Photo ***credit:*** *Stephen C. Delaney*

Chapter 5

Impacts of Waste Disposal on Marine Resources

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Chapter 5

Impacts of Waste Disposal on Marine Resources

OVERVIEW

Marine resources are affected by a wide range of natural and human perturbations, including pollutants from waste disposal. Waste disposal occurs directly in marine waters, but also indirectly as wastes are carried to the sea by rivers. It can be difficult, however, to establish a clear understanding of the precise connections between pollutants from these activities and impacts on marine resources. Nevertheless, sufficient evidence is available to conclude that pollutants from disposal activities have resulted in a wide variety of impacts on water quality, sediment quality, and marine organisms.[1]

[1] Space limitations preclude a detailed presentation of all evidence documenting these impacts. The reader interested in an extensively documented, detailed discussion of this evidence is referred to ref 588, prepared by OTA and available from the National Technical Information Service.

Most of the impacts that are attributable to pollutants from waste disposal have been observed in estuaries and coastal waters, often the most productive marine waters. The degree and distribution of these impacts vary widely among different waterbodies and organisms, but no region of the country is immune to serious adverse impacts from pollutants. Even small quantities of certain pollutants can result in chronic, persistent, and serious effects on organisms.

Where trends in impacts over the past 10 to 15 years are discernible, they have been mixed. They have varied among specific pollutants, species, and locations. Some improvements have been observed, while in other cases deterioration is evident. Sometimes no clear trend appears.

ESTABLISHING LINKS BETWEEN POLLUTANTS AND IMPACTS

Determining the causes of impacts on marine resources can be difficult.[2] Changes can result not only from waste disposal activities and runoff, but also from natural perturbations, fishing, or other human-induced changes such as habitat destruction or freshwater diversions. Even when pollutants are correlated with impacts, the ultimate source of the pollutants may be unclear—they may emanate from any combination of surface runoff, various industrial discharges, municipal discharges, dumping activities, and atmospheric deposition, and they may come from sources in or adjacent to marine waters or from far upstream.

Another complicating factor is that impacts caused by pollutants may not be observed for years or decades after the pollutants are released, or they may occur far from the release area. For example, when a pollutant is extremely persistent in the environment or when water flow and circulation are great, pollutants can be transported great distances. In addition, some impacts on organisms may not occur until the affected organism is far from the original point of contamination.

Consequently, establishing the causes of past and present impacts and predicting future long-term impacts on marine communities is a formidable task. These difficulties are frequently aggravated by a lack of information. The picture that emerges from an analysis of the available information looks like a jigsaw puzzle with many pieces missing.

Thus, although waste disposal activities may be fully or partly responsible for many marine impacts, it is often difficult to assess their precise involvement. Despite these problems of documentation, a strong overall case can be established that waste disposal activities are contributing significantly to substantial declines in the quality of marine waters and harming marine organisms, and in some cases having effects on humans.

[2] This is assuming that the impacts are detected in the first place; while many effects can be detected rather easily, others can be detected only with great difficulty and expense or may escape detection altogether.

IMPACTS ON WATER AND SEDIMENT QUALITY

Enrichment With Organic Matter and Nutrients

Perhaps the most conspicuous and widespread impact that pollutants have on marine environment is eutrophication, a process associated with the introduction of nutrients. Eutrophication is evident in every region of the country. The impacts of eutrophication range from stress on individual organisms (which in turn may increase the incidence of disease or abnormalities) to major ecological changes. Nutrient enrichment sometimes contributes to massive blooms of tiny photosynthetic organisms,[3] sometimes dubbed ' 'green tides, ''brown tides, or ' 'red tides. These organisms can harm—and even kill—other marine organisms and humans (343,536,545). Under extreme conditions, eutrophic conditions can lead to a severe depletion of dissolved oxygen called hypoxia. The most dramatic consequences of extreme hypoxia are mass kills of organisms.

Eutrophication and hypoxia often have been linked to human activities, including waste disposal. Waste disposal activities (particularly municipal discharges) contribute large quantities of nutrients to marine environments, and hypoxia can be caused or aggravated by the introduction of oxygen-demanding pollutants (e. g., organic matter) from these same sources. Other pollutant sources, such as runoff, also contribute to eutrophic and hypoxic conditions, and natural factors such as seasonal stratification of the water column can also cause hypoxia.

Eutrophication and hypoxia are serious and regularly recurring problems in many major waterbodies (695). Hypoxic areas vary widely in magnitude, from a fraction of a square mile to thousands of square miles. Examples of large and regularly occurring hypoxic waters are an area (up to 8,000 square kilometers (km^2)) off the Louisiana coast (Rabalais (465) and a portion (up to 3,000 km^2) of the Chesapeake Bay (419).

Trends in the occurrence of hypoxia around the country are mixed. In some areas, the problems have been alleviated because discharges of organic matter and nutrients have been reduced (395,463, 554,703). In other instances, the problems have grown in severity, either because quantities of nutrients and organic matter have increased or because other changes have reduced the natural system's capacity to accommodate the discharges without major ecological impacts (31 5,419,486).

Hypoxia is least extensive along the Pacific coast; conversely, the Atlantic coast and particularly the Gulf of Mexico are greatly affected by hypoxia. Extensive hypoxia has been found along the southern coast of Louisiana (figure 15), and it is common in the Chesapeake Bay (figure 16) and the New York Bight. Its causes are multiple and include natural factors as well as pollutant inputs from raw sewage, sewage sludge, and other waste materials.

Elevated Concentrations of Other Pollutants in the Water Column

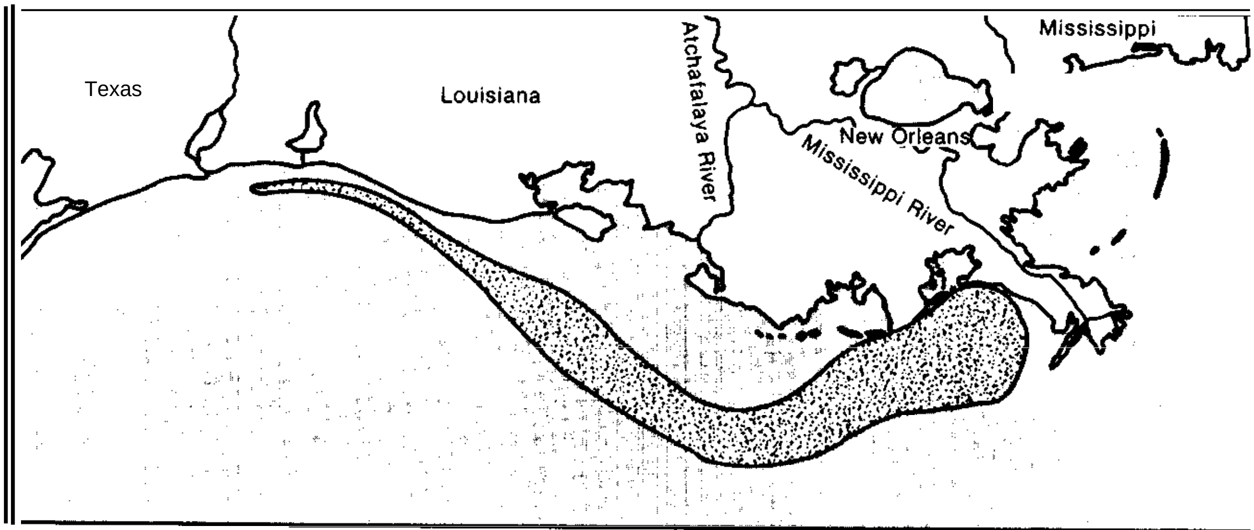
In addition to organic matter and nutrients, many other pollutants are discharged into marine waters in large quantities. Among these are pathogens, metals, and organic chemicals such as chlorinated and aromatic hydrocarbons. Contamination can vary from levels scarcely above the threshold of detectability to extremely high levels. Contamination tends to be greatest in the vicinity of estuaries flanked by heavy urban or industrial development, or near estuaries that receive pollutants from developed areas upstream. Contamination also tends to be most serious near municipal and industrial outfalls, and in the vicinity of major dumpsites for sewage sludge or other contaminated materials (figure 17).

Even at a given location and time, contamination may vary considerably according to its vertical position in the water column. Some pollutants concentrate at the very surface of the water-column

3A photosynthetic organism is one which uses sunlight to synthesize compounds.

4The precise conditions needed for the initiation, propagation, and maintenance of these blooms are not completely understood. It is known, however, that nutrients are required for a bloom to proceed. If nutrients from waste disposal have enriched marine waters, they may contribute to a bloom greater (and hence more damaging) than it otherwise would be.

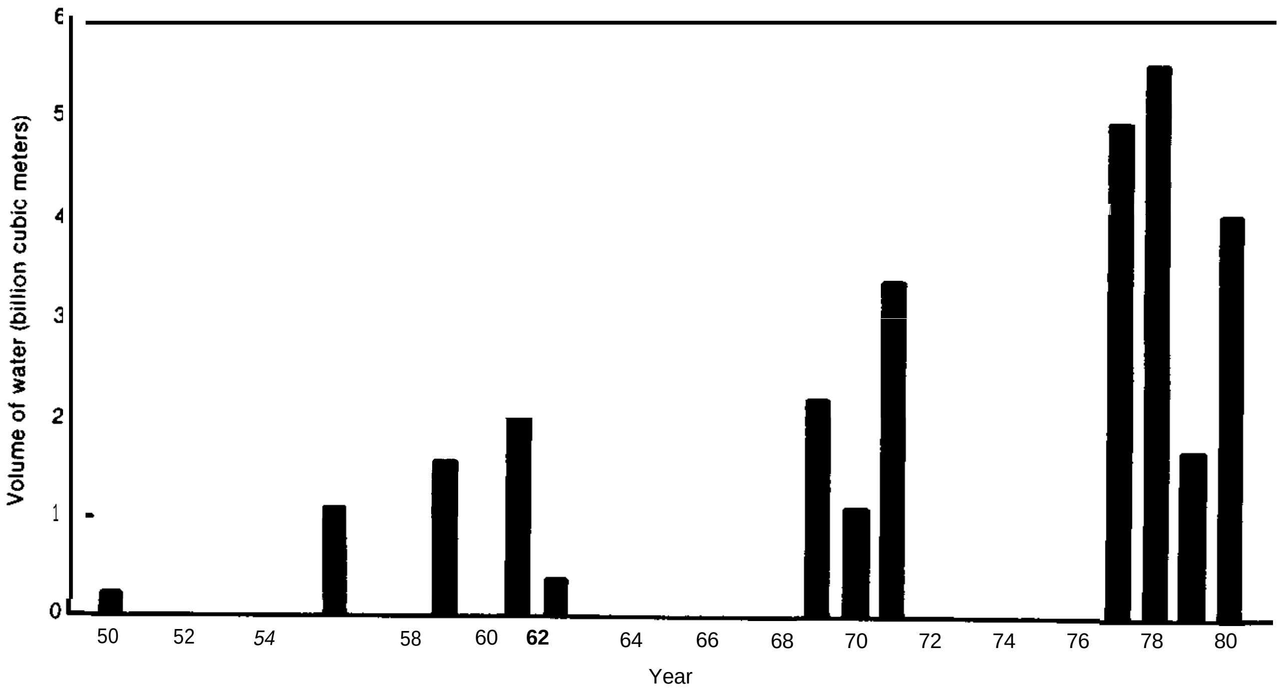
Figure 15.—Extent of Oxygen Depletion in Bottom Waters of the Louisiana Shelf, July 1985



Stippled area depicts bottom waters with dissolved oxygen concentrations less than 2 milligrams per liter (a condition known as hypoxia). Most animal life cannot survive for long in water with such low oxygen concentrations.

SOURCE: N. Rabalais and D.F. Boesch, Extensive *Depletion of* Oxygen *in Bottom Waters of the Louisiana Shelf During 1985* (draft manuscript, 1986).

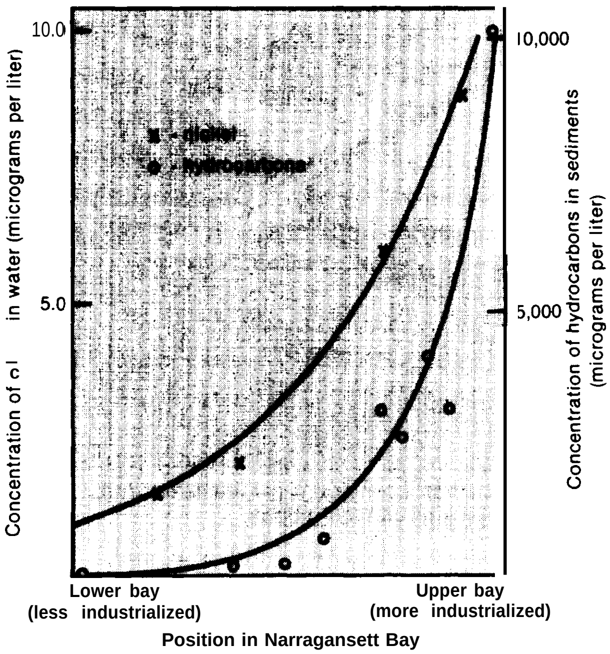
Figure 16.—Volume of Water in Chesapeake Bay With Levels of Dissolved Oxygen Lower Than 0.7 Milligrams Per Liter, 1950.80



NOTE: Years lacking bars, no data are available,

SOURCE: Office of Technology Assessment, 1987; after U.S. Environmental Protection Agency, Region 3, Chesapeake Bay Program, *Chesapeake Bay. A Profile of Environmental Change,* PB 84119197 (Philadelphia, PA: 1983).

Figure 17.—Concentration of Nickel and Hydrocarbons in Narragansett Bay, Rhode Island, in Relation to Distance From Discharge Points



As in many other locations in the United States, concentrations of pollutants in Narragansett Bay tend to be greatest near discharge points, especially where many such discharges are concentrated in a highly industrialized or urbanized area. Note that one microgram equals one-millionth of a gram.

SOURCE: Save The Bay, Inc., *Down the Drain. Toxin Pollution and the Status of Pretreatment in Rhode /s/and* (Providence, RI: September 1986).

(the "surface microlayer''[5]), an ecologically important zone where the presence of pollutants may be particularly damaging. In the urbanized areas of Puget Sound, for example, the microlayer has been found to contain relatively high concentrations of some pollutants. One type of pollutant—polynuclear aromatic hydrocarbons (PAHs)—was present at concentrations which in many cases were acutely toxic to flatfish eggs in laboratory experiments. Scientists believe the pollutants are responsible in part for the lower quantities of flatfish eggs and other organisms found in the microlayer in the developed areas of the Sound (610).

The presence of pollutants in the water column is important in three respects, First, marine organisms may be affected by the direct exposure to contaminated water. In Puget Sound, for example, some samples of contaminated bottom water were found to cause sublethal toxic effects in some organisms (89). Evidence from the Chowan River in North Carolina suggests that herring have detected and avoided pulp mill effluent in the river, to the detriment of some of the river's fishermen (398). These direct impacts can also give rise to additional ecological repercussions.

Second, the pollutants may be transported to other locations and transferred to sediments or to the atmosphere, thereby increasing the chances of exposure to living organisms and further ecological impacts. Third, in addition to impacts on marine organisms, elevated levels of these pollutants may reach a point where human health is directly threatened.

Human Pathogens

Pathogens often are discharged from combined sewage overflows, municipal treatment plants, runoff, raw-sewage outfalls, and boats in marinas and elsewhere. As a result, high levels of fecal coliform bacteria in the water frequently create the need for government authorities around the country to restrict shellfish harvesting. High coliform levels also result in temporary or permanent beach closures, particularly along the north Atlantic coast (486). Beach contamination appears to be less common in other regions of the country, but complete information on the nationwide extent of beach closures is not readily available and trends are not clearly discernible.

In some areas—such as parts of Chesapeake Bay (205,335)—fecal coliform contamination is not as serious as it was 10 or 15 years ago. The improvements are usually the result of greater levels of sewage treatment. Conversely, such contamination has not declined and has actually worsened in other areas, particularly those experiencing high population growth and rapid development (221). In coastal Louisiana, for example, municipal sewage treatment capacity has failed to keep pace with growth and is unable to adequately treat wastes (315). Growing numbers of residences with septic systems and increasing numbers of small boats also pose problems in many coastal areas. These water quality threats are expected to increase in some areas over the next decade.

[5]The surface microlayer comprises a very thin layer at the upper portion of the water column (ranging in thickness from less than one-tenth of a millimeter to several centimeters) (see ch. 4),

Metals and Organic Chemicals

The contamination of waters with metals and organic chemicals also is common. Concentrations of some metals and organic chemicals (e. g., DDT) in the water column have declined in many areas over the past 15 to 20 years. This is often because emissions of these pollutants have been reduced substantially from specific point sources, usually because of curtailed production of the wastes or because of greater waste treatment by industrial and municipal entities. For example, discharges of most key metals and organic chemicals into New York Harbor declined during the 1970s and early 1980s (1 1).

But there also are areas where improvements have not occurred and where concentrations of specific pollutants have increased (220,394). This has been especially true where rapid residential, agricultural, and industrial growth has resulted in greater emissions from both point and nonpoint sources. For example, monitoring data from the lower St. Johns River, Florida, indicate that concentrations of waterborne toxic metals increased from 1970 through 1980 (164).

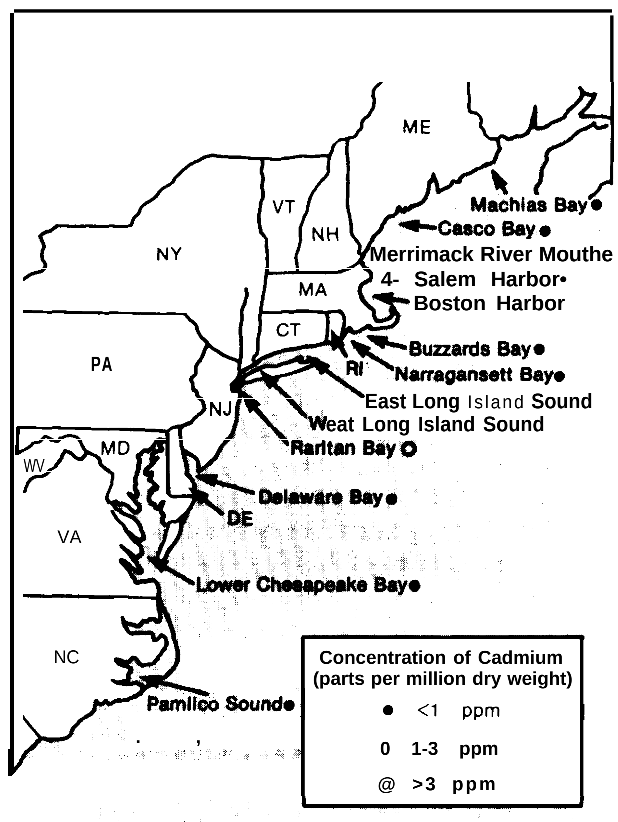
Impacts on Sediments

Sediments may be physically, chemically, or biologically altered by waste disposal activities and runoff. Physical alterations can occur when solids from pipeline discharges or dumping accumulate on the bottom. If this material differs substantially from the original sediment, then the substrate available to bottom-dwelling organisms can change significantly. In southern California, for example, the accumulation of solids discharged by ocean outfalls, in combination with other environmental changes associated with the discharges, has affected the distribution and abundance of benthic organisms over an area of approximately 170 km^2 (52,354).

Contamination of sediments with metals, organic chemicals (e. g., PCBs, other chlorinated hydrocarbons, and polynuclear aromatic hydrocarbons), and pathogens poses a particular problem. Contaminated sediments have been found around the country, and they are generally adjacent to industrial and urban areas where large volumes of contaminated material such as industrial wastes or municipal effluent have been discharged or dumped, or in estuaries that receive substantial pollutant loads from upstream, Sediment contamination is most prevalent and severe in the estuaries and coastal areas of the Northeastern United States (figures 17 and 18). The character of sediment contamination varies widely, as do its origins and consequences.

In some cases, the consequences of such contamination are relatively apparent and serious, especially where there are extremely high concentrations of particularly toxic pollutants. Among such areas are portions of Puget Sound like Commencement Bay and Everett Harbor, the Southern California Bight, and several areas along the northern Atlantic coast like Buzzards Bay. Some of these areas have been classified as Superfund sites. Many other areas exhibit various mixes and concentra-

Figure 18.—Concentration of Cadmium in Sediments Along the Northeast Atlantic Coast During 1984



SOURCE: U.S. Department of Commerce, National Oceanic and Atmospheric Administration. Ocean Assessments Division, *Progress Report and Preliminary Assessment of the Findings of the 1984 Benthic Surveillance Project* (Rockville, MD: 1986).

tions of pollutants with specific subsequent effects on the biota.

The restrictions imposed on point sources over the past 15 to 20 years have reduced discharges of some metals, organic chemicals, and human pathogens, and helped limit sediment contamination. Once sediments are contaminated, however, the duration and consequences of contamination vary. For example, in time, the pollutants may break down into less harmful byproducts. Or subsequent sediment deposition may bury the pollutants and prevent further exposure to living organisms (unless the sediments are subsequently disturbed).

Despite some progress, serious problems from contaminated sediments will continue to persist. Although releases of some pollutants have been curtailed or reduced in some areas, in other instances a growing variety and quantity of pollutants continue to be released to the water column and make their way to the sediments. The sediments often act as a repository for such pollutants, holding them for days, years, decades, or even centuries, As long as the pollutants persist in a toxic form, contaminated sediments can continue to affect organisms.

IMPACTS ON ORGANISMS

Pollutants from waste disposal activities and other sources have affected marine organisms and ecosystems in many different ways. The impacts vary widely, from acute and lethal to minor, from extremely adverse to relatively beneficial. The geographic scale also varies, ranging from very small areas to many thousands of square miles (41 7).

Some organisms are especially vulnerable to waste disposal activities and pollutants. Among these are bottom-dwelling (benthic) organisms and those which spend all or part of their lives in coastal waters or estuaries. Organisms that inhabit polluted waters during sensitive life-stages are particularly susceptible to environmental perturbations.

Striped bass, for example, spend their early life-stages in or near estuaries and during that time are very sensitive to substances (e. g., copper, cadmium, and aluminum) contained in waste discharges. High mortality rates during these stages appear to be related to the presence of pollutants and other factors. The precipitous declines in striped bass stocks in recent years are thought to result in part from low survival rates during the first 60 days of life (218,219,625).

Birds and Mammals

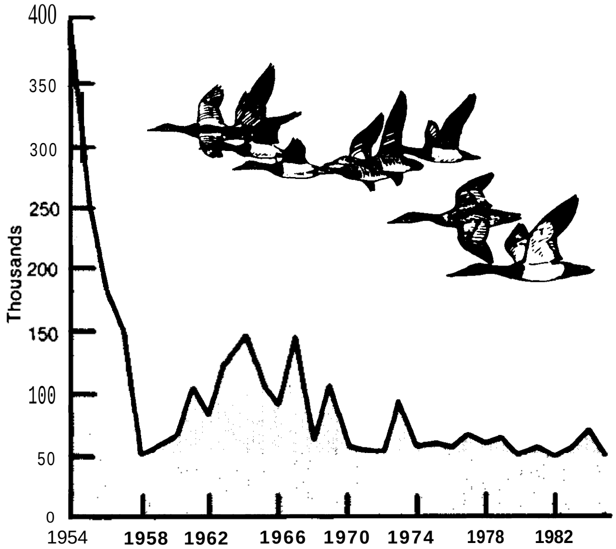
Birds and mammals are affected by pollutants in several ways. For instance, they can be affected indirectly when pollutants alter their habitat or food supplies, as is the case with canvasbacks ducks in the Chesapeake Bay. Pollutants caused drastic declines in the Bay's seagrasses, including the ducks' preferred food—wild celery. This has contributed to a precipitous decline in the Bay's population of canvasbacks ducks (624) (figure 19).

The strongest evidence linking pollutants to impacts on birds and mammals occur when organisms ingest a pollutant or a metabolize of a pollutant. The most important pollutants are those—e. g., chlorinated hydrocarbons—that persist and tend to increase in concentration as they are transferred through the food web (i.e., "biomagnify") (ch. 4). Marine birds and mammals often feed at relatively high trophic levels and thus are particularly susceptible to biomagnification.

Some evidence exists to directly link pollutants discharged from point sources to elevated concentrations of pollutants (or body -burdens[6]) and adverse effects in birds and mammals (65,421 ,698). Although the full consequences of such contamination in birds and mammals are not always known, impacts such as reproductive impairments have been observed. A well-known example involved discharges of DDT into southern California waters, where elevated concentrations of organochlorine chemicals and subsequent population declines in brown pelicans and several other bird species were linked to DDT-contaminated fish (92,422,423,485),

[6]The body-burden of a contaminant is its concentration in an organism's body.

Figure 19.—Canvasback Duck Population on the Chesapeake Bay, 1954-85



SOURCE. U.S. Department of the Interior, Fish and Wildlife Service, The *Canvasback* (Annapolis, MD: 1985).

Photo credit: *Stephen C Delaney*

Photo credit" A.W. Smith, Naval Biomedical Research Laboratory

Reproductive problems in sea lions breeding in southern California have been associated with DDT, large quantities of which were dumped offshore or discharged from marine pipelines prior to the early 1970s. Pictured here is a female sea lion attempting to carry her prematurely delivered pup.

Photo credit: K A King, U S Fish and Wildlife Service

Elevated levels of selenium and other metals have been found in waterbirds in Galveston Bay, Texas, sometimes at levels sufficient to impair reproduction. The birds pictured here are Laughing Gulls.

Reproductive problems in sea lions also have been associated with organochlorine pollutants (126, 187). Other less dramatic, yet nevertheless significant, examples exist elsewhere in the country. For example, three waterbird species nesting in Galveston Bay, Texas, were found to contain elevated levels of several metals (including selenium), in some cases at levels associated with impaired reproduction (268).

Reduced emissions of some pollutants have led to noticeable improvements. In particular, the banning of DDT production and disposal helped reverse the decline in brown pelicans (5), Nevertheless, impacts related to pollutants continue to be documented in birds and mammals (162).

Acute Lethal Effects on Fin fish and Shellfish

Given large enough quantities, some pollutants or combinations of pollutants will quickly kill finfish and shellfish. The mechanisms by which this occurs can vary from the depletion of oxygen (associated with discharges of nutrients and organic mat-

Photo credit. North Carolina *Division of Marine Fisheries*

Fish kills are frequent and severe in the Gulf of Mexico and along the southern Atlantic Coast. They result from low oxygen levels (hypoxia) that are caused by various factors, including waste disposal and natural processes.

ter) to the crippling of an organism's nervous system by certain toxic organic chemicals. These effects are difficult to measure in the field because seriously debilitated or dead organisms quickly disappear.

One type of uniquely compelling evidence which does arise in the field occurs when large numbers of organisms are killed at once by pollutants. The occurrence of mass mortalities varies around the country. They are least frequent along the Pacific coast, but are more common and serious in the Northeast. However, the greatest problems exist in the Gulf of Mexico and along the southern Atlantic coast, where hypoxic conditions cause frequent fish kills (315,359,554).

The magnitude of the kills varies widely. The largest incidents can involve millions of fish. The species reported as killed are often commercially valued species. For example, 109 fish kills were reported in the State of Maryland in 1985; 97 percent of the estimated 4.6 million fish killed were menhaden, a very abundant and important commercial species. The majority of the kills investigated in Maryland—some involving hundreds of thousands of fish-occurred in estuarine waters in the Chesapeake Bay (452).

While the causes of fish kills are not always clearly understood, evidence suggests that waste disposal activities in many instances are often significant contributors. Most kills occur in estuaries and are caused by low levels of dissolved oxygen (hypoxia). Municipal sewage treatment plants appear to be important contributors to the hypoxic conditions that cause fish kills because they discharge nutrients or oxygen-demanding materials that lead to oxygen depletion. Industrial dischargers too are important, although to a lesser extent. In the Chesapeake Bay, discharges contribute large quantities of nutrients but the precise magnitude of their contribution to the fish kills is unknown (452). The extent and severity of fish kills have been reduced in many areas over the last 10 to 15 years, but information is not available to accurately judge the reduction (N. Harllee, U.S. EPA, pers. comm., March 1986).

High Levels of Pollutants in Fin fish and Shellfish

Shellfish Contamination

The concentrations of coliform bacteria and natural marine biotoxins in shellfish have been periodically surveyed for many years. This information is now supplemented with information from ''biomonitoring" surveys, which measure the concentrations of toxic chemicals (e. g., metals and organic chemicals) in shellfish.

Since 1966, the National Shellfish Register (ch. 7) has provided an important indicator of the extent to which shellfish in U.S. waters are contaminated with coliform bacteria. In 1985, the register showed that 58 percent of the ''productive' shellfish areas in the United States were approved for harvest, while the rest were subject to some level of restriction (603) (table 7), Commercial shellfish harvests from roughly one-third (27 to 42 percent) of the productive areas are limited because of actual or potential contamination. Over 80 percent of the harvest-limited productive shellfish areas in the Nation are in the Gulf of Mexico and along the southern Atlantic coast. (603).

Although the register does not show a clear, overall national trend in shellfish contamination, it does, in combination with other evidence, indicate that bacterial contamination is a significant problem nationwide. Trends vary from one body of water to the next. In some areas, such as in the vicinity of Savannah, Georgia (9) or San Francisco Bay (69), shellfish contamination by fecal coliform has fallen to the point where shellfishing areas have been reopened for the first time in decades.

However, in other regions—particularly in rapidly developing areas such as the coastal portions of the Gulf of Mexico and southern Atlantic States —the problem is growing (221 ,356,394). The contributing causes include both point sources (primarily municipal sewage treatment plants and combined sewage overflows, and growing numbers of recreational boats) and nonpoint sources (including runoff and groundwater seepage from increasingly developed and often unsewered coastal areas).

Shellfish contamination with metals and organic chemicals also has been surveyed by State and Federal authorities (71,5 12,537,597,62 1). These efforts have varied widely among programs and from year to year. In some areas—usually in marine waters adjacent to or downstream from urban, industrial,

Photo credit: Office of Technology Assessment

Contamination of fish and shellfish with toxic pollutants sometimes compels local or State authorities to issue warnings or impose restrictions on the harvest, sale, or consumption of contaminated organisms. This sign has been posted on the tidal Passaic River in New Jersey, where dioxin contamination is so severe that the State forbids the sale or consumption of any fish or crabs from the waterway.

Table 7.—Classification of Shellfish Growing Waters (thousands of acres)

	Productive						
		Harvest limited areas					
Region and State	Approved for harvest	Prohibited	Conditionally approved	Restricted	Percent of total productive waters approved	Nonshellfish/ nonproductive	Total
Northern Atlantic:							
Maine	936	87	13	10	89	0	1,046
New Hampshire. .	4	6	0	0	40	0	10
Massachusetts . .	255	41	1	5	84	500	802
Rhode Island	96	20	12	0	75	0	128
Connecticut	309	78	6	0	79	0	393
New York	828	192	1	0	81	0	1,021
New Jersey	236	118	20	21	60	0	395
Pennsylvania	0	0	0	0	—	6	6
Delaware	209	19	3	0	90	44	275
Maryland	1,369	64	0	0	96	97	1,530
Virginia	1,295	174	33	0	86	2	1,504
Subtotal	5,537	799	89	36	86	649	7,110
Southern Atlantic:							
North Carolina . . .	1,755	370	0	0	83	0	2,125
South Carolina. . .	200	72	9	0	71	0	281
Georgia	61	144	0	0	30	0	205
Florida.	40	36	37	0	35	748	861
Subtotal	2,056	622	46	0	75	748	3,472
Gulf of Mexico:							
Florida.	266	260	306	0	32	578	1,410
Alabama	74	103	195	0	20	2	374
Mississippi	123	96	171	0	32	0	390
Louisiana	0	31	3,462	0	—	0	3,493
Texas.	1,310	358	0	0	79	2	1,670
Subtotal	1,773	848	4,134	0	26	582	7,337
West coast:							
California	2	263	12	1	1	248	526
Oregon	14	14	0	12	35	44	84
Washington	147	49	45	0	61	1,795	2.036
Subtotal	163	326	57	13	29	2.087	2.646
U.S. total.	9,529	2,595	4,326	49	58	4,066	20.565

DEFINITIONS

Productive: Any areas which are not classified "nonshellfish/nonp reductive.' At one time this category only contained areas which did or could produce shellfish (either naturally or aquaculturally) in quantities sufficient to justify commercial harvesting. As a result of changes in the classification system, however, there is an effort underway nationwide to classify all coastal waters within subcategories of this category, consequently, it includes areas which formerly were termed "nonshellfish/ nonproductive "

Approved for **harvest:** Area surveyed and found free of hazardous concentrations of pathogenic organisms and/or pollution. Molluscan shellfish may be commercially harvested at any time

Harvest limited:

a) Conditionally *approved:* Area surveyed and shellfish are found to meet "approved" area requirements for only part of the year. Molluscan shellfish may be harvested only during periods when pollutant levels are deemed acceptable. The area may be closed for the balance of the year because of high pollutant levels or because the shellfish control authorities have failed to establish that "approved" area standards are being met during that period; such failure may result from various factors, including cutbacks in funding of classification activities.

b) *Restricted'* Area surveyed and shellfish are found to be contaminated. Shellfish may be harvested but only can be marketed if they first are purified in a deputation facility or "relayed" to an approved area, In either case, the shellfish may be marketed once they are depurated (cleansed of pollutants).

c) *Prohibited;* Area surveyed and closed due to hazardous levels of contamination; or area has not been surveyed at all. Molluscan shellfish may not be commercially harvested at any time.

Nonahellfish/nonproductive: At one time, if areas were determined to be inaccessible, or did not or could not produce shellfish (either naturally or aquaculturally) in quantities sufficient to justify commercial harvesting, waters were classified into this category. As a result of changes in the classification system, however, acreage in this category is now being transferred into subcategories of the "Productive" category. At present the "Nonshellfish/nonp reductive" category accounts for less than 20 percent of total classified acreage.

SOURCE U S Department of Commerce, National Oceanic and Atmospheric Administration; and Department of Health and Human Servicas, Food and Drug Administration, 1985 *A/atlonal Shellfish Register of Classified Estuarine Waters* (Washington, DC: December 1985).

or agricultural areas—elevated levels of metals and organic chemicals are frequently present in shellfish. These concentrations sometimes are high enough to adversely affect the shellfish and to threaten consuming organisms, including humans. In some cases this has prompted government warnings or restrictions on fishing or consumption (see ch. 6). The full national extent of contamination by metals and organic chemicals, and its consequences and trends, are not known.

Finfish Contamination

Only a limited number and variety of fish have been analyzed for specific pollutants. These data reveal that the level of measured contamination varies widely—geographically, among species, among individuals, and even in different tissues of a single contaminated specimen. Likewise, the origins of the contamination and its significance to the health of both humans and marine organisms varies. Finally, there are wide differences in trends; some contaminants are increasing in importance while others are declining (340).

Generally, contamination by metals and organic chemicals from point sources is most severe near urban and industrial centers and in estuaries downstream from such areas (figure 20). Contamination also has been detected at distant points in the open ocean, but little information is available on the level of contamination and its consequences (198).

Bottom-dwelling fish that spend a substantial portion of their lives in close proximity to contaminated sediments are the most seriously exposed and contaminated, as are other fish in the same food webs. Sole and other bottom-dwelling fish have been contaminated with metals and organic chemicals in many areas of the country, including Boston Harbor; Commencement Bay, Washington; Santa Monica Bay, California; and others. In most cases, contaminant levels do not pose a clear threat to the well-being of the fish or to consumers of such fish (other organisms or humans). The concentrations found thus far usually have been below the levels set by the Food and Drug Administration (FDA), which has set some standards to restrict consumption of contaminated fish by humans (1 78, 593).

There are, however, instances around the country where contamination levels have been sufllcient to move officials to warn the public or restrict or prohibit the capture or sale of the fish. Many of the most serious and widely publicized problems have resulted from point source discharges that contain long-lasting toxic chemicals (e. g., DDT and PCBS) that accumulate in the tissues of fish (337, 463). For example, the capture and sale of striped bass in New York has been banned because of PCB contamination and signs have been posted warning against the eating of fish caught in Santa Monica Bay in southern California (194,340,577).

Other Effects on Fin fish and Shellfish

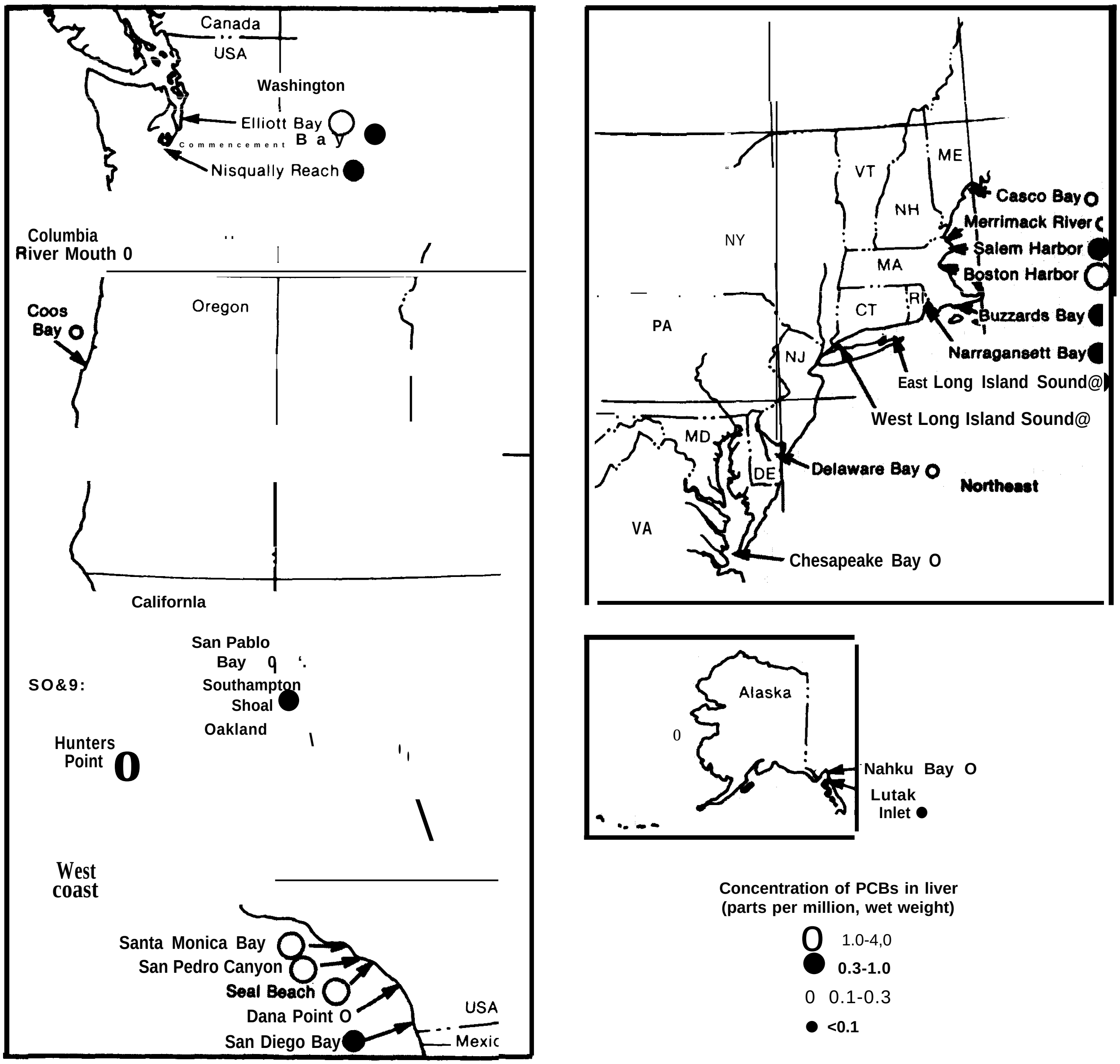
In addition to acute lethality and elevated body-burdens of pollutants, individual finfish and shellfish also exhibit behavioral and physiological effects, and populations of these organisms exhibit changes in abundance and distribution. These effects may be negative, positive, or inconsequential from the human standpoint.[7] Although many effects are difficult to document, a growing body of evidence links these effects to exposure to pollutants that sometimes are present at very low concentrations or to environmental changes induced by pollutants (127). The effects are concentrated in estuaries and coastaI waters, but detectable effects also have been found in fish far from shore in the open ocean (198,535).

The effects of pollutants on behavior are diverse. Some fish and shellfish will, if they can, avoid hypoxic bottom waters or waters containing various contaminants. Likewise, organisms living on or in sediments may avoid sediments that have been altered physically or chemically. Other aspects of their behavior may also change: for example, they may eat fewer or different organisms, be less active, or grow more slowly.

Pollution also has been linked with physiological and biochemical changes and diseases in fish.

[7]Positive impacts can result from a decline in pollutant inputs, or even from increases in the volumes of wastes. Pipeline discharges or dumping of organic matter and nutrients, for example, may increase productivity of marine waters. Some observers argue that this increased productivity has in some cases been beneficial (509,526).

Figure 20.—Concentrations of Polychlorinated Biphenyls (PCBs) in the Livers of Fish From Selected Sites



The PCB concentrations found in the sampled areas generally are lower than those found to biologically affect freshwater or saltwater organisms. **In** *some* **situations, however, biological effects have** been detected at the PCB concentrations found **at these sites.** PCBs **may cause reproductive failures, birth defects, tumors, liver disorders, and skin lesions, and they may suppress the immune system.**

SOURCE: **U S Department of Commerce, National** Oceanic **and Atmospheric Administration, Ocean Assessments** Division, *Progress Report and Preliminary Assessment of the Findings of the 1984 Benthic Surveillance Project* (Rockville, MD: 1986)

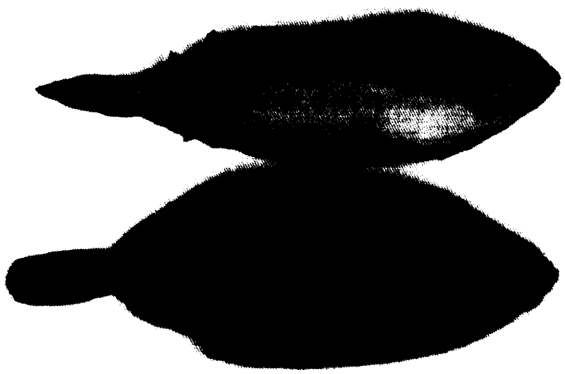


Photo credit: Southern California Coastal Water Research Project

Pollutants have been linked with physiological and biochemical changes and diseases in fish, ranging from minor effects to conspicuous pathological abnormalities. Pictured here are two Dover Sole from the coastal waters near Los Angeles; the top fish exhibits severe "fin erosion," while the lower one is normal.

These range from subtle and relatively minor responses to physically visible and conspicuous pathological abnormalities. Most noticeable are effects such as fin erosion (or fin rot), ulcers, shell disease or erosion, tumors, and skeletal anomalies. Affected organisms may be less resistant to infection, or suffer impaired growth or reproduction. Some of these effects, although not immediately lethal, may eventually precipitate an organism's death.

These kinds of effects have been documented in polluted marine waters around the country. In Boston Harbor, for example, pollution has been linked to fin erosion and cancerous lesions in winter flounder, a major commercial and recreational fish (373). In San Francisco Bay, evidence links pollutants and pathological problems—including impaired reproduction—in striped bass and starry flounder. In Puget Sound, various pathological conditions, most notably liver tumors, found in English sole and other fish are correlated with exposure to pollutants. Numerous other examples have been documented, as well (for example, see refs. 307,516, 544,621).

In some instances, especially in small areas or for limited periods of time, evidence links the disposal of wastes to changes in the abundance, distribution, or diversity of some fish and shellfish. These changes most frequently result from pollution-induced changes in various closely interrelated ecological parameters such as food supplies, water quality, and habitat. For example, pulp mill effluents discharged into the Fenholloway River estuary, located along Florida's Gulf coast, have been significant contributors to the decline in the extent and productivity of the area's seagrasses and some types of algae. Because those photosynthetic organisms are of central importance in the coastal ecosystem, their decline has had major repercussions on other populations and on community structure (307).

On longer time-scales and over larger areas, however, evidence is rarely sufficient to conclusively establish cause-and-effect relationships between changes in fish populations and waste disposal activities, Nor is evidence usually adequate to detect trends. Despite this, considerable circumstantial evidence indicates that pollutants from waste disposal activities have contributed to declines of major fish populations in the United States (529,610,640,691). For example, officials in eight Southeastern States along both the Gulf and Atlantic coasts believe that widespread declines of anadromous species in those States have been caused in part by pollutant discharges (492).

Submerged Aquatic Vegetation

Waste disposal activities have had substantial impacts on submerged aquatic vegetation (SAV). This is particularly important in view of the significance of SAV in marine ecosystems; it provides vital shelter and food sources and performs other important ecological functions such as stabilizing sediments. During the past century, the general trend has been toward decreases in the extent of SAV, although some increases have occurred during the last 10 or 15 years. A major cause for the declines has been increased turbidity resulting from discharges of suspended solids and from growing populations of plankton fostered by releases of nutrients.

Examples of vegetation loss exist around the country (17). In Florida, for example, seagrass meadows have suffered significant losses; indeed, seagrasses in some areas have been virtually wiped out since 1940 and the outlook for remaining seagrass beds in Florida is bleak (221,309). Perhaps the best known example in the United States is the

Chesapeake Bay, where the SAV has declined precipitously over the last 15 to 20 years (427,640).

Benthic Organisms

Changes in sediment or water quality induced by waste disposal often affect the benthic plants and animals that live on or near the bottom (including many fish, shellfish, and plants). Benthic communities have been affected by waste disposal in every region of the country. The impacts are most severe in and near estuaries that receive high inputs of pollutants from rivers, near developed coastal areas, and near dredged material disposal areas—particularly in the estuaries and coastal areas of the Northeast.

Problems related to waste disposal arise from sediment contamination, hypoxic bottom waters, increased turbidity, and physical changes in the sediment resulting from the settling of solids (e. g., from dredged material), The effects on benthic organisms vary from relatively rapid death to subtle effects on species diversity and numbers; the effects range from long term and permanent to short term and transitory. For example, a study of the disposal of fine-grained dredged material at a site in the Chesapeake Bay found that while many organisms were buried and consequently killed, the area apparently had recovered completely within 15 months (Harrison, 1976, cited in ref. 701). Conversely, far more serious impacts have been observed in the New York Bight. Among the effects caused at least in part by waste disposal have been mass mortalities of benthic organisms, large-scale and long-term contamination, diseases and abnormalities, changes in abundance and distribution of particular species, and changes in community structure (21 2,343,546,621).

As is the case with other organisms, trends pertaining to impacts of waste disposal on benthic communities vary from place to place. Some areas have improved since the early 1970s. For example, one study of the coastal shelf of Pales Verdes, California, between 1971 and 1981 showed that reduced emissions of pollutants (e. g., suspended solids, DDT, and PCBs) resulted in a reduction in the extent of observed benthic impacts (539). On the other hand, continued deterioration is being observed in other waters; for example, this is the case in the areas where shellfish contamination is increasingly prevalent.

GEOGRAPHICAL VARIATIONS IN IMPACTS

The extent of impacts on marine resources that are caused by waste disposal activities and nonpoint sources varies considerably among different waterbodies. Limited space precludes a detailed discussion of site-specific impacts, but generalizations can be made about the physical characteristics, degree of development, and types and extent of impacts that are exhibited in different regions of the country (figure 21).

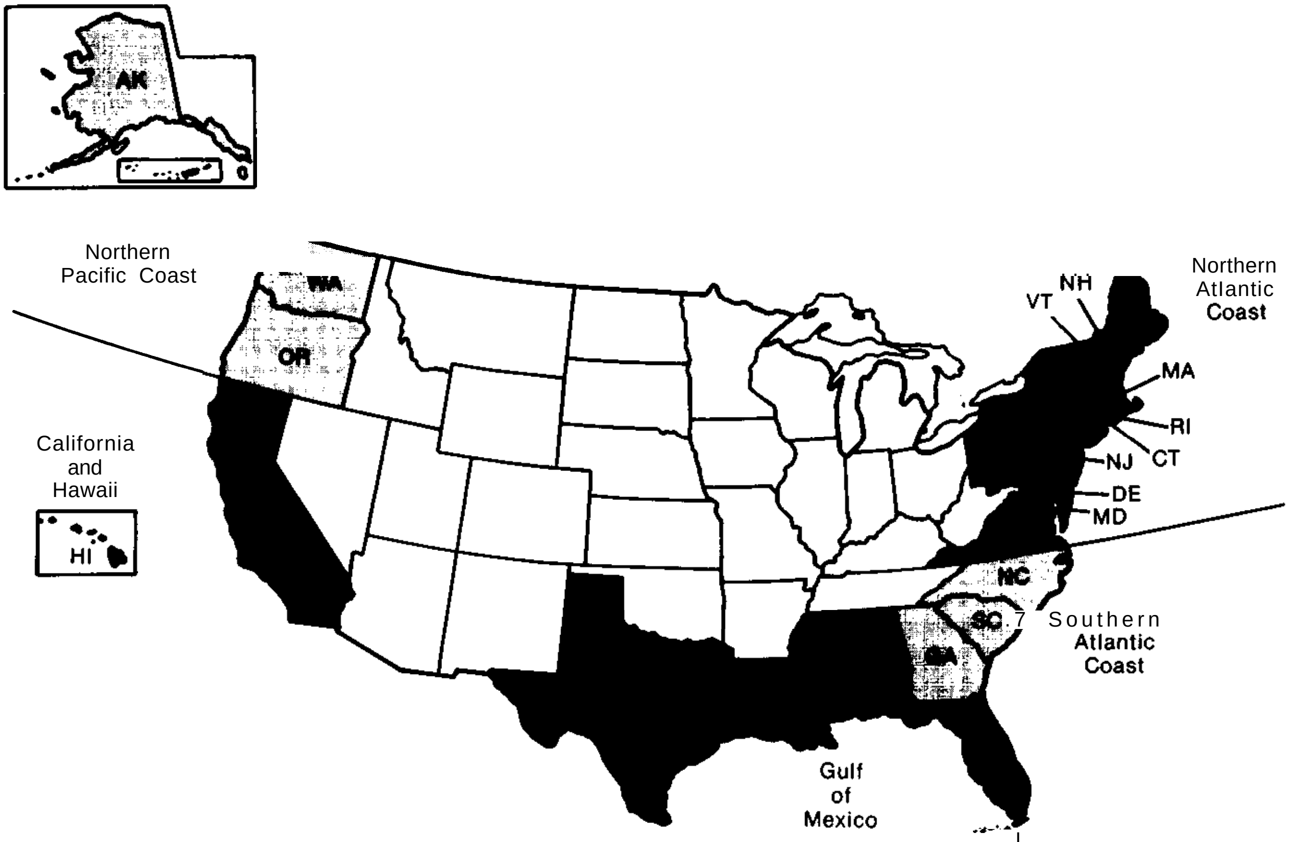
Northern Pacific Coast

The Northern Pacific region includes the marine resources off the coasts of Alaska, Washington, and Oregon. This region contains more coastline and more stretches of relatively enclosed bodies of water (e. g., estuaries, bays, and sounds) than any other region, largely because of the size and shape of Alaska's coast. Much of the region, with some notable exceptions, is relatively free of conspicuous and serious marine impacts induced by waste disposal activities.

The region does have some major industrial development, including the forest products, seafood processing, petroleum refining, and chemical industries. The municipal and industrial effluent discharged into the region's coastal waters originates primarily from two areas: coastal areas around Puget Sound and inland areas along the rivers, particularly the Columbia River. The region's most severe impacts have occurred in Puget Sound.

The impacts of pollutants have been manifold in Puget Sound (313,463,483). The most severe problems occur in urban embayments. Many commercial shellfish beds have been closed because of fecal coliform contamination. In Commencement Bay, levels of toxic pollutants are high enough to

Figure 21.—The Five Coastal Regions of the United States Used in This Report



SOURCE: Office of Technology Assessment, 1987.

make it one of the most contaminated areas in the country and a' Superfund' site. Diseases and abnormalities, most notably liver tumors, have been detected in bottom-dwelling fish. These pathological conditions and other impacts have been linked with exposure to chemicals found in sediments, the water column, and food particles (89,326,351 ,376). The health of humans who consume large amounts of contaminated fish also maybe endangered (293).

Outside of Puget Sound, waste disposal activities and pollutant inputs generally tend to be less intense and appear to cause less severe problems. Impacts are generally localized and poorly documented (425). They include contamination of shellfish with fecal coliform bacteria, decreased levels of oxygen near outfalls from mills and seafood processing plants, and effects from dumping of dredged material offshore of the Columbia River estuary.

California and Hawaii

The region that includes California and Hawaii differs from other regions in that relatively more of its coast are open, rather than enclosed in areas such as bays. In addition, its continental shelf is relatively narrow.

Relatively few impacts have been documented in Hawaii. Some problems, however, have been associated with the discharge of nutrients. These problems were alleviated during the 1970s and early 1980s as sewage treatment plants were built and upgraded, and as outfalls were extended into deeper, open waters. In Kaneohe Bay, for example, sewage discharges prior to the late 1970s had seriously degraded marine communities. In the late 1970s, the discharges were diverted to a deep-ocean outfall and conditions in the Bay improved considerably, with notable reductions in turbidity and a marked recovery in coral communities. In areas such as Pearl Harbor and Mamala Bay, however, treated sewage from dense urban populations continues to result in impacts (228,330,52 1).

Most of the urban and industrial development, and the associated waste discharges, are in California, most notably in the San Francisco Bay and along the coast of southern California. Municipal wastes from California's large and growing population are voluminous and contribute substantial quantities of many different pollutants. Industrial effluents, dominated in the coastal regions by the petroleum refining, metal finishing, and inorganic chemicals industries, also are sizable. Runoff from cities and from the State's extensive agricultural areas is also a major contributor of pollutants.

The State contains waters of widely varying quality, ranging from relatively pristine to some of the most polluted in North America (69,71 ,351). In particular, two areas are heavily affected by waste disposal activities— the San Francisco Bay and the southern California coast. Pollutant impacts also frequently occur in other localized areas.

San Francisco Bay is a large and enclosed estuary. Much of it is ringed by intense urban development, including San Francisco, Oakland, and San Jose, and industry, including major petroleum refineries. The Bay receives pollutants from these municipal and industrial sources and from the rivers that drain California's Central Valley. These pollutants, along with other factors, have significantly altered the Bay's ecosystem (395).

Some impacts have been markedly reduced since the early 1960s, largely because of the construction of waste treatment facilities. Serious problems persist, however, especially in shallow and poorly flushed portions of the Bay, because substantial volumes of pollutants continue to be discharged directly and indirectly into the Bay. Eutrophication and low concentrations of dissolved oxygen are localized problems. Large numbers of the organisms are exposed to elevated concentrations of various pollutants (e. g., pathogens, metals, PCBs, and DDT), and impacts to benthic organisms, fish, and birds continue to be documented (71 ,90,321,421, 493,529,691).

The marine waters of southern California support a wealth of marine resources that are of considerable value, including extensive commercial and recreational fisheries, numerous beaches, refuges, and sanctuaries. The great beds of giant kelp present along the open coast provide habitat for many valuable fish and shellfish and support a substantial kelp harvesting industry. Marine mammals and birds also are present and many breed in the area (24).

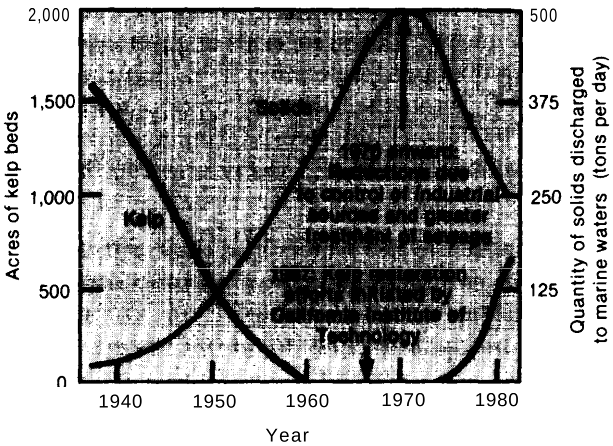
Juxtaposed to the waters and their resources is one of the continents great urban concentrations. These urban areas discharge large volumes of wastes (mostly municipal) to marine waters, which exhibit elevated concentrations of many pollutants. Fecal coliform bacteria reach high concentrations near man y ocean outfalls, but serious problems are confined primarily to an area near the Mexican border where high concentrations originating from Mexico have compelled the closure of U.S. beaches and restrictions on shellfishing (356).[8] Elevated concentrations of chlorinated hydrocarbons and metals have been detected in various organisms (1 94, 423,499).

Shellfish, finfish, birds, mammals, and aquatic vegetation have all been affected (17,126,187 ,485). Fish, for instance, suffer liver abnormalities, fin erosion disease, and reproductive problems linked to pollutants (18,52,92, 119,350,539). Kelp beds have undergone dramatic changes during the last 50 years (figure 22). In 1984, 108 km^2 of the benthic community around three of the area's major outfills was changed or degraded. Although a substantial area, this is an improvement over the 163 km^2 that were changed or degraded in 1977 (53).

One issue of particular importance is the human consumption of fish and shellfish contaminated with toxic pollutants. Although DDT concentrations in fish and shellfish have fallen since discharges of DDT were curtailed in the early 1970s (340), residues are still high in some areas and some organ-

'The problem of bacterial contain inat ion in U S waters close to the border should be greatly alleviated by a new sewage treat ment plant in Tijuana, Mexico, which began operating in January 1987 Furthermore, under an international agreement, Tijuana will divert its sewage to treatment plants in San Diego when pollutants in d ischarges from the Tijuana plant would otherwise be moved by marine cu rrents into U. S waters.

Figure 22.–Reiationship Between Size of Kelp Beds and Quantity of Solids From Municipal Discharges at a Southern California Site



These kelp beds are located near Pales Verdes, California; discharges are from the Joint Water Pollution Control Plant, operated by the Los Angeles County Sanitation Districts.

SOURCE" After J C.Meistrell and D.E. Montagne, "Waste Disposal in Southern California and Its Effects on the Rocky Subtidal Habitat, " *The Effects of Waste Disposal on Kc/p Communities*, W Bascom (cd.) (La Jolla, CA University of California Institute of Marine Resources, 1983)

isms. High concentrations of DDT and its metabolizes, as well as PCBs, have been found in fish caught by southern California fishermen and sold in the area's fish markets; in shellfish sampled as part of California's Mussel Watch monitoring program (see ch. 7); and in the blood of recreational fishermen (577).

Because of apprehension over human exposure to these pollutants, especially DDT and its metabolizes, commercial fishing has been prohibited around some outfalls. The State has established guidelines to reduce ingestion of contaminated fish and posted signs warning against consumption of fish caught in Santa Monica Bay.

Gulf of Mexico

The Gulf of Mexico, with its extremely productive habitats and wealth of sea life, is one of the most important marine environments in the United States (23). It also receives large amounts of pollutants. By far the largest volume of many pollutants is carried to the Gulf by the region's rivers, especially the Mississippi River. Many pollutants are generated from both point and nonpoint sources in areas beyond the immediate coastal area. The Mississippi River, for example, carries wastes from the heavily developed Baton Rouge and New Orleans area, and from urban and rural areas deep in the Nation's interior (607).

Although small relative to the quantities of riverborne pollutants, considerable waste is discharged from municipal and industrial sources along the coast. Large amounts of dredged material also are dumped in the region's marine waters. The major industrial discharges along the coast are associated with refineries and the petrochemical industry, especially in Louisiana and Texas. The forest products and seafood processing industries are major contributors all along the Gulf coast. Despite the overall dominance of riverborne pollutants, in many areas these local sources substantially affect the quality of the marine environment.

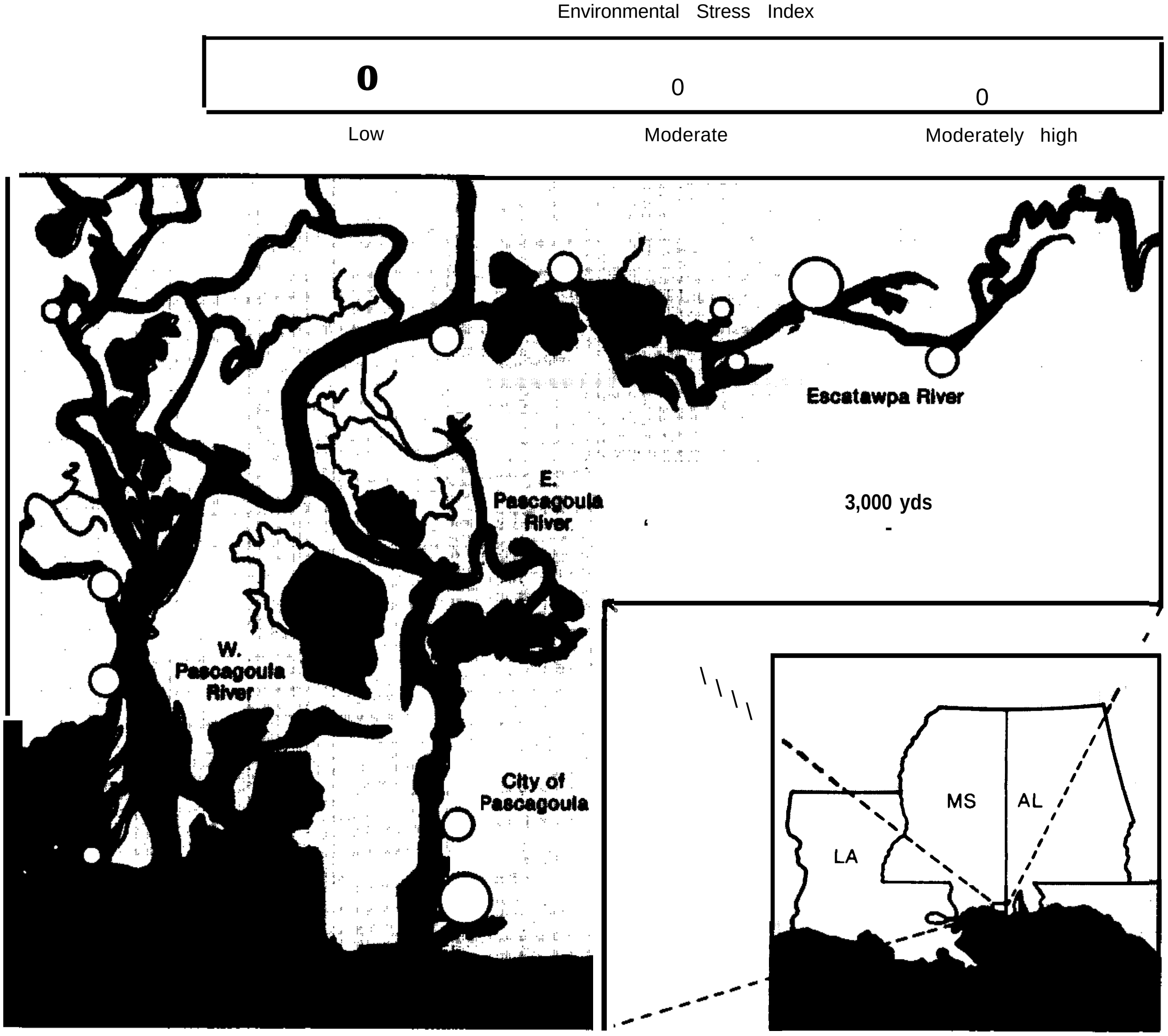
Wastes from permitted discharges have been linked to a variety of ecological impacts (2,220,221, 315,359,554). The first problem is the depression of dissolved oxygen levels and accelerated eutrophication in areas close to shore (156,181 ,454,465,466, 703). Extensive hypoxia also has been documented in the waters further offshore, south of Louisiana, but the degree to which waste disposal contributes to the phenomenon has not been ascertained.

The second major problem is the contamination of waters with human fecal coliform. This happens in virtually every coastal State in the Gulf and appears to result primarily from nonpoint sources (e. g., contaminants from septic tanks are washed into estuaries and coastal waters by runoff). However, point sources, including municipal sewage plants, also contribute to the problem in some areas.

Other problems, often less evident, result from releases of metals, chlorinated hydrocarbons, and other chemicals. The impacts usually are localized, but they can be quite serious in highly developed areas and in waters where circulation is relatively poor—for example, in the Mississippi Sound (figure 23) and in Galveston Bay. Other affected areas occur throughout the Gulf (185,268,309,333,428).

Marine resources have been harmed by these types of pollutant discharges. Many of the region's shellfish beds are contaminated with fecal coliform. Vital beds of seagrasses are declining throughout the region (309). Fish and shellfish populations have

Figure 23.—Environmental Stress in the Pascagoula Area of the Mississippi Sound



The Environmental Stress Index indicates the ecological risks associated with sediment contamination; a high value represents a higher risk of serious environmental stress. The index is a mathematical product of numerical ratings in four categories:

1. toxicity of sediments to selected organisms under laboratory conditions;
2. how readily sediment settles to the bottom after disturbance;
3. likelihood of sediment disturbance (e.g., from boat traffic or dredging); and
4. vulnerability of organisms to toxic substances (including factors such as ecological importance of indigenous species, life stages present, species diversity, mobility, and others).

SOURCE Adapted from T F Lytle and J S. Lytle, *Pollutant Transport in Mississippi Sound* (Ocean Springs, MS: Mississippi-Alabama Sea Grant Consortium, 1985) been declining in some areas (476,492), and birds have been found with elevated levels of contaminants— sometimes at levels that may impair reproduction (268).

Since the late 1960s and early 1970s, some locations along the Gulf have significantly reduced the release of nutrients and oxygen-demanding substances from municipal and industrial discharges. Reflecting this change, problems associated with low dissolved oxygen concentrations—e. g., major fish kills—have been alleviated in some instances. Likewise, point source discharges of fecal coliform and some metals and organic chemicals have been reduced in some areas (137,364).

These and other pollutants nevertheless still pose severe and sometimes worsening problems in parts of the region, largely because of rapid population growth. Some observers are concerned that these problems may become still more serious as rapid urban and industrial development proceeds (137, 308). There is also concern that dredging and impacts associated with disposal of dredged material may increase dramatically as several deep-water ports are created (314).

Southern Atlantic Coast

The Southern Atlantic region bordering the Southeastern U.S. coast has an irregular shoreline, with many bays, drowned river valleys, [g] wetlands, and islands (25). Municipal waste discharges are concentrated along the relatively small portion of the coast that is densely populated, largely in Florida. Industrial effluent in the region is dominated by the forest products industry, which is scattered along the coast. Nonpoint sources are important and are sometimes the predominant sources of pollution. They contribute significant amounts of pollutants directly to marine waters and indirectly through rivers and streams.

Waste discharges have been linked to various impacts in the region (182,220,221 ,276,399), including increased levels of nutrients and fecal coliform and reduced concentrations of dissolved oxygen (13, 534,703). The resultant hypoxic and eutrophic conditions have been associated with fish kills, depressed populations of benthic organisms, fish diseases, and the decline of commercial and recreational fisheries, including those based on anadromous fish (42,397,398,552).

Although some localized reductions in releases of fecal coliform in some instances have occurred (9), in general growing amounts of fecal coliform bacteria are being released to many of the region's coastal waters. Poor sewage treatment and increasingly serious contamination from a variety of nonpoint sources, aggravated by extremely rapid development, contribute to the problem. As a result, more restrictions on shellfishing have been instituted. In North Carolina, between 1980 and 1985, ''approved' shellfishing areas declined by 1 percent, while the ' 'prohibited' acreage increased by 4 percent (603).

In selected areas, problems associated with point source releases of nutrients and fecal coliform have been alleviated over the past 15 years as a result of Federal and State pollution control legislation. These gains have been offset to varying degrees elsewhere, however, by development that has resulted in increasing releases of these same pollutants from both point and nonpoint sources (13,552).

Elevated concentrations of metals and organic chemicals occur in the waters and sediments of some coastal areas, in particular those with substantial urban or industrial development. Both point and nonpoint sources contribute to the contamination. Where documentation exists, trends in emissions and impacts are mixed. Some areas show considerable reductions in the concentrations of metals and synthetic organic chemicals, while elsewhere increases are evident.

Pollutants may be linked to several important changes in fish populations, particularly anadromous fish populations in many of the region's river systems (492). In North Carolina over the last decade, for example, pollutants from point sources may be partly responsible for the decline of commercial fisheries relying on striped bass and herring. Generally, however, it is difficult to link specific pollutants and declines in fish populations. The relatively high incidence of ' 'ulcerative mycosis' in some fish, a disease characterized by skin ulcers, may be linked to pollutants but a clear explana-

'These are talleys that cut through coastal lands when the shore - line extended further out than it does today. These river valleys have since been ' 'drowned' by higher marine waters.

tion for the disorder has yet to be found (36, 135,396).

Northern Atlantic Coast

The Northern Atlantic coast, running from the North Carolina/Virginia border to Canada, contains many major bays, estuaries, and shallow coastal areas, and is graced with remarkably rich marine resources. It also is the location of extensive agricultural, urban, and industrial development which has occurred for several centuries. Consequently, marine ecosystems in many parts of the region are polluted and degraded, sometimes severely (62 1).

The problems in these estuaries and coastal waters (e. g., Chesapeake Bay, New York Bight, Long Island Sound, Narragansett Bay, Boston Harbor, and Buzzard's Bay) have been extensively studied (7,343 ,373,5 12,640,688). Impacts in the Chesapeake Bay, New York Bight, and Deepwater Disposal Sites are described in chapter 1, and details of impacts in other waterbodies are available from the U.S. Congress (588). This section describes the nature and extent of impacts in these waters in more general terms.

Municipal and industrial discharges, plus dumped sewage sludge and dredged material, are important sources of pollutants in this region; their quantity and composition vary from place to place. Pollutants from these waste disposal activities have been associated with various impacts. Some improvements have occurred since the late 1960s and early 1970s, but deterioration has occurred in other cases (108,335,336,347,394,480,486,597 ,609,681).

Eutrophication and hypoxia appear to be the most pervasive and serious consequences of pollution in the region. These problems occur in many estuaries and bays, and over wide, shallow areas of the continental shelf that are often quite distant from the original sources of the nutrients and organic material. Such impacts are most severe south of Connecticut. Natural changes in water quality along with inputs of nutrients and organic material from numerous sources (e. g., municipal and industrial effluents, runoff, raw sewage, dredged material, combined sewer overflows) all contribute to the problems (302,347,419,694).

Contaminated water and sediments are common throughout the region, Bacterial contamination of the water, particularly from raw sewage in combined sewer overflows, has sometimes closed beaches, in most cases temporarily but sometimes permanently (77, 199,302). Sediments in many areas contain elevated concentrations of pathogens, metals, and organic chemicals (5 12). Among the most seriously contaminated sediments are those in the James River estuary, the Patapsco River around Baltimore, the Hudson River estuary, Raritan Bay and the New York Bight, New Bedford Harbor, and Boston Harbor (57,239,640,687).

Many impacts on marine organisms have been linked, with varying degrees of certainty, to waste discharges. These include major kills of fish and benthic organisms (452), increased incidence of disease and abnormalities, declines in major fisheries, and changes in community structure (407,495,7 11, 7 13). For example, in Boston Harbor, fin erosion and cancerous lesions have been found in winter flounder, a major commercial and recreational species.

Commercial harvesting is limited in 14 percent of productive shellfish areas, mostly because the shellfish contain high concentrations of bacteria. Over one-half of the shellfish beds in Boston Harbor are closed, at an estimated annual loss of $4 million. The size of the areas in the region in which harvesting is limited has been slowly increasing over the past 5 years, although there are localized exceptions to the trend (277,603).

In addition to being contaminated with pathogens, many fish and shellfish also contain elevated concentrations of other pollutants, especially metals and hydrocarbons. As with pathogens, these concentrations have sometimes been high enough to prompt officials to restrict fishing or harvesting.

Some of the most extensive and serious instances of contamination are associated with large releases of PCBs by industrial manufacturers into the Hudson River between 1950 and 1976 and into New Bedford Harbor (in Buzzard's Bay, Massachusetts) from 1947 to 1977 (271 ,339). This has caused widespread contamination of some fish and shellfish, and diseases and abnormalities in some organisms (76, 475). Fishing and the sale of contaminated organisms is restricted over wide areas. For instance, in

New Bedford Harbor, a total of 18,000 acres were closed to lobstering.

Impacts to submerged aquatic vegetation (SAV) and birds also have been severe in some cases. The most important impact to aquatic vegetation in the region apparently results from the large-scale introduction of nutrients in coastal estuaries. This has had major repercussions on aquatic organisms of all kinds, including valuable fish and waterfowl (427)640). Some birds have exhibited elevated concentrations of pollutants as a result of ingesting contaminated organisms (162). In some cases these high concentrations led to reproductive failures and population declines—most notably, in the fish-eating osprey that once was common throughout the region (698). Since restrictions on the production and use of DDT were imposed in the early 1970s, many parts of the region have witnessed a dramatic increase in osprey populations.