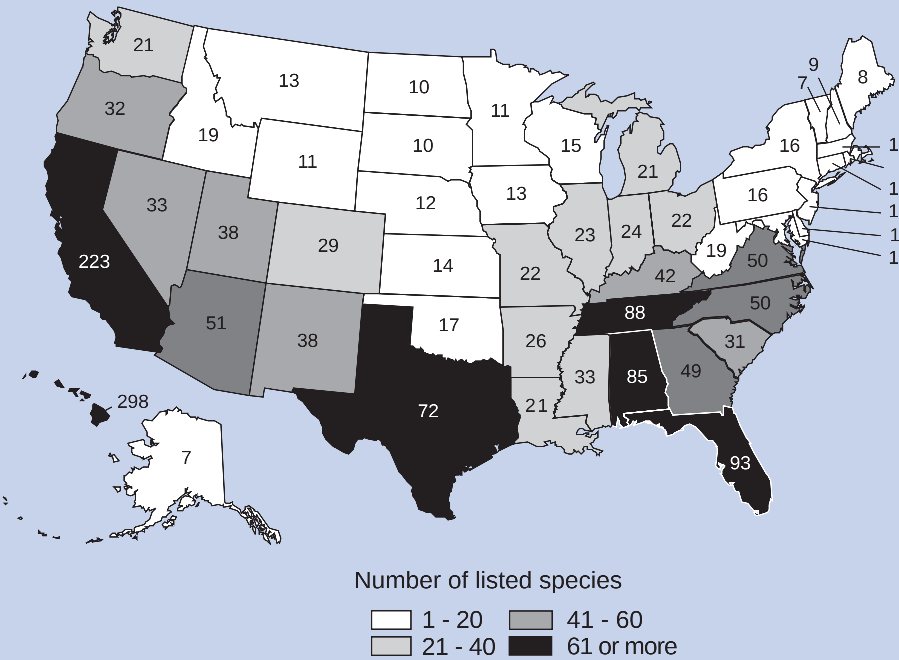
PROTECTING COASTAL SPECIES AT RISK

Of the 1,126 species of plants and animals in the nation that are listed as threatened or endangered (as of February 1998), half or more are found within coastal states (Figure 6.16). There are numerous causes of these species' decline, including habitat loss, unwise forestry and agricultural practices, overharvesting and exploitation, dredging and filling of wetlands, development in ecologically sensitive areas, and the introduction of non-native species.

Many projects are underway to assist species at risk. For example:

- At the Dare County Air Force Base in Dare County, North Carolina, stands of Atlantic white cedar have not been able to fully re-establish themselves since extensive logging operations in the 1880s. The Air Force and several other partners are beginning a $500,000 project that will identify the factors in cedar forests that are critical to successful, natural reforestation. A variety of methods of naturally introducing white cedar will be evaluated, including the cultivation of cones, seeds, and seedlings. The project will produce guidelines for restoring traditional white cedar ecosystems.
- Protection of the manatee is a high priority for the South Florida Water Management District. Between 1974 and 1993, 73 manatees died in the Okeechobee Waterway and in the Central and South Florida Flood Control Project locks and water control structures. In partnership with the

Figure 6.16 U.S. Threatened and Endangered Species by State



Source: U.S. Department of the Interior, Fish and Wildlifel Service, Division of Endangered Species, Listed Species by State/Territory as of February 28, 1998 (an Internet accessible map).

Corps of Engineers and others, automatic gate reversal sensors are currently being designed, tested and installed on lock sector gates and spillway gates. Whenever manatees are caught by a closing gate, the sensors would automatically stop and reverse the gate closure before the animal is injured or killed.

- The Aransas National Wildlife Refuge on the Gulf Coast of Texas, which is a seasonal home for the endangered whooping crane, is immediately adjacent to the Gulf Intercoastal Waterway. Since 1950, the refuge may have lost as much as 1,000 acres of crane habitat as a result of bank erosion caused by boat wakes from commercial and recreational vessels, wind-driven waves, and storms. To temporarily stem the erosion, the Fish and Wildlife Service and many other partners worked from 1989 to 1992 to install anchored cement bags along 3,850 feet of channel bank, thus protecting about 100 acres of salt marsh. The project attracted strong local support; some 500 non-federal volunteers contributed over 7,000 hours to the effort. The Corps is developing a proposal for a more permanent solution to the channel erosion problem.

- The snowy plover, which was listed as threatened by the state of Oregon in 1975 and added to the federal threatened list in 1990, has been declining in part because the growth of European beachgrass along the coast has eliminated much of the flat, open, sandy beaches required by the plover for nesting. At the Umpqua River North Spit within the Oregon Dune National Recreation Area near Reedport, a project completed in the fall of 1994 created approximately 10 acres of sustainable nesting habitat for the plover. The project created the habitat using clean dredged sediments removed from the Winchester Bay federal navigation project. (For examples of DoD beach and dune restoration, see Box 6.3.)

Successful projects in species protection in the last few years have identified some valuable lessons about process. For example, the migratory bird treaties with Canada, Japan, Mexico and Russia have enabled many federal agencies to justify their participation in collaborative activities dealing with neotropical songbirds, migratory waterfowl, and shorebirds. Public-private partnerships between groups such as The Nature Conservancy and federal agencies have contributed to a balanced blending of private funding for this work.

In many projects, volunteers have provided a significant source of both labor and expertise. Active public participation can not only help accomplish a project, but can also improve the public's awareness of environmental problems and the restoration process.

NEW STRATEGIES

As the complex nature of coastal environmental predicaments has become clear, resourceful groups and individuals have come up with new ways to marshal resources and share responsibilities. These new strategies represent attempts to meet the goals of water quality and

Rivers meet the sea along the rocky Maine shore.

Photo Credit: USDA—93CS0380

Box 6.3
DoD Works to Restore Beaches and Dunes

Beaches and dunes are often relatively fragile structures built from sediment carried down rivers, transported along coasts by nearshore currents, and redistributed by tides and wave action. They provide a first line of protection during storms by buffering wind and wave energy. They can be easily disturbed both by human activities and by natural factors such as major storms.

Many Defense Department agencies are actively engaged around the nation in beach and dune restoration projects.

At Tyndall Air Force Base on the northwest coast of Florida near Panama City, wind damage and human use has severely eroded the primary dune system and is threatening the interior dunes. Using funds from the Defense Department's Legacy Resource Management Program, the project has installed an elevated boardwalk system and picnic areas for visitors. To protect the dunes from further wind damage, sand fences were installed along with plantings of native vegetation.

The Florida Department of Environmental Protection participated in the Tyndall project and plans to take similar measures on the adjoining state park. Nongovernment partners included the Sea Oats Garden Club and Friends of St. Joe Bay.

On the east coast of Florida near the city of Cocoa Beach, Patrick Air Force Base is located on a barrier island that has been eroding badly during storms. The erosion was threatening coastal habitats and threatening to degrade the Indian River Lagoon National Estuary. A plan was developed to regrade the shoreline and install large coquina rocks over filter cloth combined with the planting of mangroves and other native species. Project partners included the Fish and Wildlife Service, Corps of Engineers, National Marine Fisheries Service, Florida Department of Environmental Protection, Florida Marine Resources Council, St. John's River Water Management District, and the Indian River Lagoon National Estuary Program.

In 1991, a severe winter freeze destroyed the vegetation on about 44 acres of coastal dunes near the city of Monterey, California, and the nearby Naval Postgraduate School. Without this protective cover, the dunes were in jeopardy of shifting and causing severe damage to the Navy's facilities and to adjacent private properties. As part of its "good neighbor" policy with the city, the Navy provided $295,000 for a project to restore the dunes.

The vegetation that had succumbed consisted mostly of the exotic African ice plant, which has poor tolerance for freezing temperatures. The city and the Navy agreed to remove all the exotic vegetation with the help of volunteers from the Monterey Dune Coalition and the Big Sur Land Trust. Over 150,000 seedlings, including 26 species of native vegetation, were planted on the dunes. The native plants should enhance the habitat for endangered species known to frequent the area such as Smith's blue butterfly. Furthermore, the use of native vegetation should reduce the risk of vegetative loss in the event of another freeze.

The project has been endorsed for its use of native plant material by the California Coastal Commission, the Fish and Wildlife Service, the Monterey Dune Coalition, the Big Sur Land Trust, and the California Native Plant Society.

utility through collaborative agreements based on science, innovation, and new institutional arrangements.

One new approach, point/nonpoint and point/point source trading, is being tried in the Tar-Pamlico Basin in North Carolina. Another important breakthrough is the recognition of the contribution made by air deposition to water quality problems, which is being addressed by the Tampa Bay National Estuary Program.

Reducing Pollutants in the Tar-Pamlico Basin

Over the past three decades, high levels of nutrients (mostly nitrogen and phosphorus) flowing from the Tar-Pamlico River into the Tar-Pamlico estuary in North Carolina have increased algal levels (measured by chorophyll a) in the estuary, causing fish kills and generally diminished water quality. Studies indicate that about 90 percent of the nitrogen entering the river is from nonpoint sources, largely from agricultural sources. The 5,400-square-mile watershed includes five of the state's ten leading hog-producing counties and the leading poultry-producing county. About 37 percent of the watershed's area is farmland, mostly in row-crop production. Prior to a modeling effort, discharges to the basin of the overall nitrogen and phosphorus load were estimated at 15-20 percent. Once modeling tests were completed, municipal wastewater discharges to the basin were estimated to contribute about 8 percent of the overall nitrogen and phosphorus load to the estuary.

In 1979, the North Carolina Environmental Management Commission adopted a water quality standard for chlorophyll a of 40 micrograms per liter (ug/l) for lakes, estuaries, sounds, and other slow-moving waters. Since algal blooms with chlorophyll a densities ranging from 40 to 300 ug/l were not unusual in the Tar-Pamlico during the summer months, the new standard meant that state regulators would have to do something about algal blooms in the Tar-Pamlico estuary.

In the late 1980s the state made progress on phosphorus discharges, passing a statewide ban on the sale of phosphate detergents in 1988 and issuing a new permit for Texasgulf Industries, Inc., which alone was responsible for 50 percent of the phosphorus discharged into the estuary. The new permit required Texasgulf to reduce its phosphorus loadings by 90 percent, which the company achieved by March 1994.

Even as the state was making progress on phosphorus, the problem with nitrogen pollution was continuing. A 1988 study indicated that about 83 percent of the nitrogen load came from nonpoint sources, mostly agriculture, and only 17 percent came from point sources.

To meet North Carolina's stringent proposed point source limitations, dischargers would have to build expensive new advanced treatment facilities. The Tar-Pamlico Basin Association, which included 12 municipalities and one industry in the watershed, estimated capital costs for implementing the nutrient control measures at $50 million plus additional operation and maintenance costs. Many were troubled by these high treatment costs, especially given the relatively small impact of point source nutrient removal on overall nutrient emissions into the estuary.

In response to the state's proposed nutrient management strategy, the Tar-Pamlico Association proposed to develop an alternative strategy that would more cost-effectively address both point and nonpoint sources of pollution. Working with the state, the North Carolina Environmental Defense Fund, and the Pamlico-Tar River Foundation, the association proposed several steps: immediate nutrient load reductions through improved treatment plant performance; development of an estuary model to evaluate nutrient impacts, alternative pollution control strategies, and set nutrient loading targets; establishment of a mass-based cumulative discharge cap for all members; establishment of a schedule of short-term nutrient reduction goals; development of a management framework to target and track nonpoint sources; and initiation of a best management practices (BMPs) pilot program to demonstrate the efficacy of a point/nonpoint source trading program. In December 1989, after considerable debate, the state approved the alternative strategy. Phase I (1990-94) identified the actions and implementation schedule necessary for the new approach. In Phase II (1995-2004), trading can occur to avoid nitrogen and phosphorus load increases into the estuary.

Having established a baseline discharge level of 625,000 kg/year, the association members agreed to a total nutrient reduction of 200,000 kilograms (of both nitrogen and phosphorus) during the program's first phase.

The association hired a consulting firm to identify immediate and relatively low-cost facility improvements and assess the relative capabilities of different treatment processes. With the help of this analysis, the association members were able to meet the Phase I reduction targets simply by optimizing existing treatment works and maximizing the performance of expansion projects. The study also established the limits of the existing treatment works to achieve nutrient reduction; further reductions could only be achieved with expensive capital modifications or other more energy- or chemical-intensive alternatives.

In the initial stages of this point-nonpoint trading program, the association agreed to pay $56 for each kilogram of nutrients discharged above the group's yearly nutrient reduction targets, with the funds paid into a nonpoint source control fund administered by the state's existing agricultural cost-share program. The figure was derived by the state based on the average nonpoint source control cost in a nearby watershed and included a 3:1 safety factor for cropland BMPs and 2:1 for confined animal operations.

A subsequent study by the Research Triangle Institute found that the $56/kg figure generally overestimated the cost of nitrogen removal. In Phase II, the parties agreed to revise the figure to $29/kg, with the figure to be evaluated and adjusted as necessary every two years.

Once the high-priority BMPs are addressed, it is likely that the cost of nitrogen reduction via BMPs will increase. Nevertheless, the current $29/kg cost estimate for nitrogen removal supports the conclusion that implementing BMPs may be a more cost-effective means to achieve nutrient reduction than further point source controls.

Identifying Air-Water Linkages

The contribution of atmospheric pollution to water pollution is significant. For example, about 54 percent of the nitrogen emitted from fossil-fuel-burning plants, vehicles, and other sources in the United States is deposited on U.S. watersheds and coastal estuaries. The largest sources are point sources: coal- and oil-fired electric utilities and large industries. Mercury and other toxics also are atmospheric pollutants that affect water quality.

Atmospheric-borne nitrogen is a major contributor to nitrogen loadings in many estuaries. About 27 percent of the nitrogen in the Chesapeake Bay is from the atmosphere, while the atmospheric contribution in the Albemarle/Pamlico Sound is estimated at about 44 percent.

In 1996, EPA and its partners began a new initiative to bring Clean Air Act and Clean Water Act activities into closer coordination and address air deposition to the nation's waters and coastal watersheds. For example, the Tampa Bay National Estuary Program, recognizing the impacts of air deposition of nitrogen on water quality in Tampa Bay, convened a Nitrogen Management Consortium to address nitrogen loadings to the Bay that come from atmospheric deposition—in addition to the more traditionally recognized municipal and industrial point sources. The Consortium is developing a novel plan under which the group as a whole will come up with individual and/or joint projects to achieve the reductions deemed necessary to preserve the water quality gains already achieved in the rapidly growing Tampa Bay area.

GLOBAL LINKAGES

In a great many cases, the fate of the nation's environment and resources depends critically on developments well beyond the nation's borders. All the effort to protect the habitat of migratory songbirds in the United States, for example, may not be sufficient if their winter habitat in Central and Latin America is lost. Each country's attempt to protect marine resources, the stratospheric ozone layer, and the global climate cannot succeed without the cooperation of all the world's nations.

Climate Change

The scientific evidence that climate change is occurring is now clear and compelling. Emissions of greenhouses gases—mainly carbon dioxide—from human activities are amplifying the Earth's natural greenhouse effect and are leading to a warming of the planet's surface. Climate change is likely to lead to a series of global disruptions, including sea-level rise, changing patterns of precipitation, shifts in atmospheric and ocean currents, and changes in the ideal ranges for plants and animals.

Melting ice is an important factor in sea-level rise.

Photo Credit:
S.C. Delaney/EPA

Increased variability of the hydrologic cycle is expected to result in more severe droughts and/or floods in some regions. Climate change would likely add to the stress in U.S. river basins, particularly the Great Basin, California, Missouri, Arkansas, Texas Gulf, Rio Grande, and Lower Colorado. Reductions in runoff of up to 25 percent in the Colorado River Basin are projected under some scenarios. In the United States, the regional impacts of climate change are potentially very serious:

- In the Northeast, sugar maples and beech trees may move completely into Canada, with considerable economic impact. Coastal areas are likely to be affected by intensifying storms, sea-level rise, and reduced freshwater input to estuaries.
- In the Southeast, the low elevation of states such as Florida makes this region especially vulnerable to sea-level rise and storm surges during hurricanes, which are expected to worsen with climate change. A 1-foot rise in sea level, the best estimate over the next century, could erode 100 to 1,000 feet of Florida's beaches, damaging property and the tourism industry. A 20-inch rise could inundate more than 5,000 square miles of dry land and an additional 4,000 square miles of wetlands along U.S. coasts, while a 3-foot rise could inundate much of the southern tip of Florida. Precipitation

changes and salt-water intrusion from sea-level rise could adversely affect the ecological communities of the Florida Everglades and degrade the habitat for many wading birds.

- In the Great Plains, the simultaneous drop in aquifer levels (largely as a result of demand from the agricultural sector), greater run-off from extreme downpours, and shorter duration of snow cover will exacerbate the region's water supply problems. Riparian areas are extremely vulnerable to warmer, drier climate.
- In the Southwest, the region's vulnerability to water supply problems is likely to worsen. The region is expected to experience more extremely hot days, fewer cool days, and decreased winter precipitation. Alteration of the region's hydrologic cycle would affect both quantity and quality of water supply, with major implications for continued development.
- In the Pacific Northwest, changing patterns of precipitation and drought, timing of runoff, and increased inundation of coastal areas due to sea-level rise is expected. In the Columbia River Basin, where an overall decrease in annual run-off is likely, competition among hydropower production, fisheries production, and irrigation will probably increase.
- In Alaska, probable consequences include drying of Alaska's interior, inundation of fragile coastal delta areas, and, most seriously, melting of permafrost, which is already underway. In many cases, ground level can collapse 5 yards or more, leading to significant damages to ecosystems and human infrastructure. Ecosystem effects include expansion of lakes and wetlands, clogging of salmon-spawning streams, and increased rates of coastal and riverbank erosion.

The principal hope for dealing with climate change is The Framework Convention on Climate Change, which seeks to stabilize atmospheric concentrations at levels that prevent dangerous human-induced interference with the climate system. At the latest meeting of the parties in Kyoto, Japan, in December 1997, industrialized nations agreed to legally binding emissions reduction targets with a view to reducing their overall emissions of six greenhouse gases by approximately 5 percent below 1990 levels in the period 2008-2012. The U.S. succeeded in ensuring that countries could achieve their emission targets as cost-effectively as possible through market-based implementation mechanisms. Many issues are still outstanding, however, and remain for further negotiation.

The State of the Oceans

Concern about the state of the world's oceans is growing. Early in 1998, some 1,600 scientists from 65 countries issued a statement warning of the increasing threats to the world's oceans. The statement noted that life in the world's estuaries, coastal waters, enclosed seas and oceans is increasingly threatened by over-exploitation of species, physical alteration of ecosystems, pollution, introduction of alien species, and global atmospheric change.

Of the many factors contributing to the crisis, the statement noted that fishing practices such as bottom trawling are degrading habitat for bottom-dwelling creatures; that overexploitation is threatening species such as swordfish; that land-based pollutants such as PCBs and other pollutants are threatening shellfish; and that human activities seem linked to emerging epidemic diseases that are sweeping through marine species from corals to dolphins.

In recognition of the importance of the ocean and the marine environment, the United Nations has declared 1998 to be the International Year of the Ocean. Many events are planned in the United States in 1998, including a national conference to discuss a wide range of ocean-related issues.

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