Troubled Waters

Report on the Environmental Health of Casco Bay

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EXECUTIVE SUMMARY

The rich resources of Casco Bay have played a key role in the development of south central Maine. As habitat for abundant fish and shellfish, as an avenue for commerce, and as a beautiful site for recreation and relaxation, the Bay has long attracted people and a variety of human activities. Casco Bay is now the most heavily developed embayment in northern New England; the lands surrounding the Bay are home to twenty-seven percent of Maine's coastal population.

Farther south along the New England coast, in areas that have already experienced steady population growth and rapid development, coastal waters have suffered. From New Haven to Providence, from Fall River to New Bedford, from Boston to Salem, contaminants in sewage, industrial waste, and urban runoff have polluted harbors and estuaries and robbed millions of residents and visitors that use those waters of countless benefits.

Now, a growing body of scientific evidence suggests that Casco Bay is vulnerable to the same problems that plague its neighbors to the south. The waters, sediments, and living resources of the Bay are showing the signs of environmental degradation, signs that represent an early warning signal to citizens and government officials. They may be tempted to ignore the warning, since Casco Bay's woes have not become so serious as to pose an immediate threat to human health; there is <u>no</u> indication that any fish or shellfish taken from the Bay is unsafe to eat because of contaminants. But the available evidence does indicate that all is not well in Casco Bay:

<u>Bacterial Pollution</u>

- Shellfishing is prohibited or restricted in almost 15 percent of Casco Bay because of bacterial pollution.

- Expanding areas of the Bay are failing to meet even minimal water quality standards for swimming.

<u>Heavy Metals</u>

- Concentrations of heavy metals, especially lead, copper, nickel, and zinc, in the sediments of Casco Bay are well above presumed "natural" levels, and led a federal agency to conclude that it is among the nearshore bodies of water in the northeastern U.S. that can be considered contaminated.

- The concentrations of lead in mussels from Casco Bay sampled as part of a nationwide study during the 1970s were among the highest in the Northeast.

- High levels of lead, silver, and zinc in the livers of winter flounder earned Casco Bay a rating as one of the East Coast sites considered most contaminated in an ongoing federal study.

<u>Hydrocarbons</u>

- The level of polycyclic aromatic hydrocarbons (PAHs) in the sediments at a station in outer Casco Bay placed it fourth among 44 stations in a nationwide federal study of bays and estuaries. Sediment PAH levels in the Portland area are also elevated.

- Mussels from Casco Bay sampled in a national EPA-sponsored study contained hydrocarbons at levels that were among the highest found in the entire Northeast.

<u>PCBs</u>

- The sediments beneath the Bay contain significant concentrations of PCBs, especially in Portland Harbor.

Pesticides

The sediments also contain concentrations of several pesticides that are high compared to other New England coastal areas.

Casco Bay is clearly exhibiting some of the early symptoms of environmental stress, a problem that already affects other New England estuaries. And while other New England embayments are more heavily developed, many of the same pollution sources that affect coastal waters elsewhere are also present in Casco Bay:

- Casco Bay receives nearly 30 million gallons of treated sewage every day, the vast majority of it from four large dischargers in the Portland area. Untreated sewage and runoff also pour into the Bay through approximately sixty overflow pipes in Portland and South Portland.

- The Bay also receives over 23 million gallons of industrial wastewater every day, most of it from two large dischargers in the Portland area.

- Portland handles 80 percent of the petroleum products received at Maine ports; it handled about 61 million barrels in 1987. But there are no bilge cleaning facilities for the tankers that use the port each year — more than 150 in 1987.

- More than 76 tons of toxic metals, and more than 1,500 tons of petroleum hydrocarbons pour into the Bay each year. Much of this load comes from municipal treatment plants and industries in the Portland area, but a large amount also comes from urban runoff. Urban runoff accounts for about half of the petroleum hydrocarbons, 80 percent of the lead, and a significant fraction of the other metals that enter Casco Bay every year.

There is still time to turn the tide in Casco Bay. It will require serious and concerted action by state and federal authorities, and the support of citizens who enjoy and depend on the Bay for their livelihood or recreation. Among the steps that can be taken in the short term to improve the prospects for a healthy Casco Bay in the future are the following:

- Reduce or eliminate combined sewer overflows in Portland and South Portland.

- Reduce the level of fecal coliform bacteria in the discharge from the Portland Water District's treatment plant in Portland.

- Establish a Casco Bay Environmental Trust Fund, financed through penalties assessed against violators of water pollution laws, to fund studies and remedial actions around the Bay.

- Develop a joint state/EPA plan for improving water quality in the Portland/South Portland area so that it meets state water quality standards.

- Initiate region-wide comprehensive testing of fish and shellfish in the market and in the ocean, and establish federal limits for the many unregulated marine contaminants.

- Include Casco Bay in EPA's national estuary program.

- Include Casco bay in the National Oceanic and Atomospheric Administration's Mussel watch program.

- Initiate a comprehensive study of the Bay and the factors that affect environmental quality, especially human activities.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the assistance of the following reviewers, who provided helpful editorial suggestions: Philip Conkling, Richard Podolsky (Island Institute); Andrew Hamilton, Emily Bateson and Eleanor Dorsey (Conservation Law Foundation); Anne Johnson (Maine Audubon Society); and Peter Larsen (Bigelow Laboratory for Ocean Sciences).

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I. INTRODUCTION

Casco Bay is a 150-square-mile embayment in the Gulf of Maine bordered by some 180 miles of mainland shoreline and containing over 400 large and small islands. It receives freshwater input from three major rivers (the Royal, the Presumpscot, and the Stroudwater, which empties into the Fore River in Portland), whose drainage basins cover parts of five southern Maine counties. In all, Casco Bay drains a land area of 979 square miles (National Oceanic and Atmospheric Administration (NOAA), 1987b), nearly equivalent to the land area of the state of Rhode Island.

The resources of Casco Bay have played a key role in the development of south central Maine. The Bay supports an active fishery, yielding a variety of fish and abundant shellfish, including softshell clams, ocean quahogs, and even European oysters (K.M. Lyons, Maine Department of Marine Resources, personal communication). Portland Harbor is the largest port in Maine, and, as home to the commercially important Portland Fish Exchange, the largest fishing port on the Atlantic coast north of Gloucester, Massachusetts (New England River Basins Commission (NERBC), 1981). The diverse natural attributes of Casco Bay have long attracted people and human activity, and the area surrounding the Bay is now called home by twenty-seven percent of Maine's coastal population. The Portland waterfront, long ignored by government and citizens as it fell into disuse and decay, is now in the midst of a renaissance, with hundreds of millions of dollars in public and private funds spawning a wealth of new commercial and residential development.

Land use in the area drained by Casco Bay has shifted dramatically in the last century, and even in the last thirty years. Since the mid-nineteenth century, as natural resource-based activities such as agriculture and lumbering declined in importance in favor of manufacturing and, in recent years, services, land use patterns also changed (NERBC, 1981). While most of Casco Bay's drainage area is still forested (see Table 1-1), land use changes in the Greater Portland area have been significant. The industrial growth of the late nineteenth and early twentieth centuries was concentrated in the urban centers of Portland, South Portland, and Westbrook, and the postwar process of suburbanization expanded the urban-suburban area around the cities from five towns in 1950 to thirteen towns in 1975 (NERBC, 1981). Today, Casco Bay is the most heavily developed embayment on the northern New England coast.

Despite the historic importance of Casco Bay to the economy and life of the region, and increasing pressures on the Bay from population growth and changes in the scale and nature of human activities, until 1980 there had been virtually no systematic study of the Bay's physical and biological properties. Sadly, this is typical for coastal embayments, which have received little attention from the scientific community compared with offshore marine environments. Peter Larsen and several co-workers (Larsen et al., 1983c) performed the first intensive study of the Bay's environment in 1980, to provide an "environmental benchmark" against which one could measure natural changes and the effects of human activities. Their findings provide a glimpse of the richness and productivity of Casco Bay.

Larsen and his co-workers found over 260 different species of benthic (bottom-dwelling) animals living in the sediments beneath the waters of the Bay, and described the Bay's fauna as "rich in terms of diversity, density and biomass." Indeed, when compared with other inshore marine environments, Casco Bay turns out to be truly exceptional in the density of benthic organisms that it supports (see Table 1-2). The high density and biomass of the Bay's benthic fauna indicates a high level of biological productivity, according to the researchers.

The biological richness of Casco Bay, its traditional and intense use for fishing and recreation, and the growing population and industrialization of the land that it borders and drains set up a situation that is increasingly common in urbanized harbors and estuaries around the country, especially in the densely populated Northeast — the possibility that the fragile coastal marine ecosystem, long taken for granted as a source of food and recreation, has been and is being degraded by the products and waste of the people that benefit from its resources. Perhaps the residents of the towns and cities that surround Casco Bay and of its numerous island communities — as well as tourists and vacationers that visit them — are used to thinking of Casco Bay, and of Maine's coastal waters in general, as different from coastal waters elsewhere in New England, as insulated from the pollution problems that plague urban harbors from New Haven to Providence, from Fall River to New Bedford, from Boston to Salem. This report looks at the available information on the quality of Casco Bay's environment — its waters, its sediments, the living organisms that inhabit it — to develop a picture of the "health" of Casco Bay, and to see how it compares with other harbors and estuaries, both those recognized as highly polluted and those considered unpolluted or pristine. It then considers the magnitude and sources of some of the pollutants that find their way to Casco Bay. Finally, the report suggests some steps that should be taken to protect the Bay and ensure that it remains a productive resource for the future.

Table 1-1

Land Use in the Casco Bay Drainage Area

Land Use	Area (sq. mi.)	Percent
Urban/Built Up	140	14
Agriculture	102	10
Forest	710	73
Wetland	19	2
Other	8	1
TOTAL	**979**	**100**

Source: NOAA (1987b)

Table 1-2

Mean Density of Invertebrates in Unconsolidated Sediments of Temperate and Boreal Inshore Waters

(from Larsen et al. (1983c); modified from Maurer et al. (1978)

Location	Mean Density (organisms/sq. meter)	Source
Casco Bay	8,743	Larsen et al. (1983c)
Sheepscot Estuary, Maine		
Gradient Study	4,928	Larsen & Doggett (1978)
Shallow Water Study	711	Larsen (1979)
Mystic River, Massachusetts	3,000	Rowe et al. (1972)
Moriches Bay, New York	1,300	O'Connor (1972)
Delaware Bay	722	Maurer et al. (1978)
False Bay, South Africa	2,200	Field (1971)
Gullmars Fjord, Sweden	4,198	Rosenberg (1973)
Lambert Bay, South Africa	1,153	Christie (1976)

II. WATER QUALITY

The simplest indicator of the "health" of any water body is the water itself. The quality of the water in Casco Bay or any water body both reflects the impacts of human activities on it and determines how it can be used by the people who depend on it for various purposes. While water quality does not tell the whole story about Casco Bay, it is the one aspect of the Bay's environmental quality that falls under specific, numerical standards and serves as a useful starting point for our review.

The water quality standards that the Maine legislature has established for its estuarine and marine waters are set out in Table 2-1. Figure 2-1 shows the parts of Casco Bay that fall under each of the water quality classifications.

The water quality standards listed in Table 2-1 fall into two categories: qualitative standards, such as the designated uses, and quantitative standards, such as the standards for dissolved oxygen levels and for concentrations of enterococci bacteria. The qualitative standards concerning shellfish harvesting (e.g., designated uses for shellfish harvesting and propagation; bacteria standards that prohibit levels that would cause closure of shellfish areas or prevent propagation) are in fact quantitative, since they are backed up by numerical standards developed by the National Shellfish Sanitation Program within the U.S. Food and Drug Administration. The relevant standards from the National Shellfish Sanitation Program's Manual of Operations, which is referenced in the Maine water quality standards, are shown in Table 2-2.

A. Bacterial Pollution: Shellfishing

The Maine Departments of Environmental Protection and of Marine Resources do not monitor the waters of Casco Bay on a regular basis for dissolved oxygen levels (a relatively simple technical task), or for detrimental changes to estuarine and marine life and the maintenance of community structure and function (an enormously complicated and time-consuming scientific endeavor). The Department of Marine Resources does, however, test on a fairly routine basis for bacterial pollution. Data about bacterial levels in the water are crucial to determining whether given waters of the Bay may be used for specific purposes. Because of the importance of this information to users of the Bay (i.e., shellfishermen and swimmers) and its economic and health-related implications, bacterial levels are perhaps the most important and certainly the most abundant single type of information about water quality in Casco Bay.

Because bacterial levels are tied so closely to the suitability of different portions of the Bay for various uses, it is most revealing to examine how the state Department of Marine Resources (DMR) has classified the waters of the Bay with respect to their suitability for shellfish harvesting, as opposed to examining the information on bacterial levels directly. Although the Department of Marine Resources keeps no figures on the acreages of the waters within Casco Bay where shellfishing is restricted or completely prohibited, DMR maps of open and closed shellfish areas graphically summarize the available information on bacterial pollution and show the extent and seriousness of the problem in Casco Bay.

Figure 2-2 shows those portions of the Bay where shellfishing restrictions are in effect. Since all estuarine and marine waters in the state are, according to the state water quality classifications summarized in Table 2-1, supposed to be suitable for shellfish harvesting (either direct harvesting, for Class SA and Class SB waters, or harvesting with depuration or cleansing, for Class SC waters), all SA and SB waters that are not approved for direct harvesting of shellfish, and all SC waters that are not approved for direct or restricted harvesting of shellfish, fail to meet state water quality standards. Comparison of Figures 2-1 and 2-2 shows the extent of this longstanding and persistent violation of state law.

The National Oceanic and Atmospheric Administration (NOAA) has collected data on shellfish growing water classifications for 92 estuaries around the country, including Casco Bay. NOAA's information for Casco Bay is presented in Table 2-3. It shows in tabular form what Figure 2-1 showed graphically: shellfishing is prohibited or restricted because of pollution in approximately 15 percent of the waters of Casco Bay.[1]

[1]*Moreover, Table 2-3 understates the relative magnitude of the problem in Casco Bay, probably to a large degree. The total acreage in Table 2-3 is 107,400 acres, or 168 square miles. This total encompasses all of Casco Bay as it is defined in NOAA's National Estuarine Inventory, including waters that lie outside of*

(Continued on page 4)

If better information existed about which areas in Casco Bay are productive shellfish growing waters, and about the resource levels for various shellfish species, especially in those areas where harvesting is prohibited or restricted, it would be possible to compute the economic impacts of the harvesting restrictions on the local and regional economies. No such study has ever been done for the waters of Casco Bay. Studies of the economic impacts of sewage-related restrictions on the harvesting of softshell clams on the North Shore of Massachusetts (Resources for Cape Ann, 1982) and on the harvesting of hardshell clams or quahogs in the Outer Harbor and Clarks Cove in New Bedford, Massachusetts (Conservation Law Foundation of New England, 1988) show that the economic losses attributable to such closures can reach several million dollars per year in direct losses in landed value and income to the local economy, and tens of millions of dollars per year in overall economic activity.[2]

B. Bacterial Pollution: Swimming

Bacterial levels also determine whether waters are suitable for swimming. The Maine Department of Marine Resources' bacteriological surveys, in addition to supporting the management decisions of the department concerning shellfish harvesting classifications, tell health authorities whether swimming should be allowed in given areas. Because bacterial standards for swimming waters are less restrictive than the standards for shellfish harvesting areas, swimming area closures reflect much more serious pollution problems.

According to the Maine Department of Environmental Protection (1988), only 10 square miles, or less than one percent, of Maine's estuaries, bays, and nearshore waters were closed to swimming because of water quality problems as of 1988, based on the state's latest comprehensive water quality assessment. However, much of that closed area was in Casco Bay. The department (T. McGovern, personal communication) also reports that bacteriological surveys in the Fore River and the Presumpscot estuary have shown high bacterial levels in the past, and that if surveys this year continue to show high levels, it will move for expanded swimming area closures in these areas. Thus, expanding areas of Casco Bay are failing to meet even minimal water quality standards.

C. Holding the Line:
Great Diamond Island and the Threat of Further Degradation

The failure of large portions of inner Casco Bay to meet state water quality standards sends a strong signal that the inner Bay's ability to handle the pollution load it already receives from the Portland urban area has already been exceeded, and that before any additional pollutant discharges into these waters are allowed, some reductions in the existing flows must be achieved.

The issue of further degradation of the inner Bay's water quality is at the center of the con-

Casco Bay proper. (See, e.g., the maps published by NOAA and the U.S. Food and Drug Administration (1985).) It also exceeds the area for Casco Bay cited by Larsen et al. (1983c) in their landmark study of the Bay.

The total of 107,400 acres, and the percentages in Table 2-3 (which are based on that total), also assume that all of the waters of Casco Bay are actually or potentially productive shellfish growing areas. This may not be the case. Almost assuredly, certain portions of the Bay are not productive shellfish growing areas, or, for reasons not relating to pollution, are otherwise not suitable for shellfish growing or harvesting. Indeed, the state's 1988 water quality assessment report to the U.S. Environmental Protection Agency (Maine Department of Environmental Protection, 1988) noted that, for the shellfish species of the greatest commercial value in Maine, the softshell clam (Mya arenaria), there are just 71 square miles of intertidal mud flats along the entire Maine coastline that are productive enough to allow commercial harvesting. In 1988, 19 square miles of these flats (27 percent), including Portland Harbor, were closed to harvesting due to discharges of untreated or inadequately treated wastewater.

[2]*Resources for Cape Ann (1982) analyzed the effects of the closure of 115 acres of clam flats, and calculated annual losses of $674,100 in direct income to clammers, dealers, processors and restaurants, and nearly $1.9 million in total economic activity. The Conservation Law Foundation of New England (1988) found much larger losses (although smaller on a per-acre basis) for the 6,709 acres in New Bedford closed to shellfishing because of sewage pollution, and not because of the more widely known problem of contamination with PCBs (polychlorinated biphenyls). The annual losses for New Bedford were $4.8 million in landed value, $5.7 million in direct income, and $21.9 million in total economic activity.*

troversy surrounding a Casco Bay development proposed by Diamond Cove Associates (DCA), a Portland firm that proposed a residential and commercial development on Great Diamond Island, consisting of 134 condominium units and a commercial complex in a rehabilitated Fort McKinley, and 70 single-family homes. The developer plans to construct a facility to treat wastewater from the new community at a common sand-filter treatment facility and discharge the effluent — some 50,000 gallons per day — through a pipe on the western shore of the island into inner Casco Bay. DCA received a waste discharge license for the first phase of its proposed development from the Maine Department of Environmental Protection in 1986, and applied in 1987 for an amendment of its license for the second phase. At the same time, DCA had applied to the U.S. Environmental Protection Agency (EPA) for a federal discharge permit.

DCA has run into heavy opposition to its proposal all through the state permitting process, especially from the Island Institute and Maine Audubon Society. These groups have fought the project on a host of environmental grounds, ranging from failure to comply with zoning restrictions to unacceptable impacts on historic resources at Fort McKinley. DCA's proposed "amendment" of its discharge drew heavy fire from both groups because of the Maine legislature's decision in the spring of 1987 to ban all further "overboard discharges," including those of the type proposed by DCA.

The developer's journey through the federal permit process was further complicated by language in the Clean Water Act about new discharges into waters that are already failing to meet state water quality standards. The Conservation Law Foundation and the Island Institute cited this protective language to argue, from a legal standpoint, what common sense already told them: before allowing any new discharges into the waters of inner Casco Bay, federal and state authorities must crack down on existing pollutant discharges.

According to the Clean Water Act, before any new discharge could be allowed, Maine would have to study the assimilative capacity of inner Casco Bay, determine that there was sufficient capacity left to allow the new discharge, and place existing dischargers — such as the Portland Water District — under compliance schedules that would bring inner Casco Bay into compliance with the state's SB water quality standards.

As this report was being completed, EPA's regional office in Boston had not yet made a final decision on DCA's federal permit application. Its close scrutiny of the application had already set a precedent of a sort, though. Historically, EPA has granted permits virtually automatically to applicants who had already received approval from Maine authorities. For the DCA application, EPA is, for the first time, subjecting a permit application to a careful, independent review.

EPA's decision about whether and with what conditions to issue the permit, and the likely appeal of that decision to a federal administrative judge by one side or another in the controversy, will help to shape the debate about water quality and development in inner Casco Bay for years to come. In any event, the controversy itself shows just how serious water quality problems in Casco Bay have become, and has focused attention on the crying need for state and federal regulators to address those problems speedily and aggressively. See Table 2-1, next page.

Table 2-1

Water Quality Standards for Estuarine and Marine Waters in the State of Maine

Parameter	Standards: Class SA	Class SB	Class SC
Designated Uses:			
recreation	x	x	x
fishing	x	x	x
aquaculture	x	x	x
shellfish propagation/ harvesting	x	x	(restricted)
navigation	x	x	x
fish habitat	x	x	x
process/cooling water		x	x
hydropower		x	x
Dissolved Oxygen	as naturally occurs	85% of saturation	70% of saturation
Bacteria:			
General	as naturally occurs	no levels which would cause closure of shellfish areas	no levels which would prevent shellfish propagation
Enterococci (#/100 ml) (swimming areas)	as naturally occurs	8 (5/15 - 9/30)	14 (5/15-9/30)
Direct Discharges/ Biotic Standards	direct discharges prohibited; biota as naturally occurs	no detrimental change; no new shellfish closures	maintain structure/ function of community

Source: 38 M.R.S.A. § 465-B

Table 2-2
Bacterial Standards for Shellfish Growing Waters
(# per 100 milliliters)

Parameter	Standard: Approved Areas (SA and SB)	Standard: Restricted Areas (SC)
Total Coliforms		
mean	70	700
highest 10% of samples	230	2300
Fecal Coliforms		
mean	14	88
highest 10% of samples	43	260

Source: National Shellfish Sanitation Program (U.S. Food and Drug Administration, 1986)

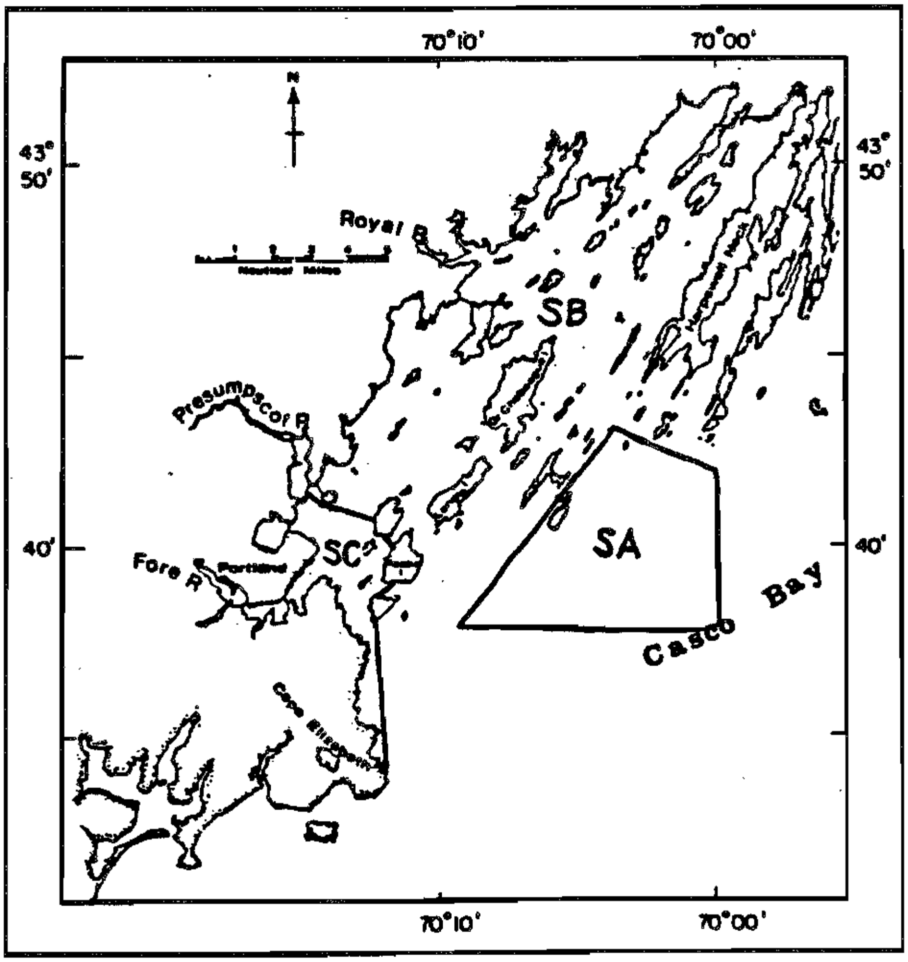
Table 2-3
Classification of Shellfish Growing Waters in Casco Bay
(1985)

Classification	Acres	Percent
Approved	91,900	85.6
Harvest Limited Areas:		
Prohibited	12,300	11.5
Conditionally Approved	2,300	2.1
Restricted	1,000	0.9
SUB-TOTAL (Harvest Limited)	**15,600**	**14.5**
TOTAL	**107,400**	**100.0**

Source: Broutman and Leonard (1986)

Figure 2-1

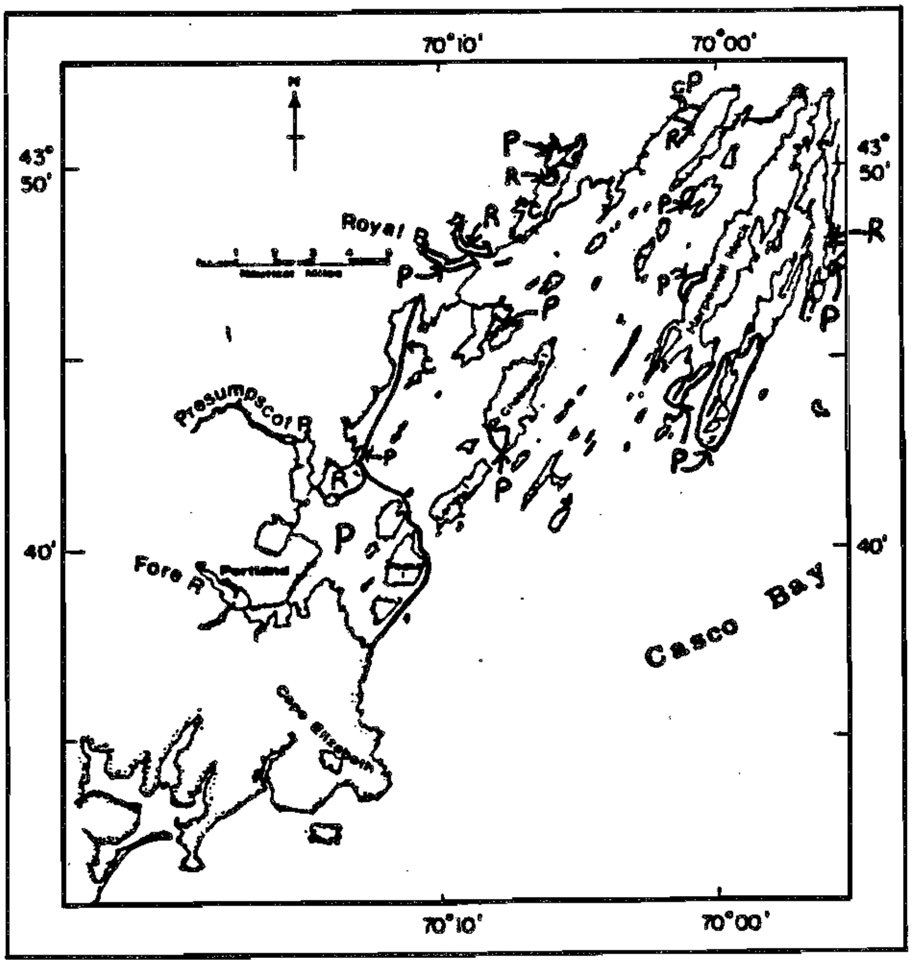
Water Quality Classifications in Casco Bay



Source: 38 M.R.S.A. § 469

Figure 2-2

Shellfish Harvesting Restrictions in Casco Bay



P = prohibited (no harvesting permitted)
R = restricted (harvest must undergo depuration)
C = conditionally approved (e.g., seasonal closures)

Source: Maine Department of Marine Resources (1987)

III. SEDIMENTS

Beneath the waters of Casco Bay lies an equally important component of the Bay's physical environment — the sediments. Besides providing a home for the benthic (bottom-dwelling) invertebrate organisms that occupy a crucial place in the Bay's food web, and habitat for demersal fish (those that live on or near the bottom), the sediments act as a "sink" for many of the pollutants that enter the waters above from the lands and rivers that surround the Bay.

Whereas the previous chapter focussed on bacterial pollution and its effects on water quality and use, this chapter will concentrate on toxic pollutants — organic pollutants, such as hydrocarbons and PCBs, and heavy metals, such as nickel and zinc — and their levels in bottom sediments. As Figure 3-1 shows, deposition in the sediments is just one of several possible environmental fates of a pollutant discharged into a coastal water body. Because of the tendency of many toxic pollutants to accumulate in the sediments (as opposed to remaining in the water), information about the levels of toxic pollutants in the sediments is a useful indicator of the toxic pollution of the Bay.

Moreover, once pollutants have become associated with bottom sediments, they continue to have the potential to affect water quality and marine organisms. Swift currents or storms can resuspend bottom sediments, allowing sediment-bound pollutants to reenter the water. In addition, organisms that spend their lives in or on the sediments, such as winter flounder, are exposed to the contaminated sediments, and can thus accumulate the same pollutants in their bodies. Bottom-feeding fish can also accumulate contaminants from food organisms that live in or on the sediments and concentrate the contaminants in their own tissues. Exposure to and resulting accumulation in fish of toxic pollutants from sediments and food organisms are known or suspected to cause changes in normal behavior, disruption of biochemical processes, and increases in the prevalence of diseases, such as fin rot and cancerous lesions in the liver (Olsen, 1984; Susani, 1986; Zdanowicz et al., 1986)(see Figure 3-2).

Ultimately, the harmful effects of contaminants on individual organisms can have devastating effects on entire populations, biological communities, and ecosystems. By altering behavior, reducing growth rates, and interfering with normal reproduction, chemical contaminants can cause decreases in populations of sensitive organisms; at the same time, species that are more tolerant of contaminants might increase in numbers as food and other resources become more available. The overall diversity of the community may decrease, as relatively few tolerant species come to dominate the ecosystem.

Such shifts in the relative abundances of even a few different species can affect the many other species populations that make up the local biological community and that interact in many ways: as competitors for scarce resources, as predators and prey, even as "partners" in symbiotic arrangements. By altering these species interactions, subtle changes in individual populations can have a ripple effect that disrupts the balance of the entire community.

As part of the biological community, people that harvest the resources of a given ecosystem can also be affected by these changes. Populations of commercially or recreationally important fish and shellfish may be among those that decrease, either as a direct response to contamination or as a result of the resulting community disruption. In addition, if levels of contamination in harvested species reach high enough levels, it may be necessary to restrict or prohibit the harvesting of those species to protect human health. (There is no indication that any fish or shellfish taken from Casco Bay is unsafe to eat due to contaminant levels.)

A. Organic Pollutants

Organic pollutants consist of an enormous variety of compounds, including aromatic hydrocarbons, polychlorinated biphenyls, pesticides, and other artificial and natural compounds. Among the natural organic compounds that are considered pollutants is coprastanol, a bacteria-produced compound associated with sewage.

1. Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) are carbon-based chemicals that contain more than one six-carbon ring (see Figure 3-3). Although some PAHs occur naturally, most PAHs in coastal environments can be traced to incomplete combustion and unburned fossil fuels (NOAA, 1987d). They reach coastal waters through surface runoff, pipeline discharges, and atmospheric deposition. PAHs form a subset of petroleum hydrocarbons, which include a wide variety of non-cyclic compounds.[1]

PAHs have been associated with a variety of deleterious effects on marine life, including acute toxicity, genetic mutations, and increased incidence of fish cancers.

Figures 3-4 and 3-5 show PAH levels in Casco Bay in relation to other coastal areas. (There are two separate figures, one for dry weight measurements and the other for wet weight measurements, because some studies report only one or the other, and most do not provide wet weight to dry weight conversion factors.) The figures show clearly that the sediments in Casco Bay contain high levels of PAHs when compared with other coastal waters. It ranked fourth among the forty-four sites in NOAA's nationwide study (NOAA, 1987d), and was one of only seven sites where PAH concentrations exceeded 4,000 parts per billion (ppb) dry weight. All but two of the remaining sites had PAH levels less than 2,000 ppb; levels at twenty-nine of the forty-four sites were less than 1,000 ppb.

It is interesting to note that the results from NOAA's Status & Trends program are from sediment samples taken in outer Casco Bay (see Figure 3-6). Larsen et al. (1983b), on the other hand, sampled a total of thirty stations throughout the Bay (Figure 3-7). Their study found a "strong geographic element" to PAH distributions in the sediments of the Bay, with PAH concentrations at stations in the upper and middle sections of the Bay typically at 900 ppb wet weight or less, concentrations in the lower Bay between 1,000 and 1,500 ppb, and concentrations of 2,000 ppb or greater limited to stations in the Portland area (see Figure 3-7). The highest concentration reported by Larsen et al. (1983b), 14,425 ppb for a station off South Portland (Station 50, Figure 3-7), was the highest concentration reported for any of the nine sites in NOAA's Northeast Monitoring Program report for 1982 (NOAA, 1985).

The relatively high levels of PAHs that they found in Casco Bay were not surprising to Larsen and his co-workers, since many of the known sources of PAHs mentioned above are present in the Casco Bay region. What did surprise them, however, was the very strong gradient in PAH levels, with the "marked concentration of highly contaminated stations in the Portland area." Such a pattern, they reasoned, is "strongly suggestive of localized, anthropogenic inputs."[2]

2. PCBs

PCBs, or polychlorinated biphenyls, are a family of hydrocarbon compounds in which chlorine atoms occupy various positions on molecular structures called biphenyl rings (Figure 3-8). With different numbers of chlorine atoms present, in different positions, 209 different PCB compounds are theoretically possible. Not all of these possible compounds, however, are formed during the PCB manufacturing process (NOAA, 1987d).

PCBs have been used primarily as insulating and cooling fluids in electrical equipment since the early 1970s; before then, they had a variety of uses as lubricants, flame retardants, and plasticizers. However, as growing evidence pointed to the ecological and human health hazards of PCBs, their manufacture was banned in the U.S. in 1979. They are still manufactured in other countries, however, and many electrical transformers and capacitors containing PCBs are still in use here (NOAA, 1987d).

Like DDT, PCBs are both lipid-soluble and persistent in the environment, and tend to bioaccumulate (accumulate in the tissues of living organisms to concentrations higher than those found in the surrounding water) and biomagnify (accumulate to successively higher concentrations at higher levels in the food chain). They have been shown to have toxic effects on birds, mammals, and aquatic organisms. Among the observed effects of PCBs are reproductive failure, birth defects, tumors, liver disorders, skin lesions, and suppression of the immune system. Marine fish and shellfish exposed to PCB concentrations of less than one to a few parts per billion for several months exhibit histopathological effects (abnormal tissues). Marine fish appear particularly susceptible to liver damage from PCBs (NOAA, 1987d).

PCB levels in Casco Bay sediments are shown in Figure 3-9, along with results from other areas in New England. Of all the New England locations listed in Figure 3-9, Portland Harbor ranks behind only Salem Harbor, Bos-

[1]*Although PAHs comprise only a small fraction (4 to 9 percent) of all petroleum hydrocarbons, estimates of the major inputs of petroleum hydrocarbons into the marine environment (National Research Council, 1985) indicate the potential relative importance of urban and industrial activities for PAH pollution in coastal waters. The council estimated that approximately 47 percent of the petroleum hydrocarbon input to marine waters came from petroleum transportation activities.*

[2]*A similar gradient in sediment PAH levels was found in Penobscot Bay by Johnson et al (1985). The results are also discussed by Pearce and Johnson (1986), and received newspaper coverage. (Crowley, 1986).*

ton Harbor, and Buzzards Bay (where sediments are almost certainly affected by the notorious PCB contamination problems in New Bedford Harbor) in sediment PCB levels. Sediments at a "control" station in lower Casco Bay (Station 29 in Figure 3-10) and at NOAA's Status & Trends sampling location (Figure 3-6) contained lower concentrations of PCBs. Even the "lower" concentration found in outer Casco Bay by NOAA placed it eleventh among the forty-four sites around the country included in that study.

The results presented in Figure 3-9 for Portland Harbor and lower Casco Bay, which were reported by Larsen et al. (1984), stand in sharp contrast to results reported by many of the same researchers just one year before. In the earlier study, Larsen et al. (1983a) did not report any detectable levels of PCBs in the sediments at any of 32 stations sampled in 1980. They found "trace amounts" of PCBs in subsequent monitoring of several stations in Portland Harbor in early 1981, and concluded that "PCBs can be dismissed as a significant contaminant of Casco Bay sediments." Wisely, though, they continued monitoring throughout 1981, 1982, and 1983, and found the substantial PCB levels shown in Figure 3-9. The messages to those concerned about the health of Casco Bay are clear: one-time, "spot" monitoring does not always tell the whole story; and (2) the situation in Casco Bay is not very different from the situation in the other threatened estuaries of the Northeast.

3. Pesticides

The nation's grim experience with DDT in the 1960s and 1970s taught us an important lesson about organic pesticides, and about chlorinated pesticides in particular — they don't quickly go away. As they are washed down the rivers from inland areas, disposed of in sewer systems, or simply dumped into the rivers or the sea, these persistent chemicals often find their resting place in the sediments of nearshore waters.

Figure 3-11 presents some results of the NOAA Status & Trends Program's sampling of New England coastal waters in 1984. Casco Bay's sediments contained the highest levels of heptachlor and aldrin among the six New England sites surveyed, and the third highest levels of chlordane and hexachlorobenzene. The results for pesticides, like the results for hydrocarbons and PCBs, indicate that Casco Bay is vulnerable to the same pollution woes plaguing the rest of coastal New England.

B. Heavy Metals

Unlike many organic pollutants, heavy metals, such as nickel, cadmium, and zinc, occur in nature, both in ore deposits and in seawater. They enter coastal waters through the natural geological processes of erosion and runoff. However, many heavy metals are also common constituents of municipal and industrial wastewater, and also enter coastal environments via urban runoff, vessel-related activities, and ocean dumping (NOAA, 1987d).

While many metals are essential nutrients for certain organisms, metals in excessive amounts can exert toxic effects on living resources. While some organisms can regulate the levels of metals in their bodies to a great extent, many benthic organisms that live in sediments with high metal concentrations often accumulate the metals in their tissues, with potential adverse effects on the individual organism and the population.

Two major studies have examined metal concentrations in the sediments of Casco Bay and compared the observed concentrations with those found in the sediments of other New England coastal environments. Peter Larsen and colleagues from the Bigelow Laboratory for Ocean Sciences in West Boothbay Harbor, as part of the "environmental benchmark" study mentioned in Chapter 1, sampled 32 stations around the Bay for metal concentrations (Larsen et al., 1983d). In 1984, NOAA began its Status & Trends Program, which included sampling and analysis of sediments from coastal areas around the country. The results of the first year of sampling were reported in 1987 (NOAA, 1987d, 1987e).

Table 3-1 presents the results reported by Larsen et al. (1983d) for Casco Bay and for several other New England coastal areas that they used for comparison. (The Casco Bay sampling stations were the same as those shown in Figure 3-7 for PAHs.) Of the sites used for comparison, four were considered "unaffected" by human inputs of pollutants: Machias Bay, Penobscot Bay, the Seabrook River estuary, and the non-industrialized Mystic River estuary in Connecticut. The other five sites were considered to have been affected by human inputs: the Saco and Kennebec River estuaries in Maine, the Great Bay estuary in New Hampshire, Branford Harbor in Connecticut, and the eastern half of the "highly urbanized" Long Island Sound.

Larsen and his co-authors summarized their results for the different metals as follows (emphasis added). (We also add comments regarding the average for their Portland Harbor sites.)

Lead: "The mean value of lead in Casco Bay sediments is higher than that of the four non-industrialized estuaries, but generally lower than the other industrialized estuaries." Portland Harbor values, though, are higher than those for all but one of the affected areas.

Copper: "Copper levels in Casco Bay are also elevated relative to the non-industrialized estuaries and are comparable to the other impacted sites with the exceptions of the Kennebec River estuary, Maine and Branford Harbor, Connecticut." Portland Harbor levels, however, are nearly as high as those found in Branford Harbor, the most heavily impacted site considered.

Zinc: "Mean zinc concentration . . . is only exceeded by that reported for Jeffreys Basin [an offshore depositional area]." The Casco Bay average exceeded that of all affected areas, and the Portland Harbor average was more than one-third higher than the overall Casco Bay average.

Nickel: "Long Island Sound is the only other site from which nickel data are available and the mean value is much lower than that of Casco Bay." Again, Portland Harbor values are still higher.

Chromium: "Casco Bay sediments appear to be only moderately enriched in terms of chromium. The mean concentration is nearly twice that of the pre-industrial levels of northern New England, but an order of magnitude lower than the Saco and Great Bay estuaries, both of which are highly enriched with chromium due to tannery operations [citations omitted]." Portland Harbor levels are only slightly higher than the Casco Bay average.

Cadmium: "Cadmium levels in Casco Bay compare favorably with the three other sites having reported values. The mean value is close to that of the unaffected Mystic River estuary and considerably lower than the values reported for Branford Harbor and eastern Long Island Sound." Values for Portland Harbor, however, are much higher than the overall average for Casco Bay, although still below the values for Long Island Sound and Branford.

In conclusion, Larsen and his colleagues wrote (emphasis added),

"Comparison with other New England sites indicate, with the exception of cadmium, that trace metal concentrations in Casco Bay are elevated well above presumed pre-industrial levels. Mean values of each of the other metals examined are comparable to levels reported from other industrialized New England areas.

"Realizing that trace metal concentrations from stations in the Portland area are generally much higher than the mean, and that the mean is reduced by low concentrations elsewhere in the Bay, it is concluded that surficial sediments in Portland Harbor and the lower Fore River estuary are affected by trace metals."

The study of Larsen and others was supported by NOAA as part of its Northeast Monitoring Program (NEMP), a five-year project whose pollution assessment functions were eventually replaced by the Status & Trends Program. Annual NEMP reports prepared by NOAA further serve to put the findings of Larsen et al. in perspective. The nickel concentrations for Portland Harbor were the highest reported in the NEMP reports for 1980 and 1981 (NOAA, 1981, 1983), and comparable to peak values from the highly polluted New York Bight (NOAA, 1985). The copper levels for Casco Bay and Portland Harbor were among the few reported levels in excess of 10 parts per million (ppm) in the report for 1981; most values were below 5 ppm (NOAA, 1983). The zinc levels from Portland Harbor were among the highest reported in 1981, exceeded only by the peaks from the New York Bight (NOAA, 1983). Overall, NOAA found that, along with Massachusetts Bay, Buzzards Bay (Massachusetts), Narragansett Bay, and Raritan Bay (New Jersey), Casco Bay was among the "nearshore bodies of water [in the northeastern U.S.] that can . . . be considered contaminated." (NOAA, 1983)

NOAA's Status & Trends Program provides the other main data set that allows comparison of metal levels in Casco Bay sediments with those from other U.S. coastal areas. Recall that the sampling station for Casco Bay in the Status & Trends Program was in outer Casco Bay (see Figure 3-6). Figures 3-12 through 3-17 present the results for Casco Bay and New England coastal areas farther south from the first two years of Status & Trends for the same six metals considered by Larsen et al. Because there are more areas for comparison, including several extremely contaminated areas such as Boston and Salem (Massachusetts) Harbors (and because the sampling locations did not include the most highly contaminated portions of the Bay), Casco Bay ranks lower in sediment metal levels than it did in the study of Larsen et al. For the six metals considered in both studies, however, the relative ranking of Casco Bay is fairly consistent: Casco Bay's ranking (in comparison with the other sites) is highest for nickel and chromium, and lower for cadmium, lead, and copper. The only inconsistency is for zinc, for which Casco Bay ranked near the top in the study of Larsen et al., but closer to the bottom among the Status & Trends sites.

Table 3-1

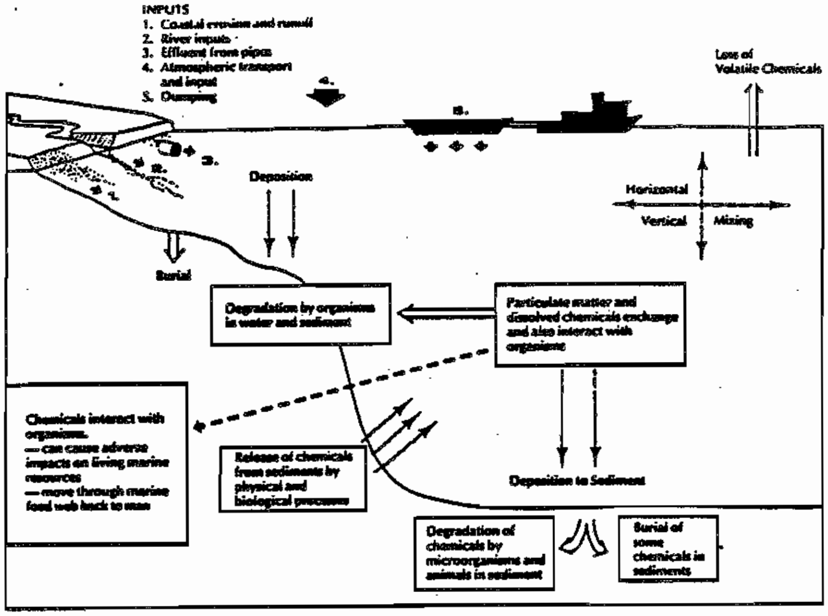
Average Metal Concentrations in Sediments
(parts per million, dry weight)

	Cadmium	Chromium	Copper	Nickel	Lead	Zinc
Casco Bay*	0.47	34.5	15.5	17.6	26.8	65.4
"Unaffected" Areas						
Machias Bay, ME**	—	16	9	—	13	35
Penobscot Bay, ME**	—	18	9	—	12	32
Seabrook River Estuary, NH**	—	19	7	—	9	29
Mystic River Estuary, CT***	0.41	—	4.4	—	14.5	56.5
"Affected" Areas						
Kennebec River Estuary, ME**	—	29	33	—	33	64
Saco River Estuary, ME**	—	274	15	—	36	47
Great Bay Estuary, NH+	—	142	16.4	—	40.7	60.6
Branford Harbor, CT***	1.16	—	34.5	—	265	54.5
Eastern Long Island Sound++	2.7	57.7	20.0	7.6	16.2	48.0

* Larsen et al. (1983d)
** Lyons et al. (in press)
*** Lyons and Fitzgerald (1980)
+ Armstrong et al. (1976)
++ Grieg et al. (1977)

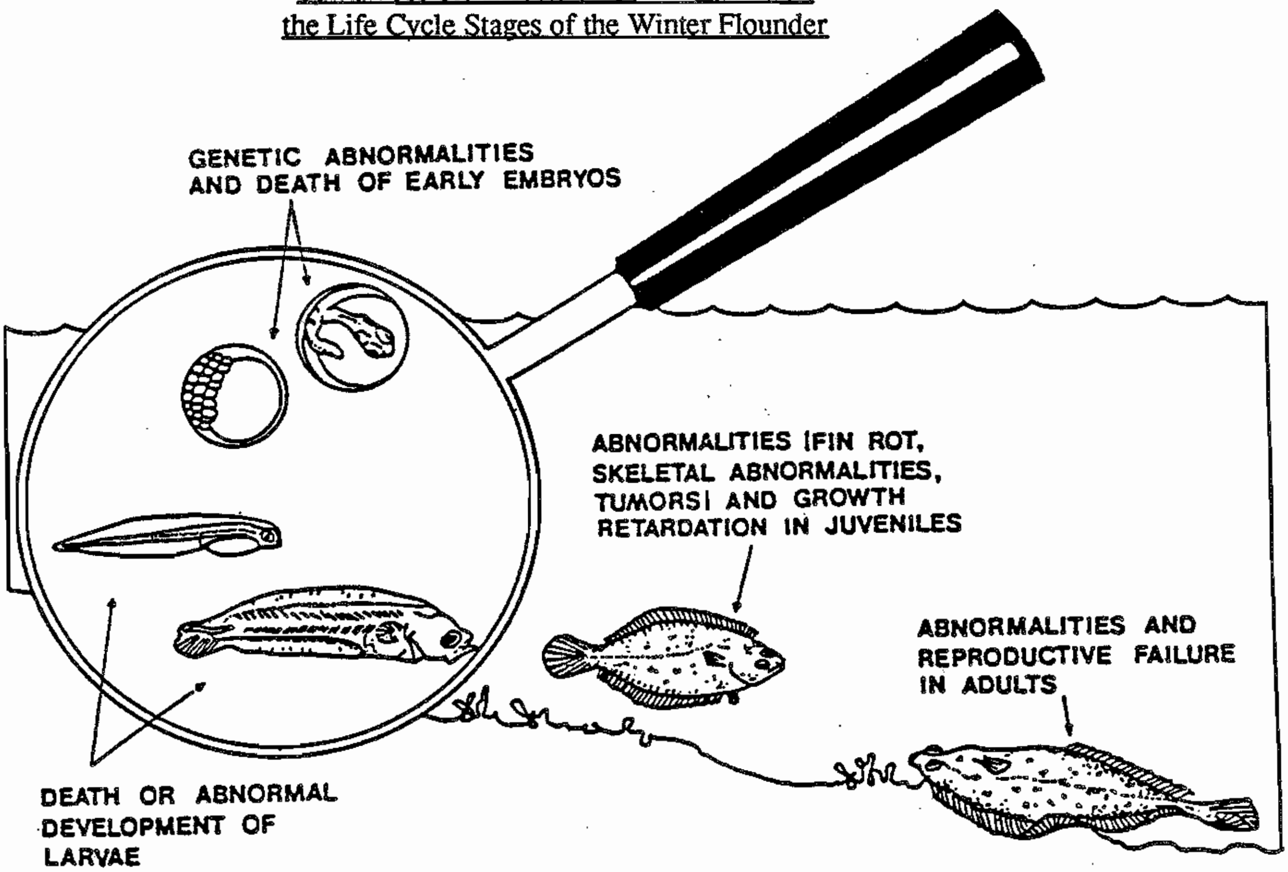
Source: Larsen et al. (1983d)

Figure 3-1
Inputs and Fates of Pollutants in Coastal Waters



Source: Farrington et al. (1982a)

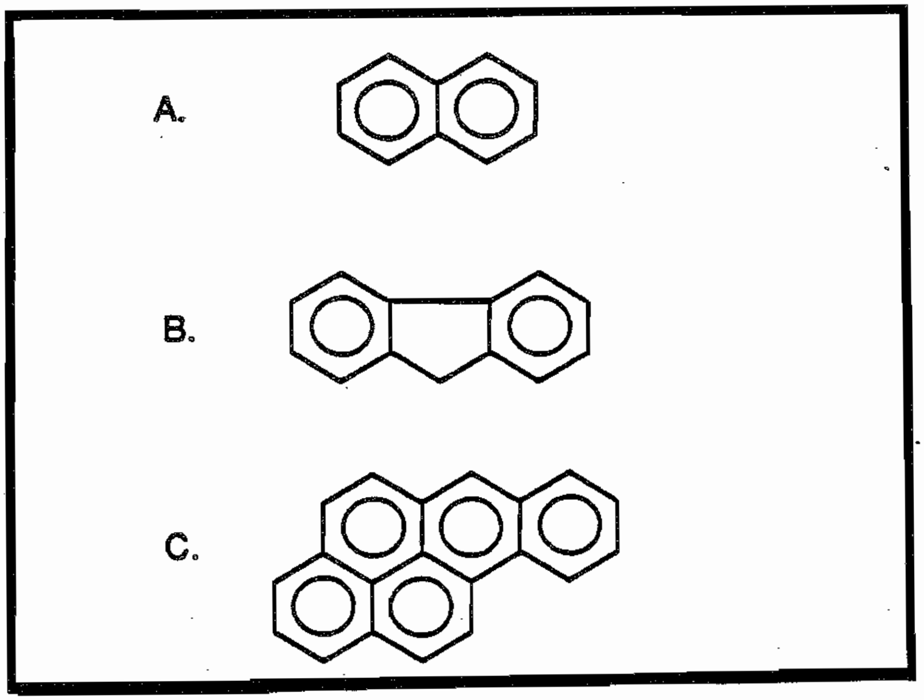
Figure 3-2
Some Possible Effects of Contaminants on
the Life Cycle Stages of the Winter Flounder



Source: Sindermann (1980)

Figure 3-3
Representative Aromatic Hydrocarbons

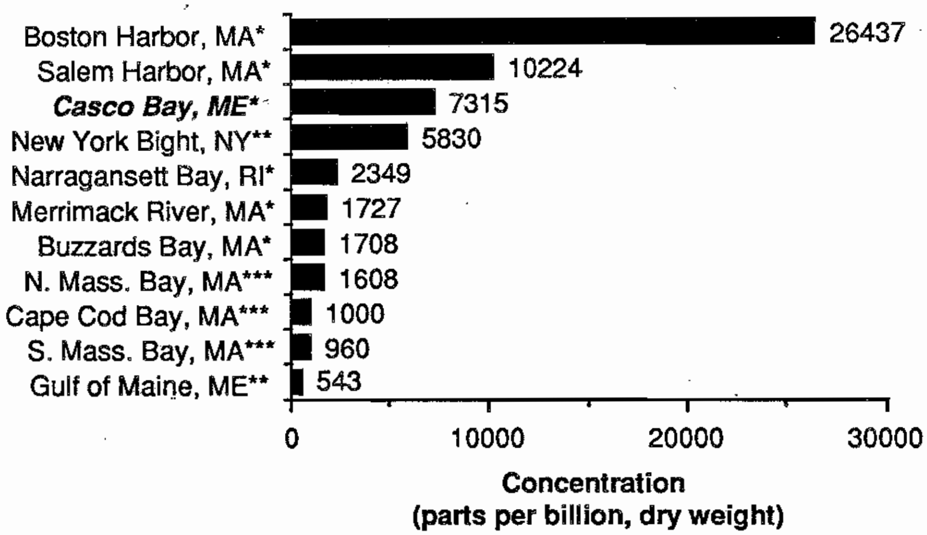
A. Naphthalene ($C_{10}H_8$)
B. Fluorene ($C_{13}H_{10}$)
C. Benzo[a]pyrene ($C_{20}H_{12}$)



Source: NOAA (1987d)

Figure 3-4

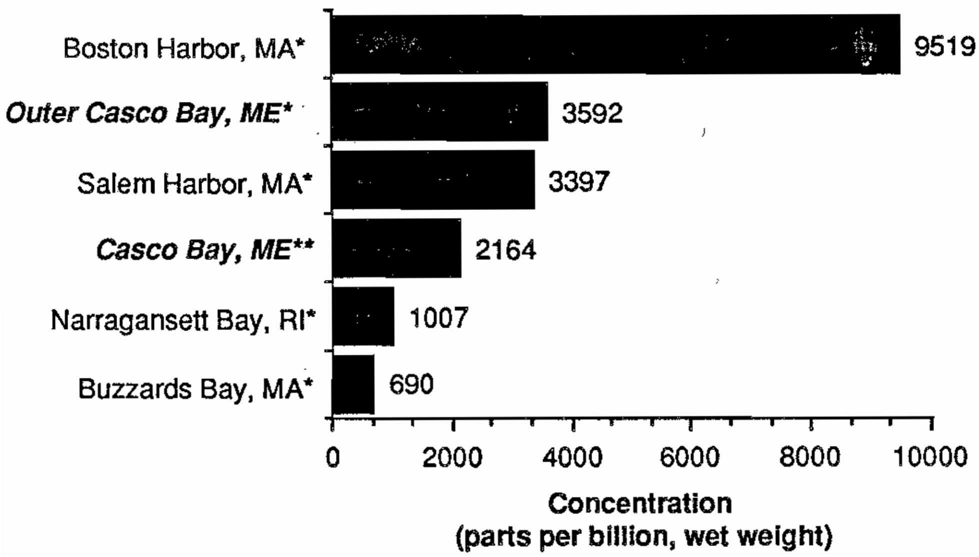
Concentrations of Polycyclic Aromatic Hydrocarbons in Sediments
(parts per billion, dry weight)



Notes:
* NOAA (1987d, 1987e)
** Laflamme and Hites (1978)
*** Boehm et al. (1984)

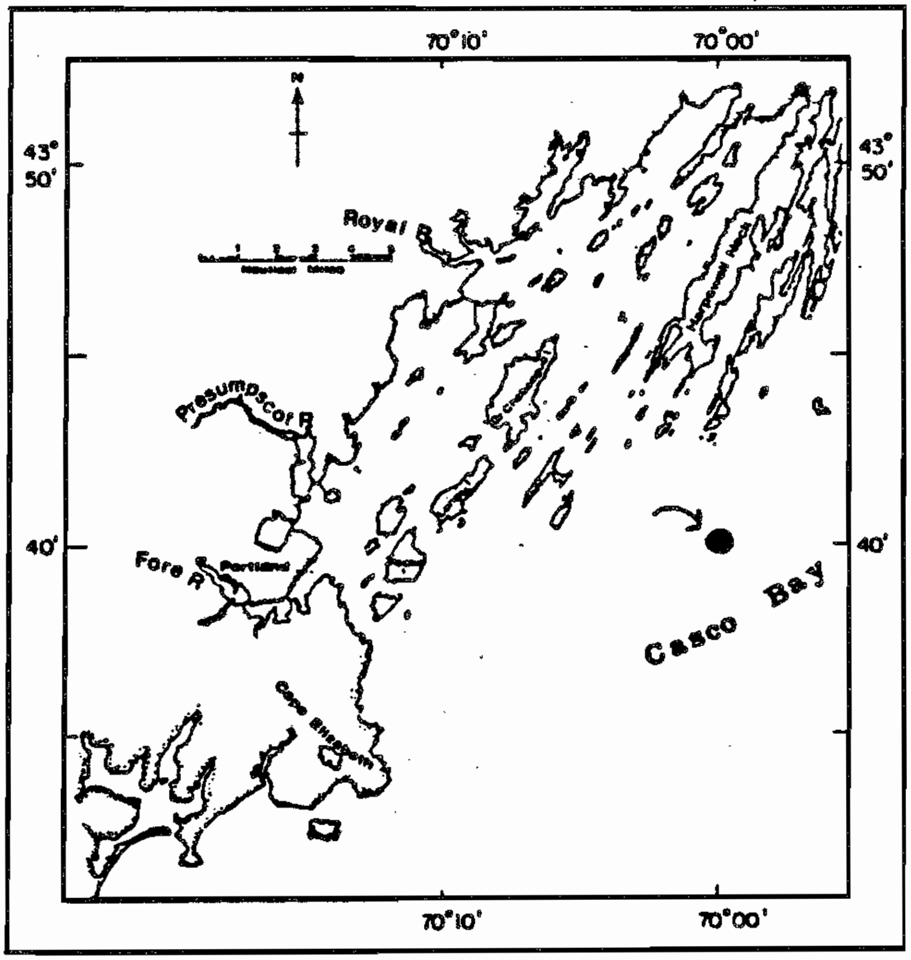
Figure 3-5

Concentrations of Polycyclic Aromatic Hydrocarbons in Sediments
(parts per billion, wet weight)



Notes:
* NOAA (1987d, 1987e)
** Larsen et al. (1983b)

Figure 3-6
Sediment Sampling Station — NOAA Status & Trends Program



Source: NOAA (1987e)

Figure 3-7

Sediment Sampling Stations for PAHs — Larsen et al. (1983b)

Small Circles — < 1,000 ppb
Intermediate Circles — 1,000-2,000 ppb
Large Circles — > 2,000 ppb

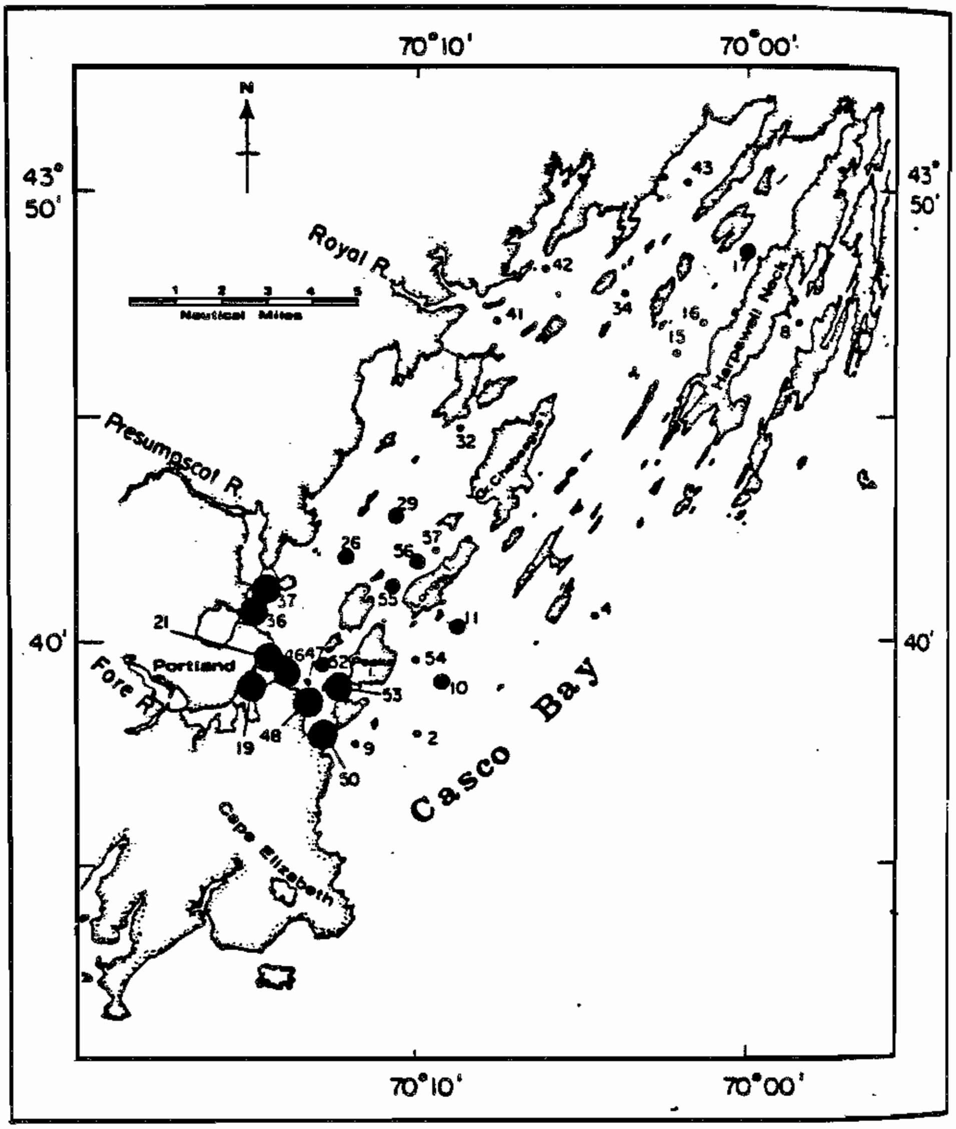
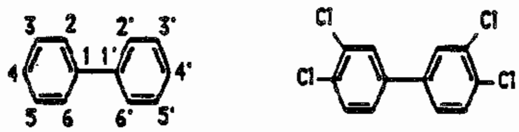


Figure 3-8

Structures of Biphenyl and a PCB



biphenyl

3,4,3',4'-tetrachlorobiphenyl

Source: NOAA (1987d)

Figure 3-9

Concentrations of PCBs in Sediments
(parts per billion, dry weight)

* NOAA (1987d, 1987e)
** Larsen et al. (1984) (average of means for each month at each station)
*** Boehm et al. (1984)

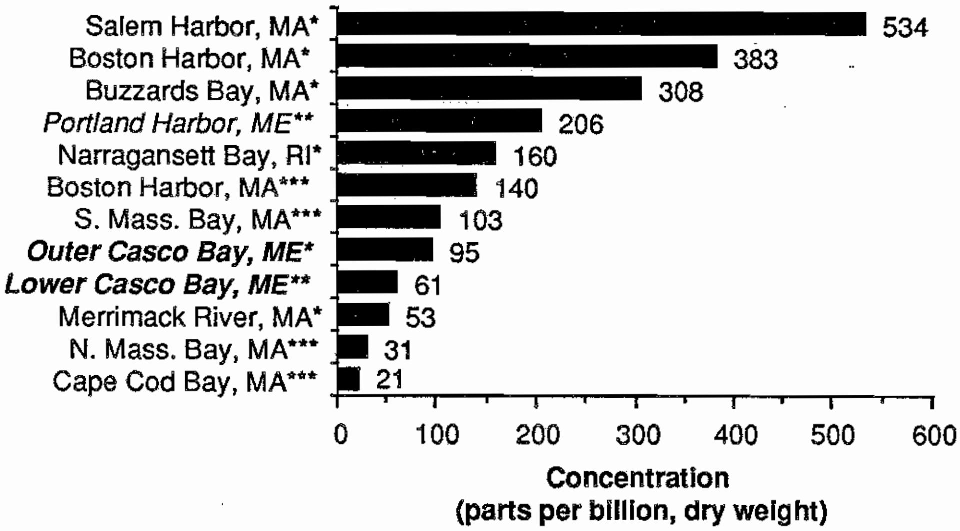


Figure 3-10

Sediment Sampling Stations for PCBs — Larsen et al. (1984)

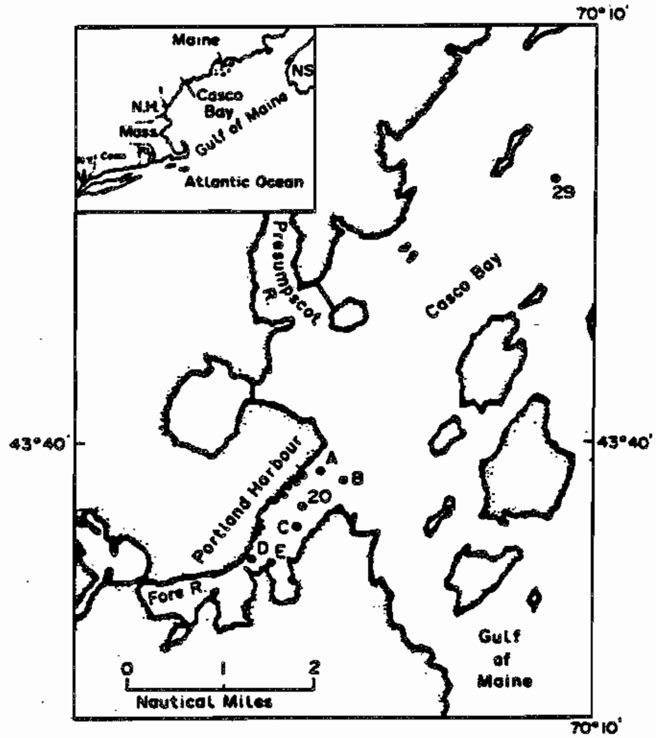
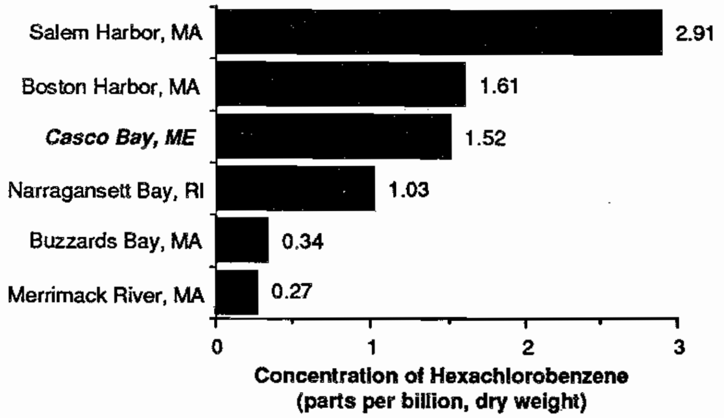
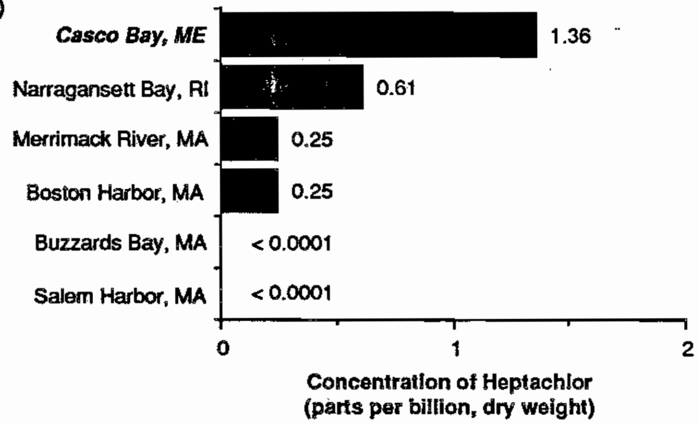
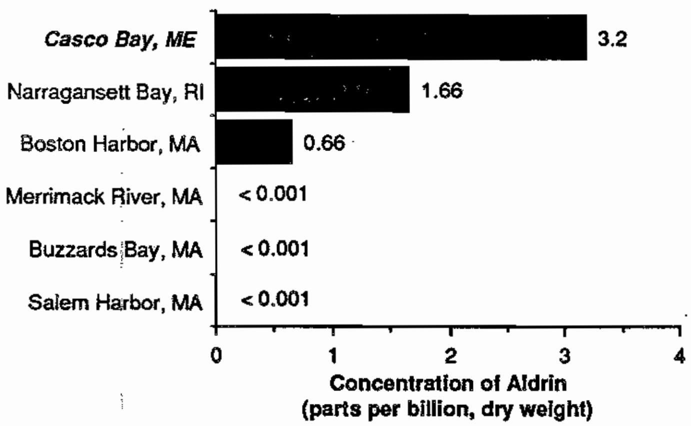
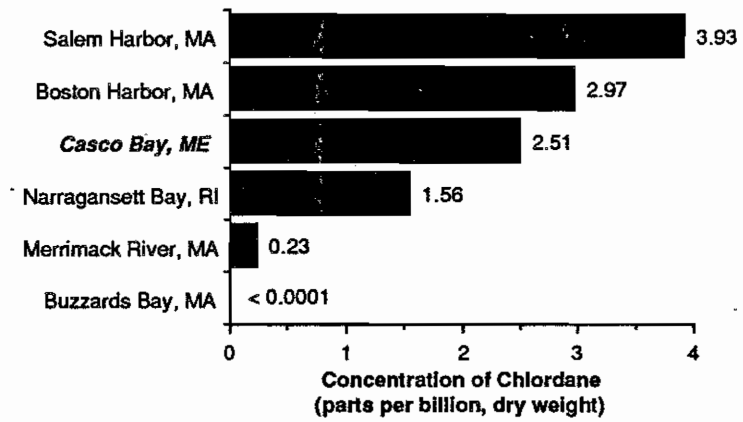


Figure 3-11
Concentrations of Pesticides in Sediments
(parts per billion, dry weight)



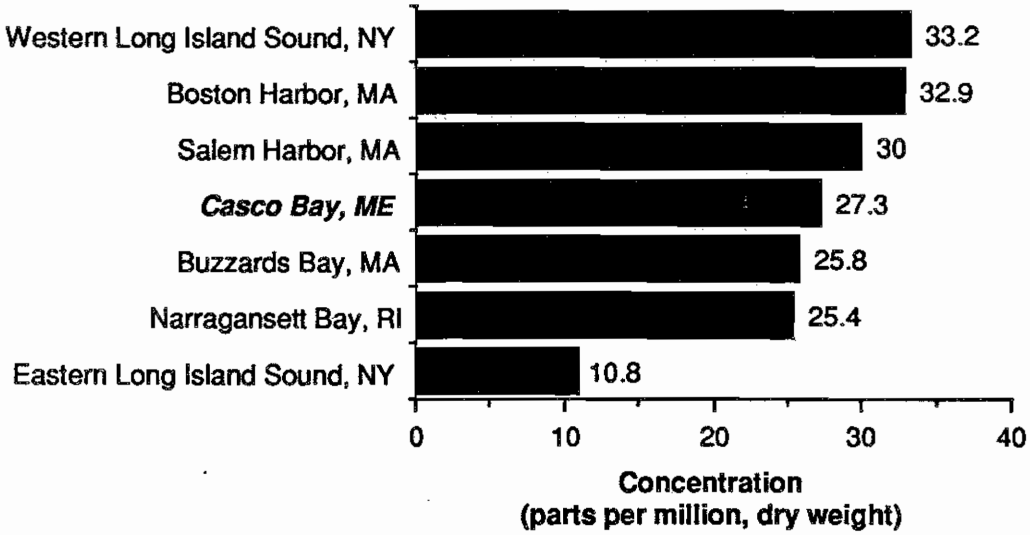






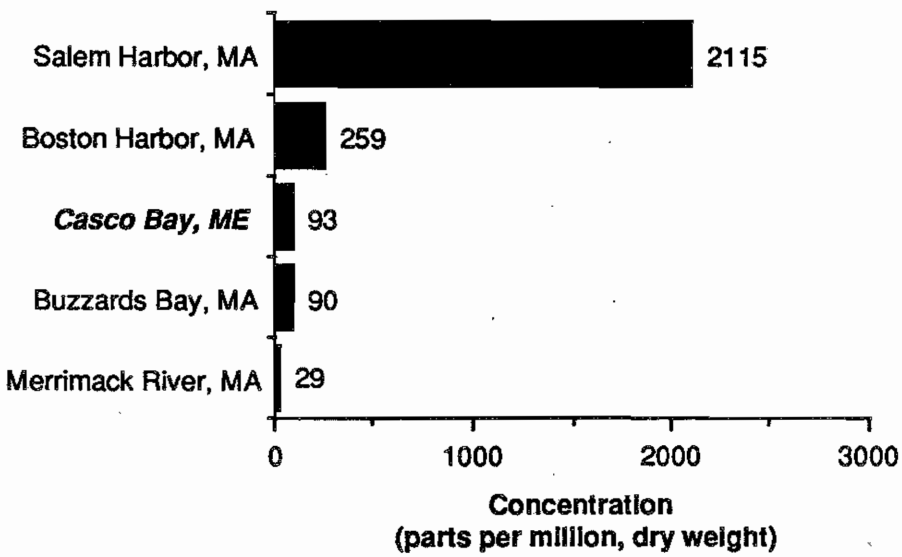
Source: NOAA (1987d, 1987e)

Figure 3-12
Concentrations of Nickel in Sediments Sampled in NOAA's Status and Trends Program



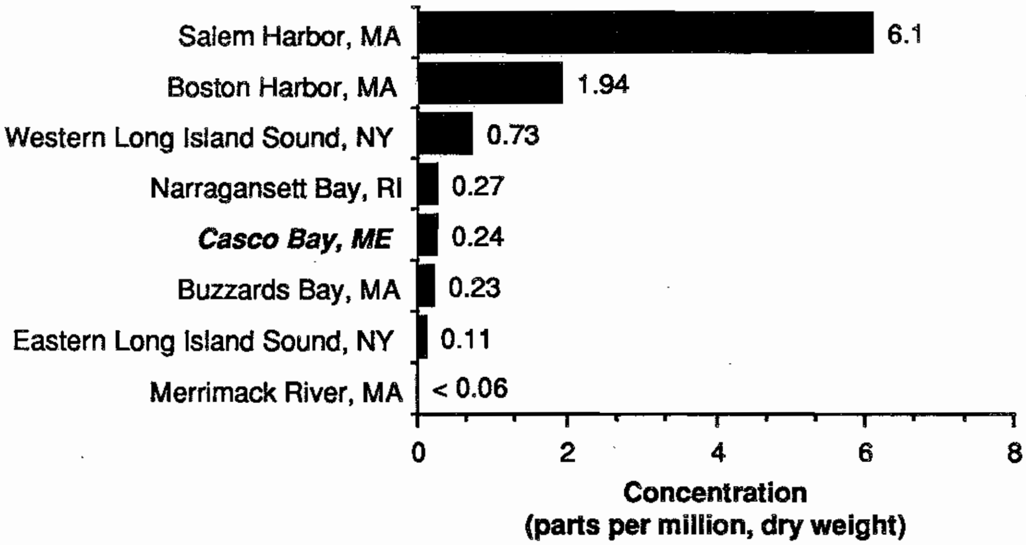
Source: NOAA (1987d, 1987e)

Figure 3-13
Concentrations of Chromium in Sediments Sampled in NOAA's Status and Trends Program



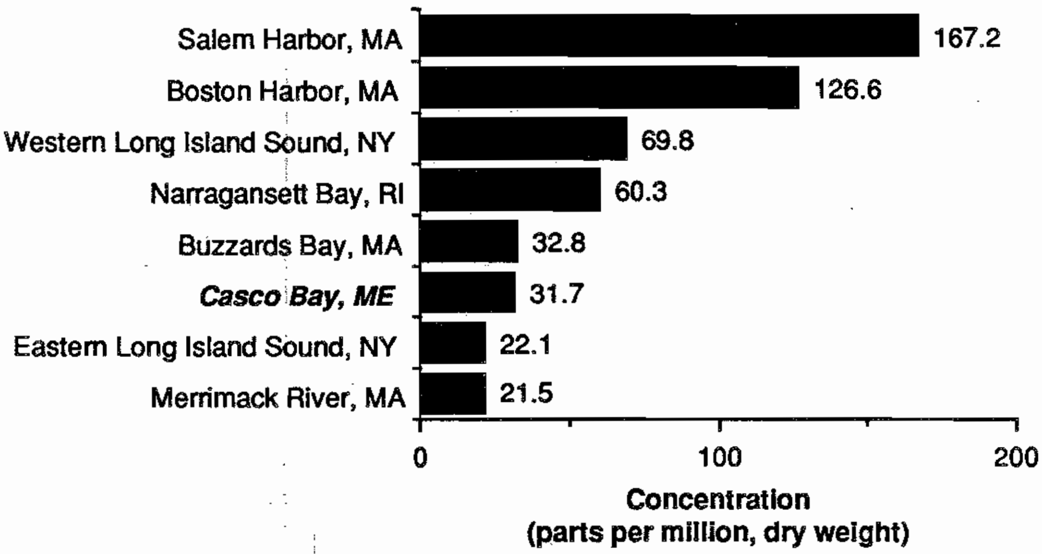
Source: NOAA (1987d, 1987e)

Figure 3-14
Concentrations of Cadmium in Sediments Sampled in NOAA's Status and Trends Program



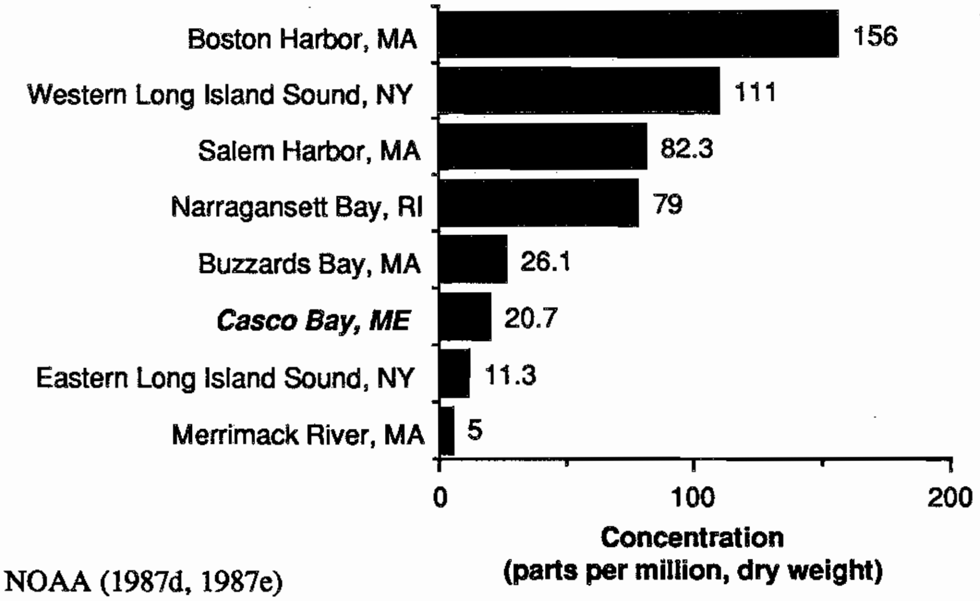
Source: NOAA (1987d, 1987e)

Figure 3-15
Concentrations of Lead in Sediments Sampled in NOAA's Status and Trends Program



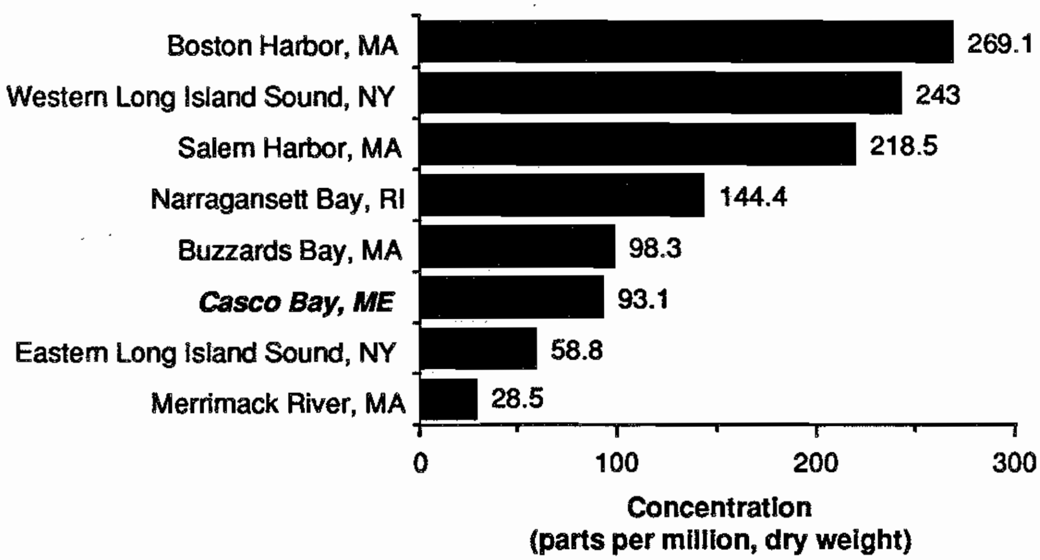
Source: NOAA (1987d, 1987e)

Figure 3-16
Concentrations of Copper in Sediments Sampled in NOAA's Status and Trends Program



Source: NOAA (1987d, 1987e)

Figure 3-17
Concentrations of Zinc in Sediments Sampled in NOAA's Status and Trends Program



Source: NOAA (1987d, 1987e)

IV. CONTAMINANT LEVELS IN ORGANISMS

As noted in the previous chapter, pollutants that enter coastal marine ecosystems can have a variety of deleterious effects on the living resources of those ecosystems. They can disrupt normal physiological processes, interfere with reproduction, cause abnormalities in larval and juvenile development, retard growth, and lead to physical malformations in adults.[1] (See Figure 3-1.) These adverse effects on individual organisms can result in reductions in the populations of various species, increases in populations of other, more pollution-tolerant species, and changes in the overall structure and functioning of the area's biological community. It is also possible for contaminants to accumulate in the tissues of fish and shellfish to levels high enough to warrant human health concerns.

Researchers, resource managers, and health officials thus care about the levels of contaminants in the tissues of living organisms because of the potential effects of the contaminants on marine and human populations. This information is also useful, however, as another reflection of the state of "health" of a given coastal ecosystem. Comparing the levels of various contaminants found in the same species in different locations gives us another indicator (as did information about water quality and sediment contamination) of the overall level of contamination in a given area.[2]

Casco Bay has been included in just two studies of contaminant levels in organisms.[3] Both studies, however, were national efforts, one undertaken in the 1970s and the other begun in 1984 and still going on, allowing easy comparison of the results for Casco Bay to those from other coastal areas. In addition, because both studies paid close attention to questions of methodology and calibration, we can be fairly confident in comparing results from different locations.

A. Contaminant Levels in Mussels: The EPA "Mussel Watch"

In the mid-1970s, as concerns over and questions about the extent and seriousness of environmental pollution were growing, scientists from around the United States, drawing on experiences gained in smaller efforts around the country and in similar efforts around the world, developed a coastal chemical pollution monitoring program based on the concept of a "sentinel organism." They chose three bivalve mollusk species (the common blue mussels Mytilus edulis and Mytilus californianus and the oyster Crassostrea virginica) as the sentinel organisms, in which levels of chemical pollutants would be measured at numerous coastal sites. Their reasons for choosing the sentinel organism strategy, and for choosing these species as the sentinels, were as follows (Farrington, 1983):

1. Bivalves are widely distributed. This minimizes problems of com-

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[1] *While it is difficult to establish a direct cause-and-effect relationship between a pollutant or group of pollutants and a particular disease or abnormality observed in the field (as opposed to the laboratory), many researchers have suggested a link between diseases in winter flounder and other flatfish and environmental pollutants. A high prevalence of fin rot in the winter flounder, for example, has been observed in Boston Harbor. A number of studies have focussed on liver lesions in winter flounder (Murchelano, 1985; Murchelano, et al., 1986; Murchelano and Wolke, 1985) and their probable link to the environmental pollutants, especially PAHs (Susani, 1986).*

[2] *Numerous biological (e.g., seasonal variability) and analytical factors can affect the results of tissue level studies, however, so it is important to know the source and reliability of the data when making comparisons of this sort. See, for example, Capuzzo et al. (1987), who called for a greater consistency in analytical methodology and better design of sampling protocols after reviewing the available data on levels of trace metals and organic contaminants in fish and shellfish in New England's coastal waters.*

[3] *Concerns about fish and shellfish contaminations have been raised in other Maine coastal areas, however. State and federal biologists were surprised in 1986 when crabs collected in Boothbay Harbor as clean "control" specimens for a study on crabs from polluted areas in New York and Philadelphia were found to contain high levels of lead (Lannin, 1986), leading to speculation about lead in the lobsters of Boothbay Harbor (Plante, 1986). The Department of Marine Resources has begun a pilot program for testing organisms for contaminants in a few areas of the state (A.C. Johnson, personal communication).*

paring data from markedly different species.

2. They are sedentary, and thus better reflect and integrate pollution conditions at a given site over time than mobile species.

3. They are more tolerant to pollution than fish and crustaceans.

4. They concentrate many chemicals in their tissues by factors of 100 to 100,000 as compared to concentrations in the water around them, making measurements of trace contaminants easier.

5. Measurements of contaminant levels in tissue give some indications of the availability of the pollutant to organisms.

6. Bivalves are less able than fish or crustaceans to break down chemical contaminants.

7. Bivalves have relatively stable, local populations that are large enough to be sampled repeatedly.

8. Bivalves survive under pollution conditions that often reduce or eliminate other species.

9. Bivalves can be transplanted and grown on moorings in areas where they do not normally grow, allowing study areas to be expanded.

10. They are commercially valuable seafood species, and information about them is useful for public health reasons.

The Mussel Watch Program was sponsored by the U.S. Environmental Protection Agency and ran for three years, from 1976 to 1978, before being phased out. It included two stations in Casco Bay: Bailey Island in Harpswell, and Mackworth Island in Falmouth (although the official station name was Portland). Figure 4-1 shows the sampling locations.[4]

1. Mussel Watch Results: Metals

Figures 4-2 to 4-7 present the results of the Mussel Watch analyses for metals from the two Casco Bay stations and the other stations in the Northeast.[5]

For most of the metals analyzed in the Mussel Watch program, levels observed in mussels from the two Casco Bay stations, Portland and Bailey Island, fall at or below the mean and median levels for all stations in the Northeast. The levels of cadmium, silver, zinc, copper, and nickel found in mussel tissues in Casco Bay are well below the highest levels found in this region.

There are no federal health-based standards for the levels of any of these metals in fish and shellfish. However, the Australian National Health and Medical Research Council has recommended maximum allowable concentrations of several of the metals considered in Tables 4-2 through 4-7, as well as arsenic (Table 4-1). For cadmium, silver, zinc, copper, and nickel, all observed levels in the Northeast fall well below the recommended maximum levels.

For cadmium, silver, and nickel, the pattern within Casco Bay is as one would expect, assuming that the urbanized region of Portland should be more highly contaminated than the more remote Bailey Island area: levels from the Portland station are higher. However, the order is reversed for zinc and copper: the values for Bailey Island are higher than those for Portland. Overall, the Mussel Watch data for these five metals give no clear indication that Casco Bay is heavily affected by metal pollution.

The story is quite different, though, for lead (Figure 4-7). The concentration of lead found in mussels from Portland was among the highest in the Northeast, and nearly five times as high as the national baseline value suggested by Goldberg et al. (1983). The value for Bailey Island, in contrast, is below the regional mean of 3.6 ppm, although it exceeds the regional median of 2.7 ppm.[6] While the value for Portland does not warrant any restrictions on or concern about the harvesting and consumption of mussels from the area (see Table 4-1), it is nevertheless a clear signal that the western portion of Casco Bay is indeed receiving significant inputs of lead,

[4]The Mussel Watch and its results are described in Farrington (1983); Farrington et al. (1982b); Farrington et al. 1983); Goldberg et al. (1978) ; Goldberg et al. (1983); and Palmieri et al. (1984).

[5]Northeast stations were chosen for comparison with the Casco Bay stations because of their geographical proximity and to limit the comparison to stations where the same species (Mytilus edulis) was used.

[6]A somewhat surprising result is that for Cape Newagen, which is located to the east of Casco Bay and south of Boothbay Harbor. Cape Newagen had the third highest lead levels in the Northeast, and also ranked above urban Portland for cadmium, zinc and nickel. The findings on lead are consistent with findings of elevated lead levels in crabs from Boothbay Harbor in 1986 (Lannin, 1986).

[7]The values for lead from Cape Ann and Boston, Massachusetts, however, may be cause for some health concern, since they exceed the lower estimate for the dry weight limit in Table 4-1.

and that those inputs can accumulate in marine organisms.[7]

2. Mussel Watch Results: Organic Contaminants

The Mussel Watch also analyzed tissues for levels of PCBs, "unresolved complex mixture" (UCM) hydrocarbons, and aromatic hydrocarbons.

a. PCBs

The values for Portland and Bailey Island are both relatively low in comparison with other stations in the Northeast. Like all of the results from the Northeast (with the exception of the notorious New Bedford Harbor), they are also well below the U.S. Food and Drug Administration health-based limit of 2 ppm wet weight, which is equivalent to 9,000-14,300 parts per billion (ppb) dry weight (see Table 4-1). The results for Portland are the highest in Maine, and over four times as high as those for Blue Hill Falls.

Nevertheless, the results from Casco Bay (as well as those for Cape Newagen) fall outside the range of 3 to 50 ppb that Farrington et al. (1982b), in discussing the data, associated with "fairly remote, relatively pristine locations." Instead, they are among the numerous stations with values greater than 50 but less than 200 ppb; the authors noted that stations with values greater than 200 ppb were in industrialized areas of the coast.

b. UCM Hydrocarbons

When hydrocarbon samples are analyzed using a gas chromatogram, different fractions of the sample, containing different types of hydrocarbons, separate out according to the molecular weight of the particular compound. Certain portions of the sample, however, do not produce sharp peaks in the resulting chromatogram, but rather form a larger "bump" (see Figure 4-9). This group of hydrocarbons is reported as the unresolved complex mixture, or UCM. UCM is often used as an indicator of the presence of fossil fuel hydrocarbons (Farrington et al., 1982b).

The Mussel Watch results for UCM hydrocarbons are presented in Figure 4-10. Portland clearly "sticks out" as an area of elevated UCM hydrocarbon levels in mussels, ranking second only to Boston in the entire Northeast. The Portland value is over twenty times higher than the non-detectable levels found elsewhere in the Northeast and at other remote areas around the country. This difference of over an order of magnitude is a clear indication of contamination, as opposed to natural variation (Capuzzo et al., 1987). The value for Bailey Island, while above that for a number of Northeast stations, is well below that for Portland, indicating some type of pollution gradient within the Bay.

c. Aromatic Hydrocarbons

The results for aromatic hydrocarbons (Figure 4-11) are quite similar to those for UCM hydrocarbons: Portland ranks among the most heavily contaminated stations in the Northeast based on levels of aromatic hydrocarbons in mussels, coming in behind only Boston and two stations in the New York area, and Bailey Island ranks closer to the bottom, but above the "cleanest" stations. In fact, the value from Portland is higher than that for Narragansett Bay, which Farrington et al. (1982b) cite as one of the urban or industrial locations that stand out because of their elevated levels of UCM and aromatic hydrocarbons.

B. Contaminant Levels in Winter Flounders: NOAA's National Status & Trends Program

The only other study of contaminant levels in organisms taken from Casco Bay is the National Status & Trends Program, carried out by the National Oceanic and Atmospheric Administration. Many of the findings on contaminants levels in sediments discussed in Chapter 3 come from the Status & Trends Program. Both the sediment findings and the results that are discussed in this section fall under Status & Trends' Benthic Surveillance Project, under which bottom-feeding fish and sediments have been collected from some fifty sites around the country since 1984. Status & Trends also has its own Mussel Watch Project, which involves the collection of bivalve molluscs and sediments at 150 sites nationwide. Casco Bay is included in the Benthic Surveillance Project, but not in the Mussel Watch Project. As with the sediment sampling, the Casco Bay sampling station for bottom-feeding fish (winter flounder) is in outer Casco Bay (Figure 4-12).

The Status & Trends Program analyzes the livers of various bottom-feeding fish species for various metals and organic contaminants. Livers tend to concentrate and/or detoxify many environmental contaminants, and thus are better suited for analysis in programs such as Status & Trends than muscle or edible tissue. (Of course, when the testing is being done for the purpose of comparing the results with health-based contaminant limits, edible tissue is used.) Bottom-feeding fish such as winter flounder are especially suited for such studies, and especially vulnerable to toxic pollution, because they live in close association with the sediments (where many contaminants accumulate) and feed on organisms that can also accumulate contaminants in their own tissues.

1. Status & Trends Results: Metals

NOAA (1987c) has published the results of the fish liver analyses from the Status & Trends Program for 1984 and some data from 1985. In addition to presenting the results for individual contaminants, NOAA's report discusses the data and attempts to draw some conclusions and to establish some rankings of sites on a nationwide basis. The conclusions for Casco Bay are striking.

Casco Bay is one of the East Coast sites that are among the most contaminated on the basis of tissue contaminant levels found in NOAA's Status & Trends Program (Table 4-2). The criterion for inclusion of a Benthic Surveillance site on this list of "most contaminated" sites was that at least two mean concentrations rank in the upper five of 43 concentrations or that a single concentration rank in the upper three. Casco Bay was a particularly strong candidate: it had concentrations that ranked in the top three for two different metals (lead and silver) and in the top five for another (zinc).

Figures 4-13 through 4-15 show the NOAA results for lead, silver, and zinc in fish livers. Livers in winter flounder from Casco Bay contained the highest levels of lead among all 43 sites sampled nationwide. The value for Casco Bay is more than twice the second-highest value, for Elliot Bay (Seattle), Washington, and over five times as high as the next highest New England value (western Long Island Sound). Casco Bay ranked third among 43 sites from around the country in the level of silver found in fish livers. It ranked first among the eight New England sites. Finally, Casco Bay ranked fifth in the country (and first in New England) in the level of zinc found in fish livers.

Figures 4-16 through 4-21 present the Status & Trends results for the levels of six other metals in fish livers. Casco Bay ranks no higher than tenth among the 43 sites for any of these other metals. However, when we consider only the eight sites in New England (simultaneously restricting our attention to those sites at which the species sampled was winter flounder) — Casco Bay, the mouth of the Merrimack River (Massachusetts), Salem (Massachusetts) Harbor, Boston Harbor, Buzzards Bay (Massachusetts), Narragansett Bay, eastern Long Island Sound, and western Long Island Sound — we find that Casco Bay ranks in the top half of those sites for all six metals. Among the eight fish liver sampling sites in New England, Casco Bay ranks first in level of copper (as well as lead, silver, and zinc), third in level of tin, cadmium, and nickel, and fourth in level of chromium and mercury.

2. Status & Trends Results: Organic Contaminants

Casco Bay ranks much lower, both on a national level and among New England stations, in the levels of various organic contaminants found in fish livers by the Status & Trends Program. Figures 4-22 through 4-24 present the results for PCBs, DDT, and total chlorinated pesticides. Casco Bay falls around the middle or near the bottom for all three contaminants in a national comparison, and seventh (PCBs) or last (DDT and pesticides) among the eight New England stations.

Table 4-1

Australian National Health and Medical Research Council
Recommended Maximum Concentrations of Metals in Seafood Products
(from Mackay et al., 1975)

(parts per million)

Metal	Wet Weight	Standard Dry Weight wet/dry = 4.5*	Standard Dry Weight wet/dry = 7.14**
Copper	30	135	214.2
Zinc	1000	4500	7140
Cadmium	2	9	14.3
Lead	2	9	14.3

* Wet weight to dry weight ratio; after Grieg and Sennefelder (1985)
** After Capuzzo et al. (1987)

Table 4-2

East Coast Sites Among the Most Contaminated on the Basis of Contaminant Levels in Fish Livers Found in NOAA's Status & Trends Program

Casco Bay, Maine

Salem Harbor, Massachusetts

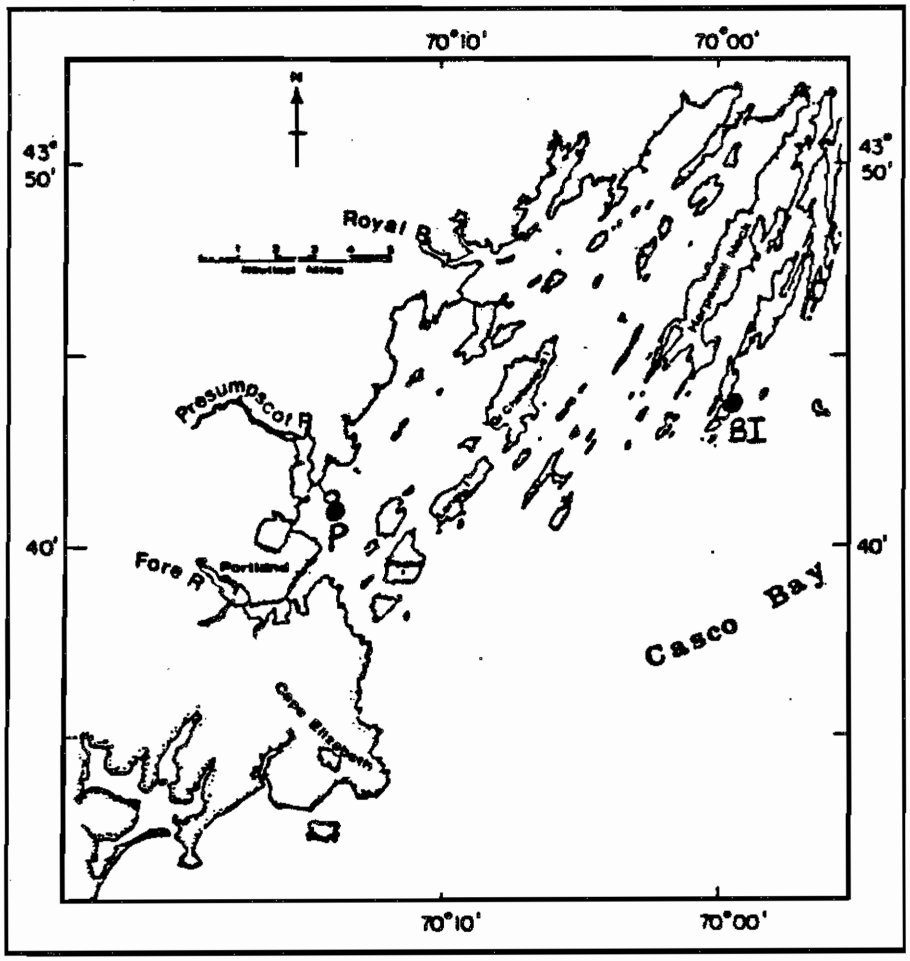
Boston Harbor, Massachusetts

Western Long Island Sound, New York

Source: NOAA (1987c)

Figure 4-1

Casco Bay Sampling Stations in the EPA "Mussel Watch" Program



P = Portland

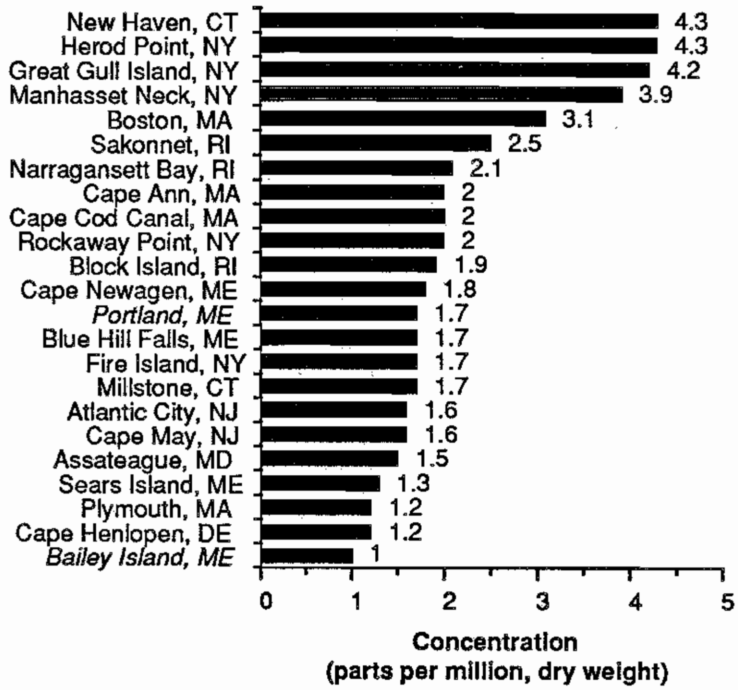
BI = Bailey Island

Source: Goldberg et al. (1978

Figure 4-2

Concentrations of Cadmium in Mussels Sampled in the EPA "Mussel Watch"

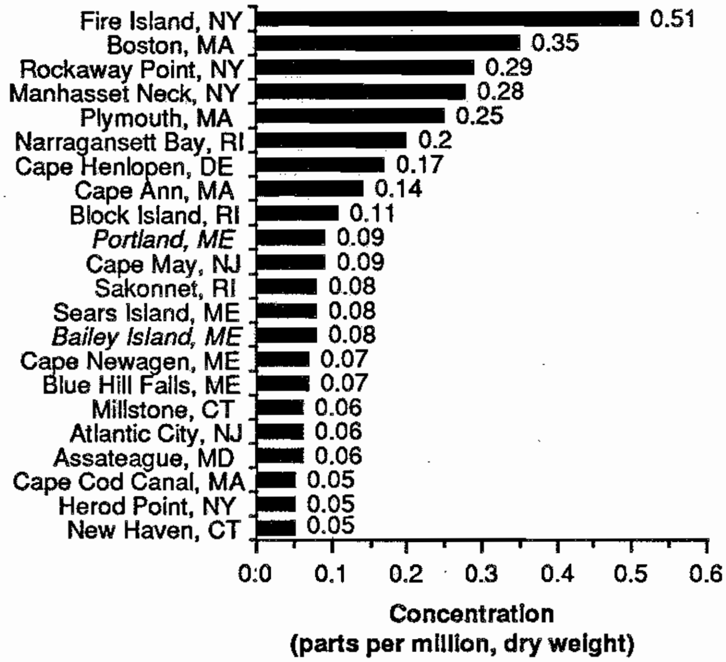
(parts per million, dry weight)



Source: Goldberg et al. (1983)

Figure 4-3

Concentrations of Silver in Mussels Sampled in
the EPA "Mussel Watch"
(parts per million, dry weight)

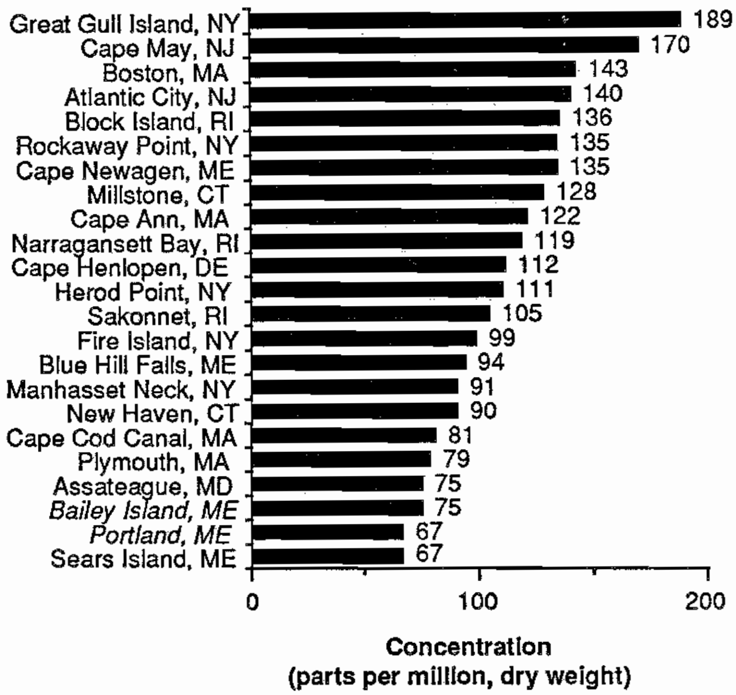


Source: Goldberg et al. (1983)

Figure 4-4

Concentrations of Zinc in Mussels Sampled in the EPA "Mussel Watch"

(parts per million, dry weight)

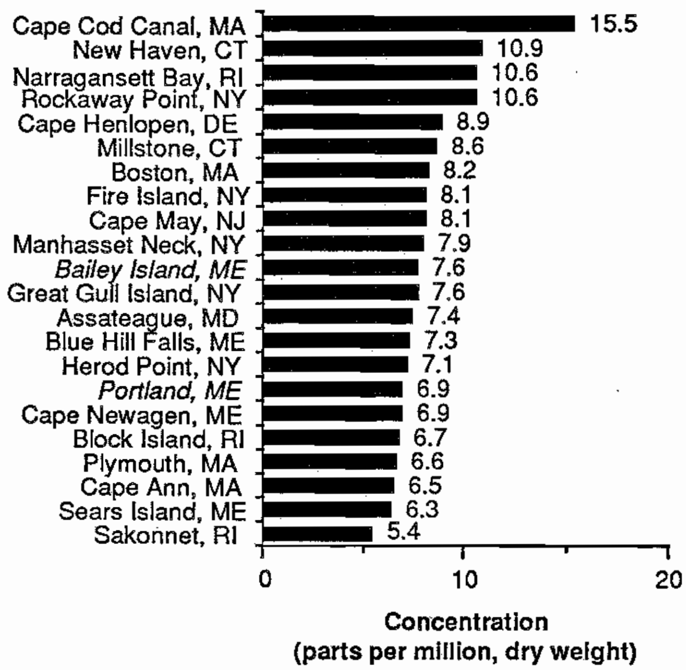


Source: Goldberg et al. (1983)

Figure 4-5

Concentrations of Copper in Mussels Sampled in the EPA "Mussel Watch"

(parts per million, dry weight)

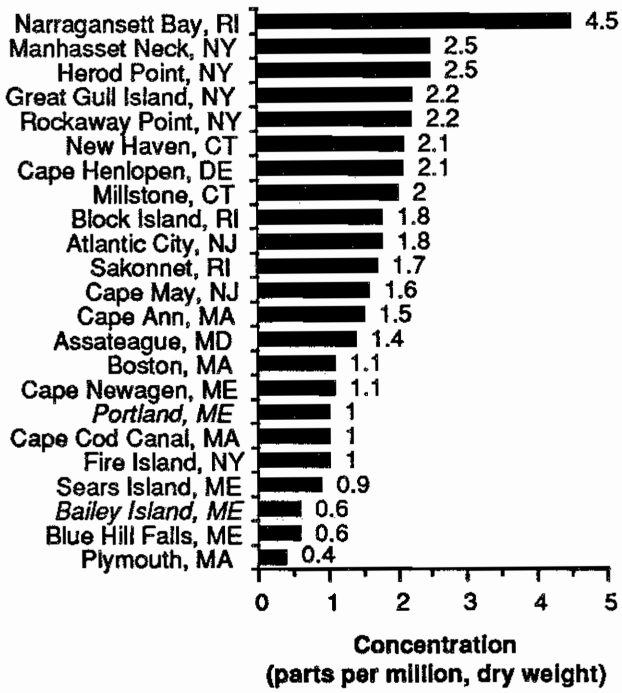


Source: Goldberg et al. (1983)

Figure 4-6

Concentrations of Nickel in Mussels Sampled in the EPA "Mussel Watch"

(parts per million, dry weight)

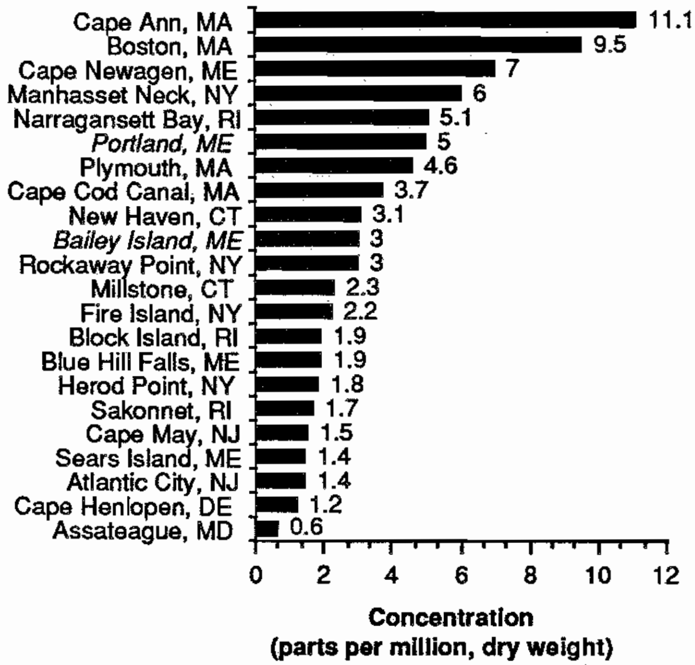


Source: Goldberg et al. (1983)

Figure 4-7

Concentrations of Lead in Mussels Sampled in the EPA "Mussel Watch"

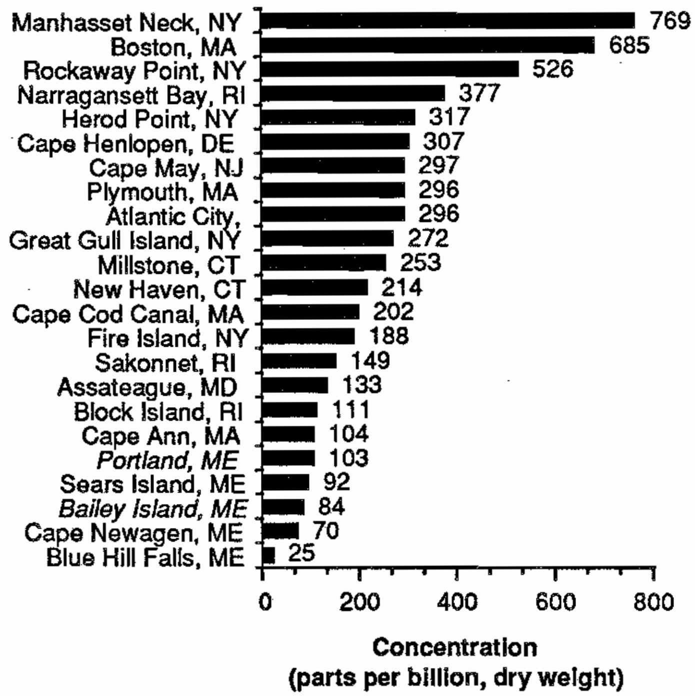
(parts per million, dry weight)



Source: Goldberg et al. (1983)

Figure 4-8

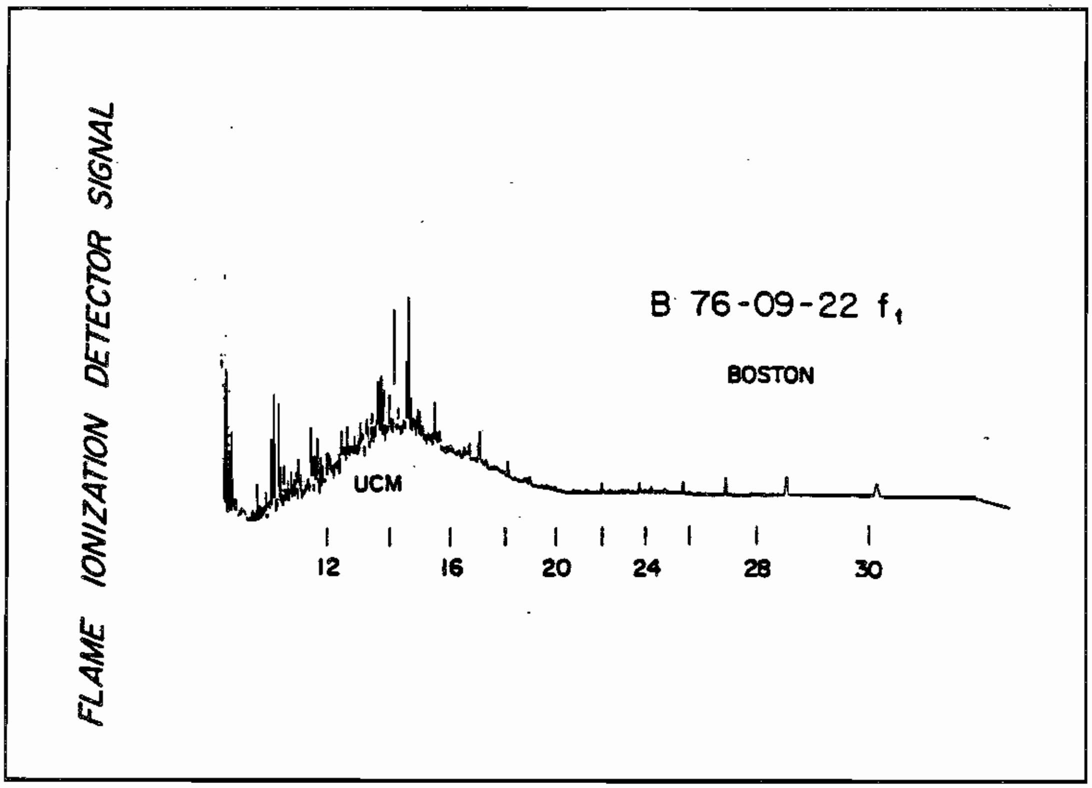
Concentrations of PCBs in Mussels Sampled in
the EPA "Mussel Watch"
(1976-77 data)
(parts per billion, dry weight)



Source: Farrington et al. (1982b)

Figure 4-9

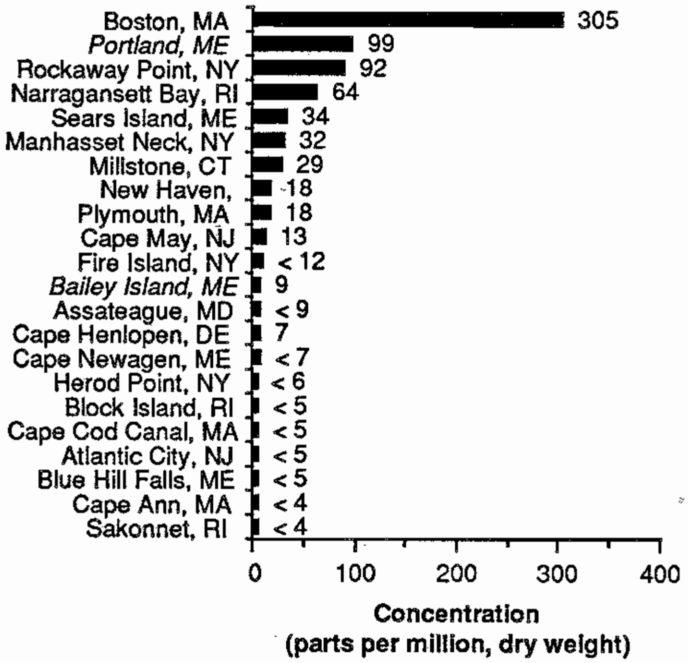
Typical Gas Chromatogram Showing
the Unresolved Complex Mixture (UCM)



Source: Farrington et al. (1982b)

Figure 4-10

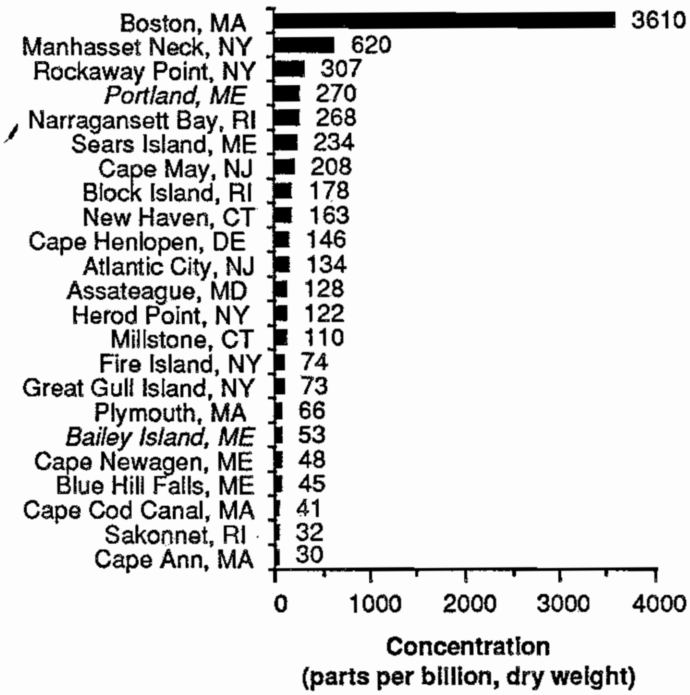
Concentrations of UCM Hydrocarbons in Mussels Sampled in the EPA "Mussel Watch"
(1976-77 data)
(parts per million, dry weight)



Source: Farrington et al. (1982b)

Figure 4-11

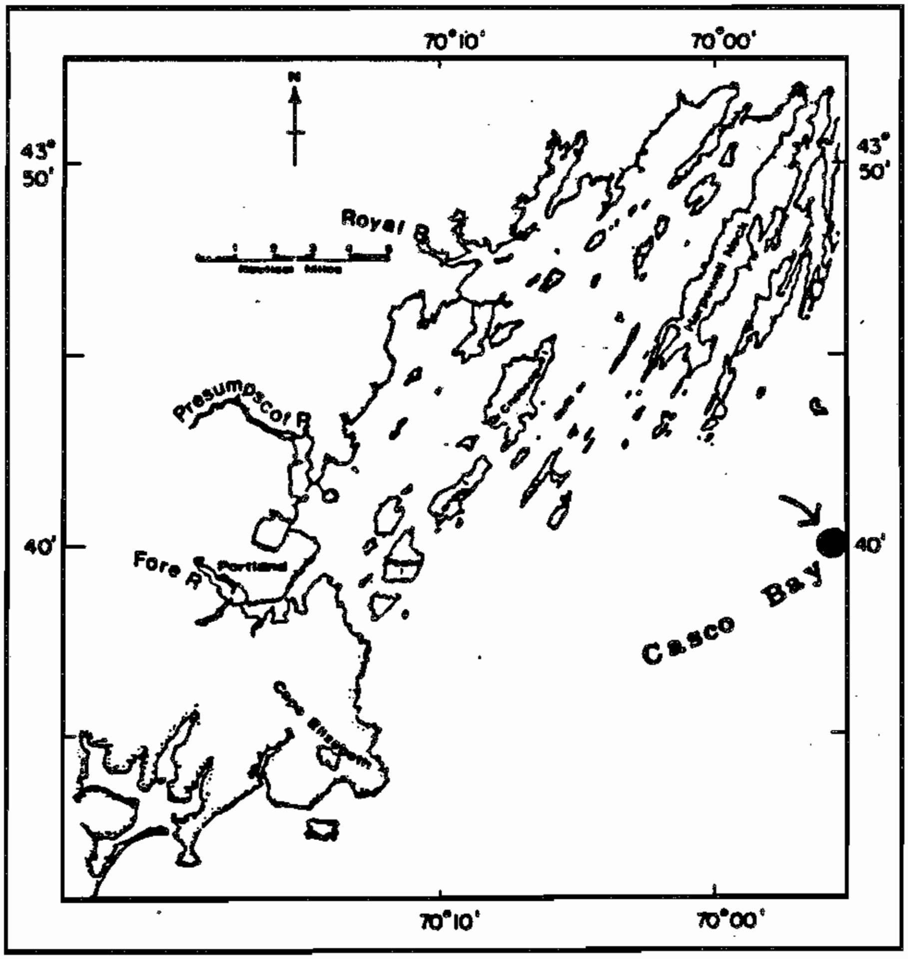
<u>Concentrations of Aromatic Hydrocarbons in Mussels Sampled in the EPA "Mussel Watch"</u>
(1976 data)
<u>(parts per billion, dry weight)</u>



Source: Farrington et al. (1982b)

Figure 4-12

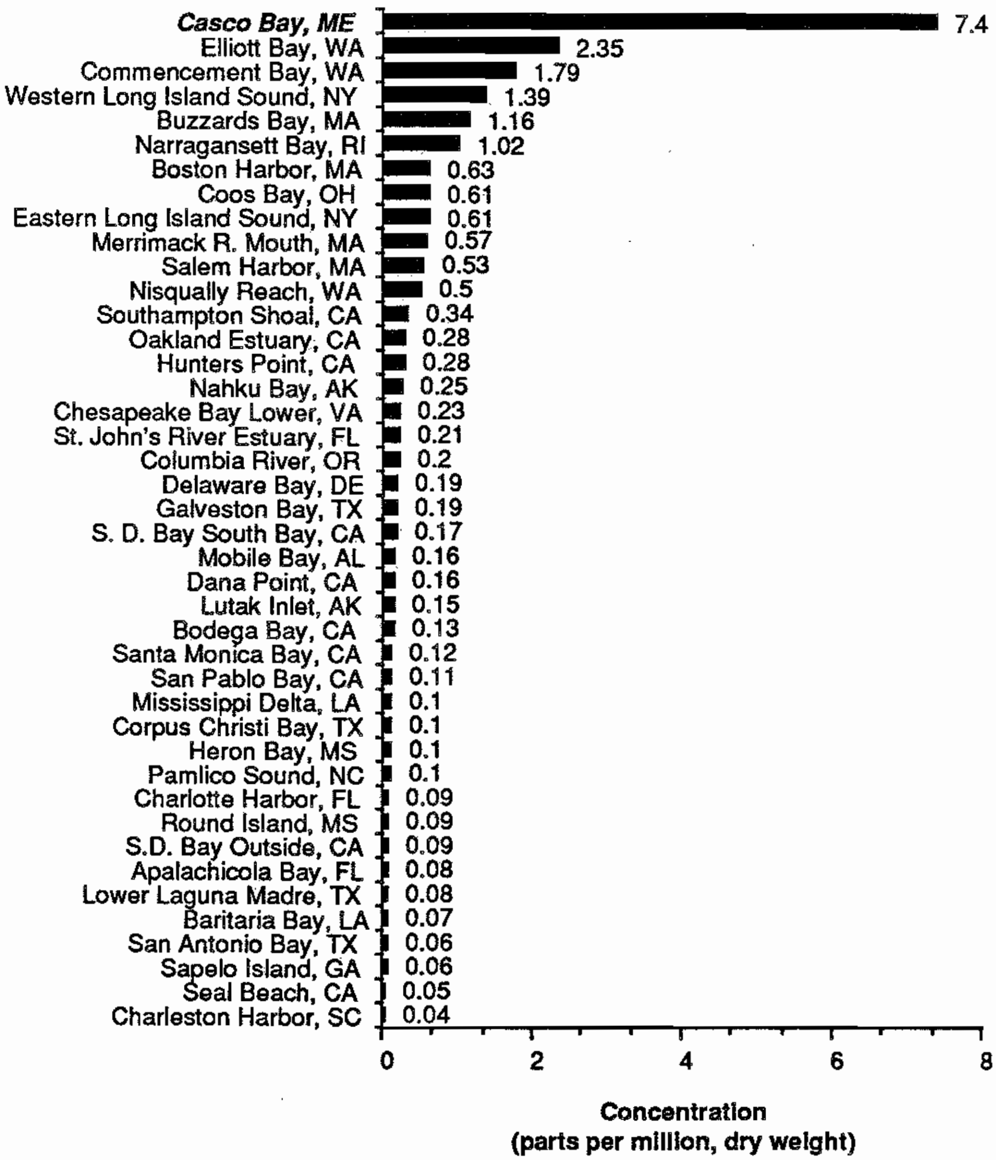
Winter Flounder Sampling Station — NOAA Status & Trends Program



Source: NOAA (1987e)

Figure 4-13

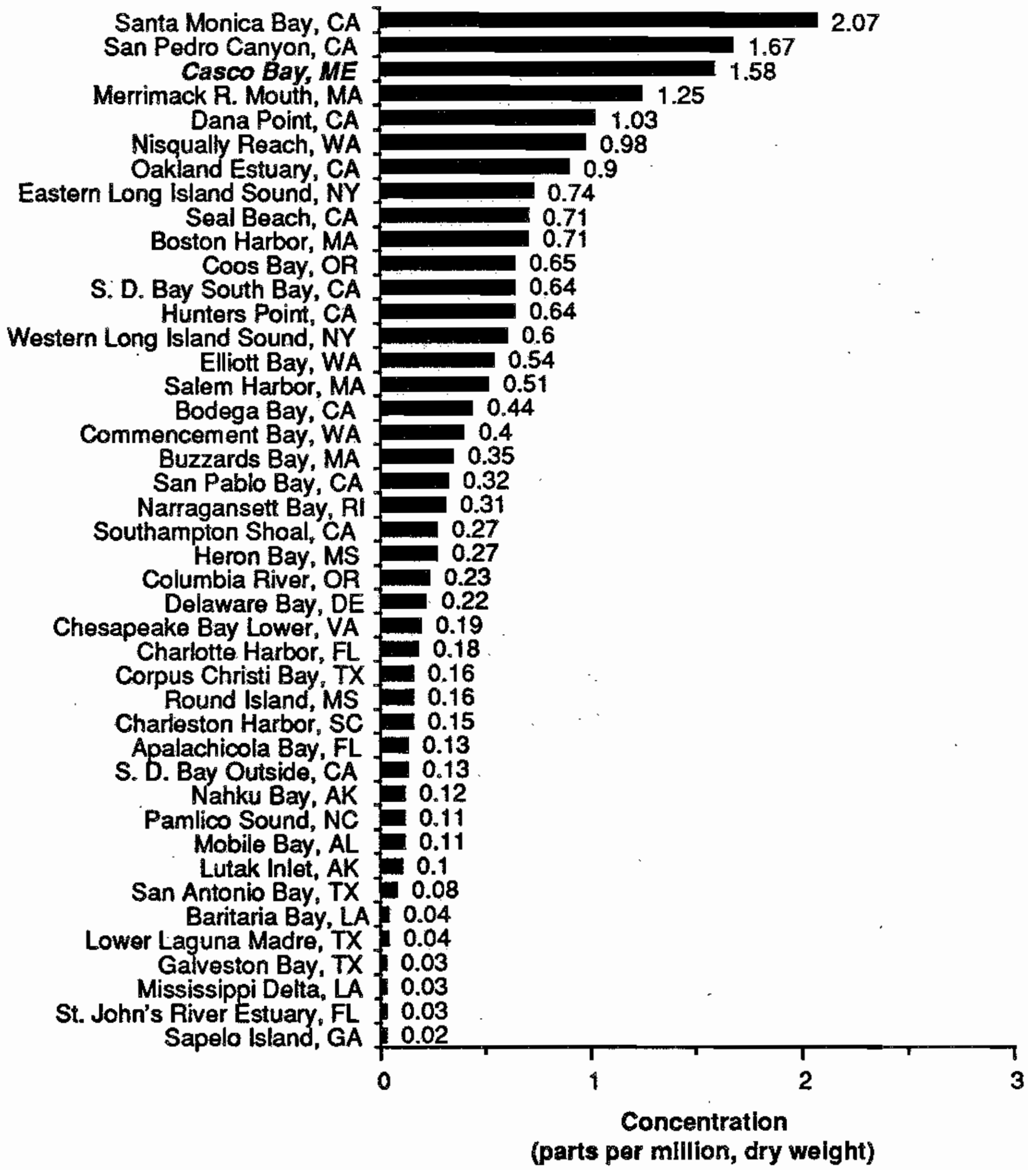
Concentrations of Lead in Fish Liver Tissue Sampled in NOAA's Status & Trends Program



Source: NOAA (1987c)

Figure 4-14

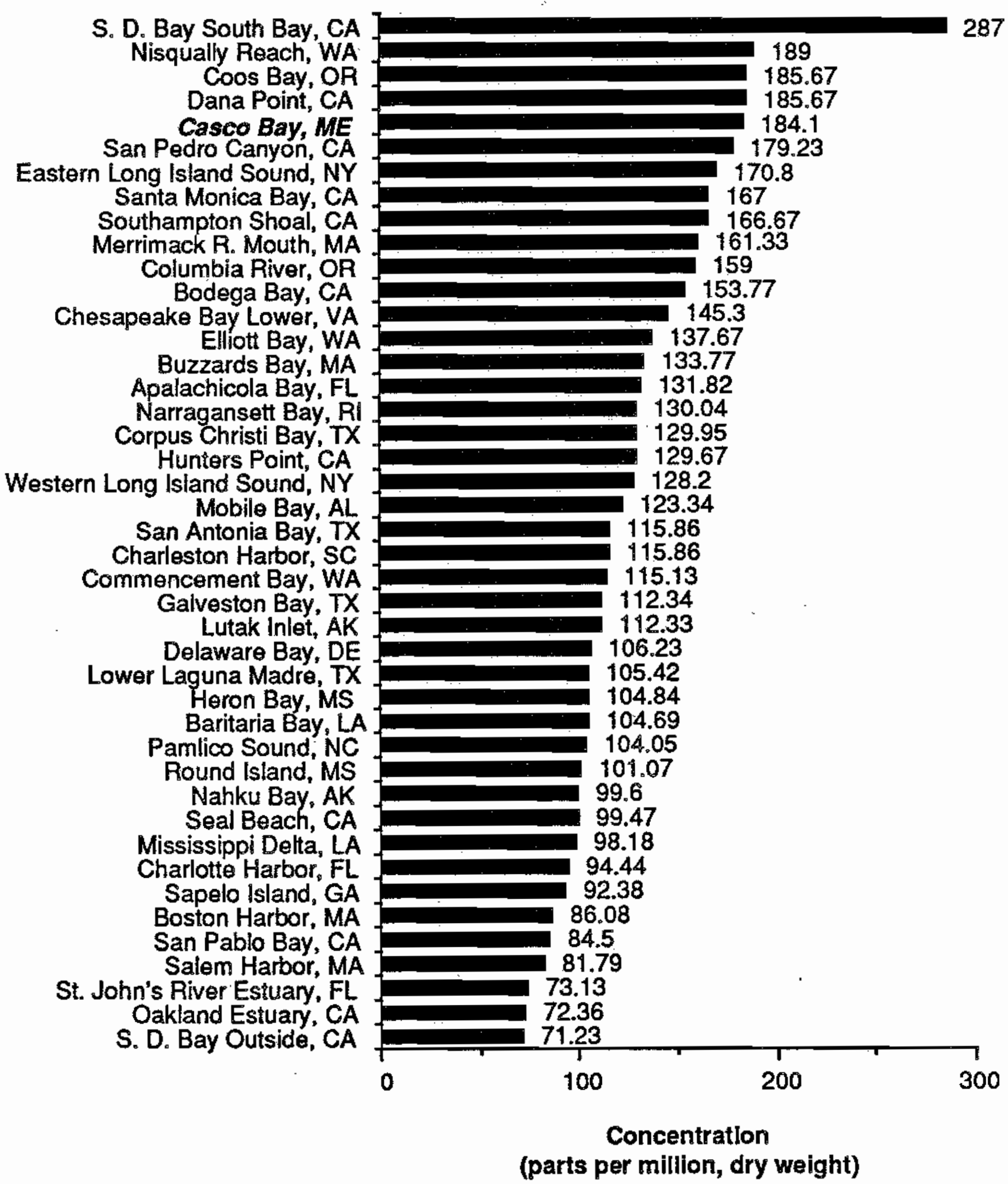
Concentrations of Silver in Fish Liver Tissue Sampled in NOAA's Status & Trends Program



Source: NOAA (1987c)

Figure 4-15

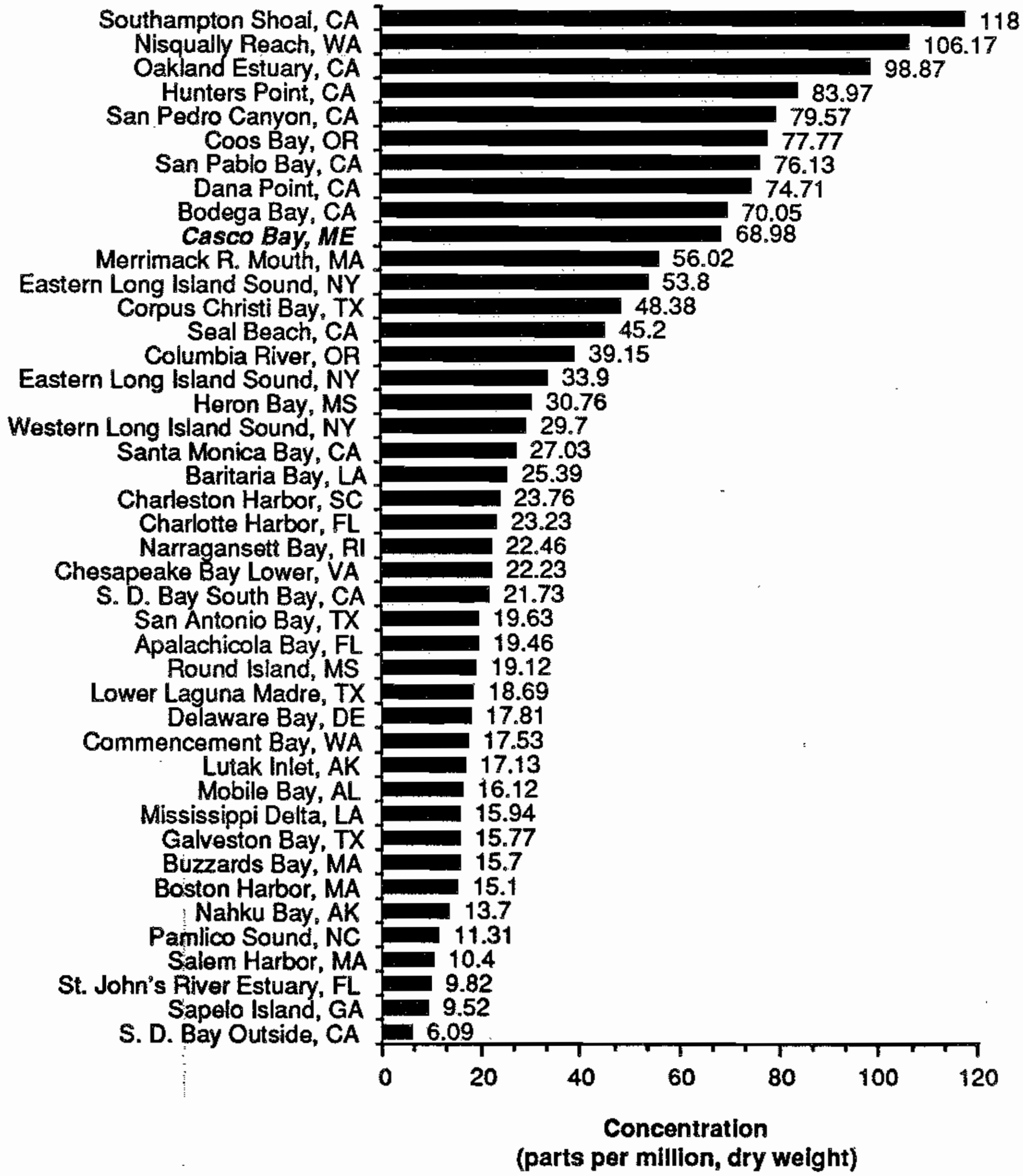
Concentrations of Zinc in Fish Liver Tissue Sampled in NOAA's Status & Trends Program



Source: NOAA (1987c)

Figure 4-16

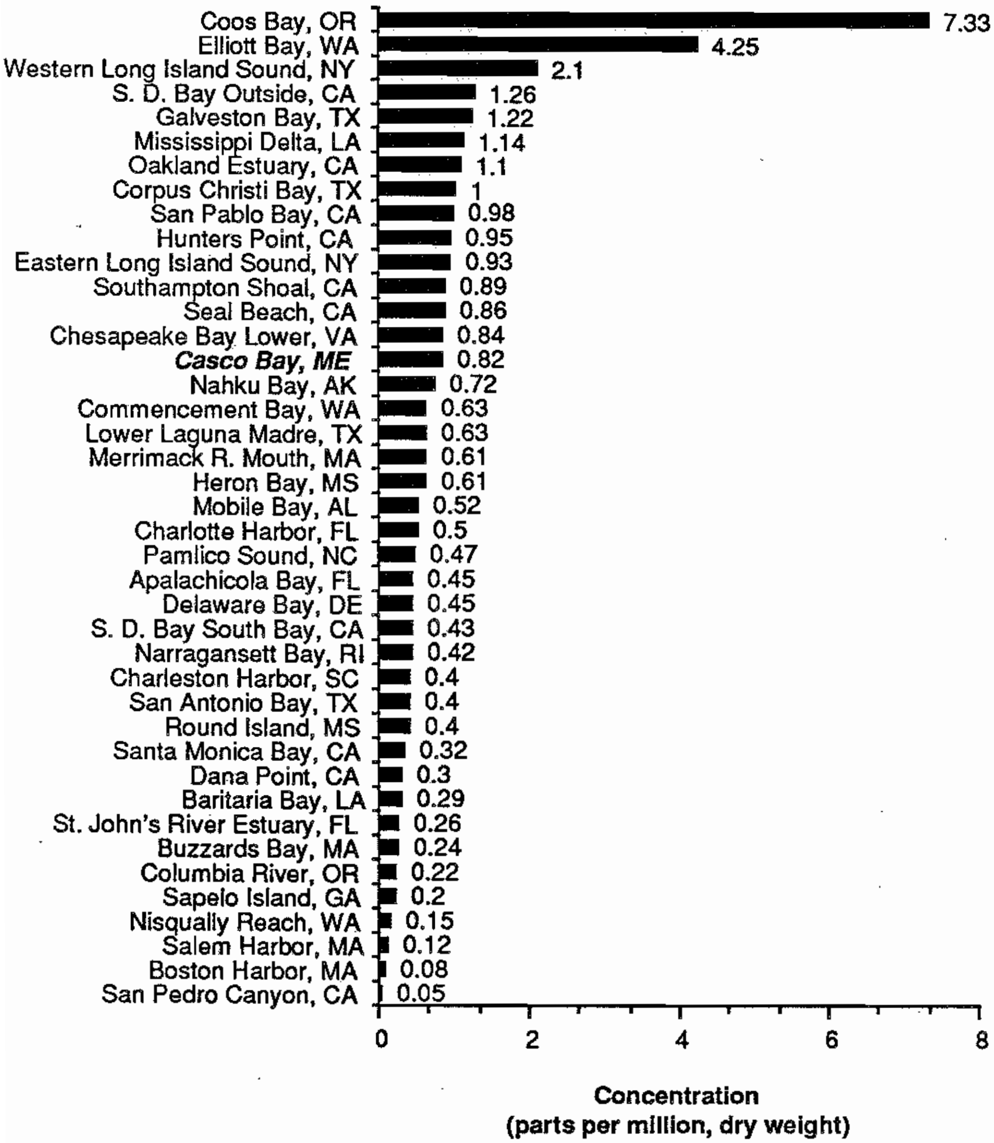
Concentrations of Copper in Fish Liver Tissue Sampled in NOAA's Status & Trends Program



Source: NOAA (1987c)

Figure 4-17

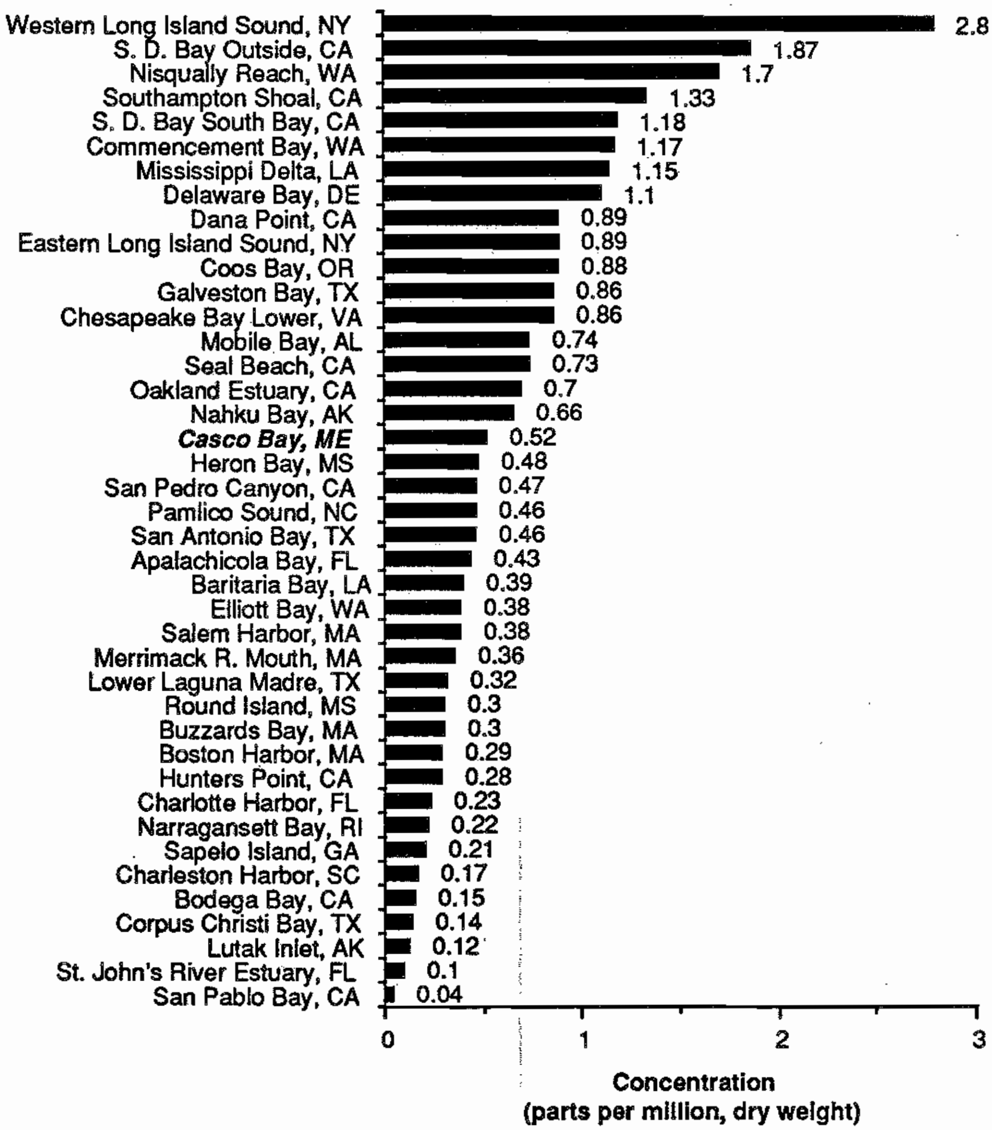
Concentrations of Tin in Fish Liver Tissue Sampled in NOAA's Status & Trends Program



Source: NOAA (1987c)

Figure 4-18

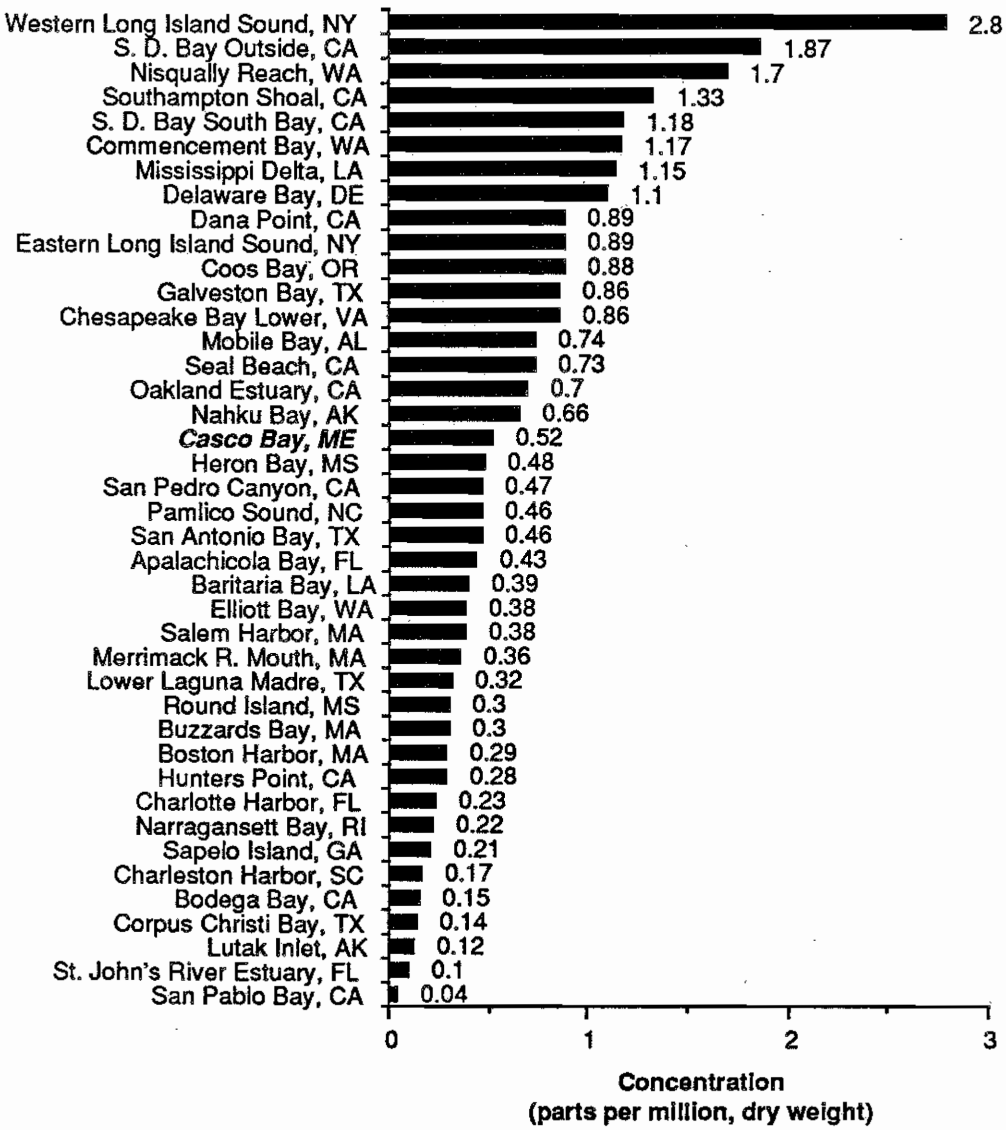
Concentrations of Cadmium in Fish Liver Tissue Sampled in NOAA's Status & Trends Program



Source: NOAA (1987c)

Figure 4-19

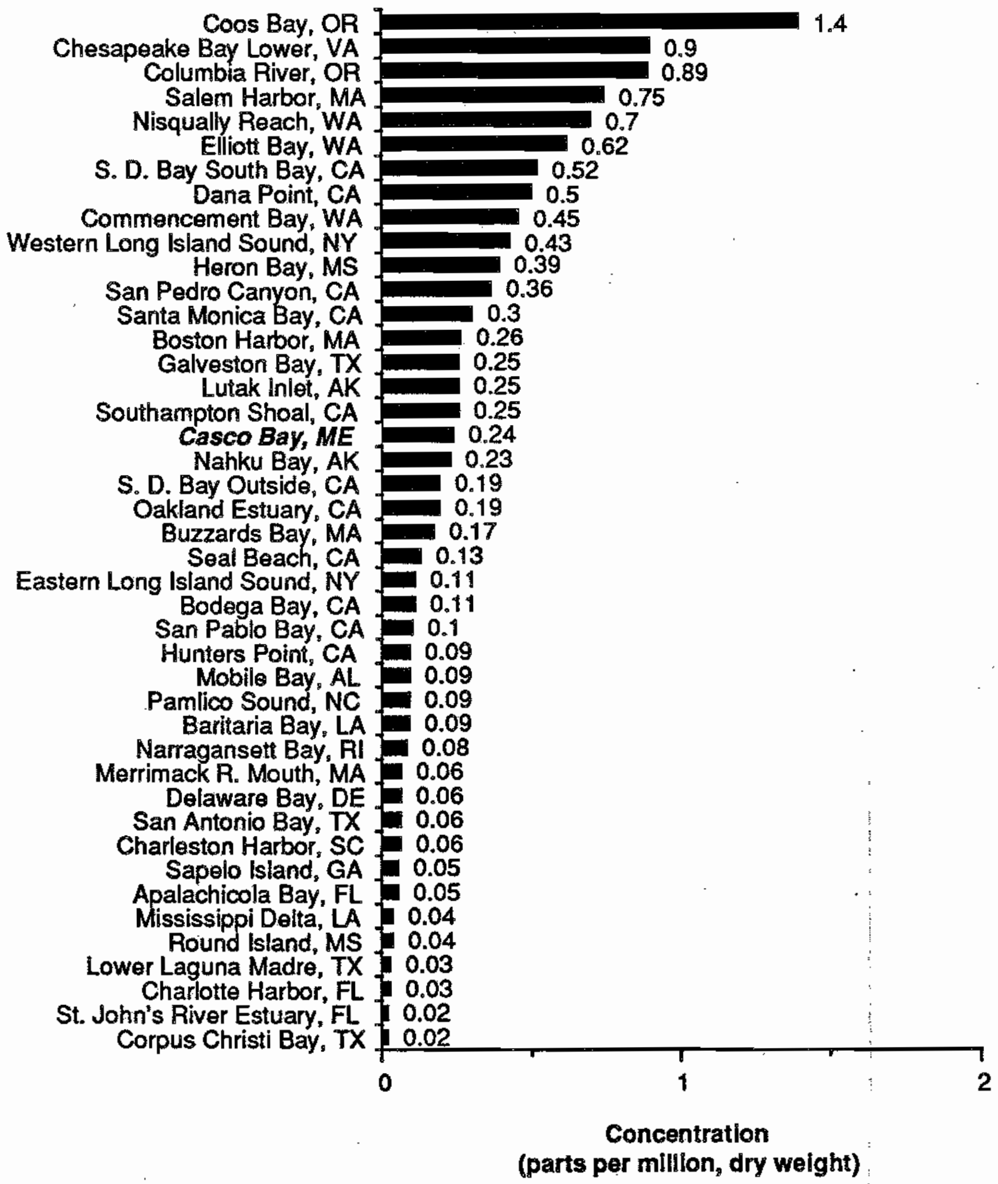
Concentrations of Nickel in Fish Liver Tissue Sampled in NOAA's Status & Trends Program



Source: NOAA (1987c)

Figure 4-20

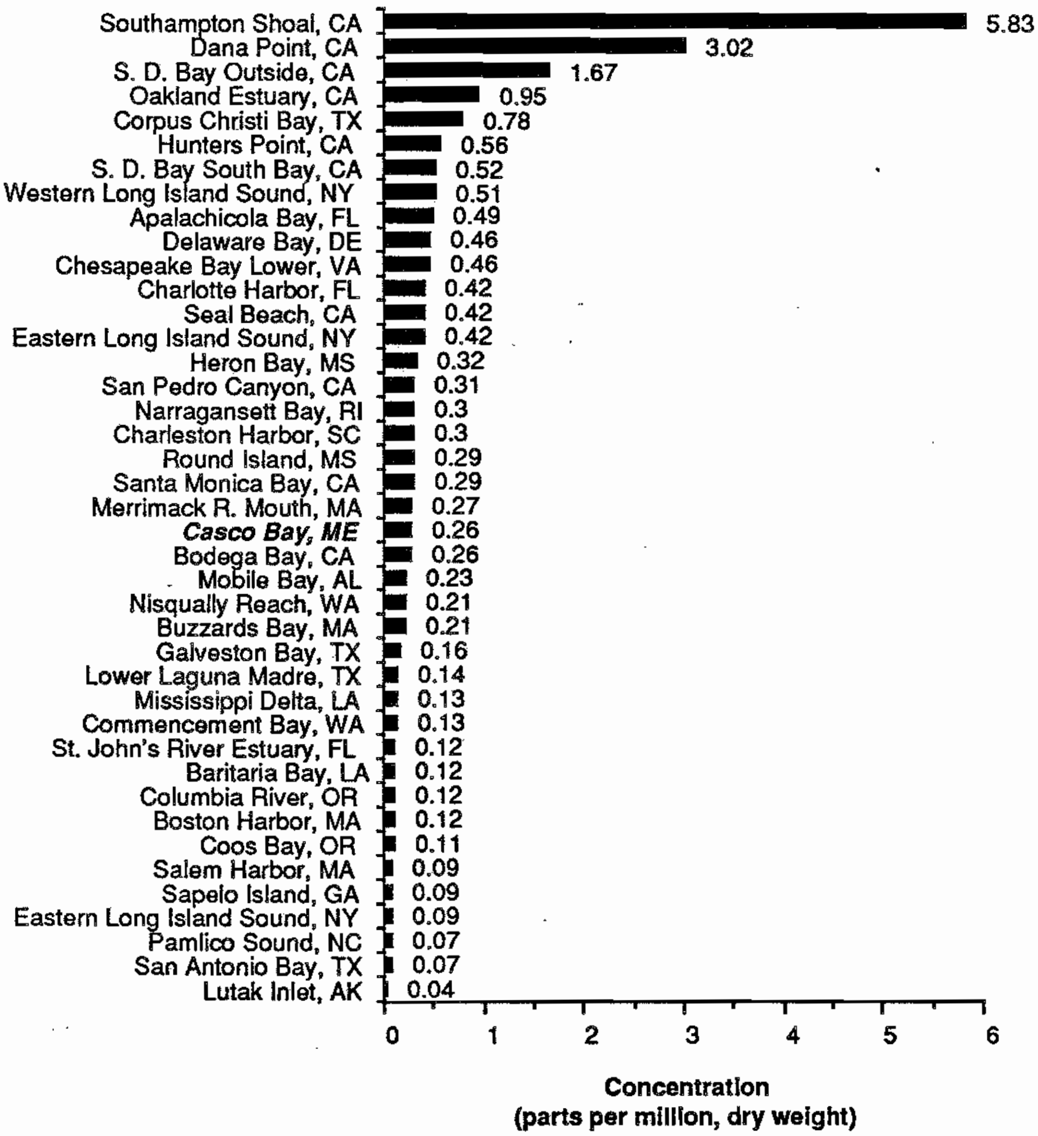
Concentrations of Chromium in Fish Liver Tissue Sampled in NOAA's Status & Trends Program



Source: NOAA (1987c)

Figure 4-21

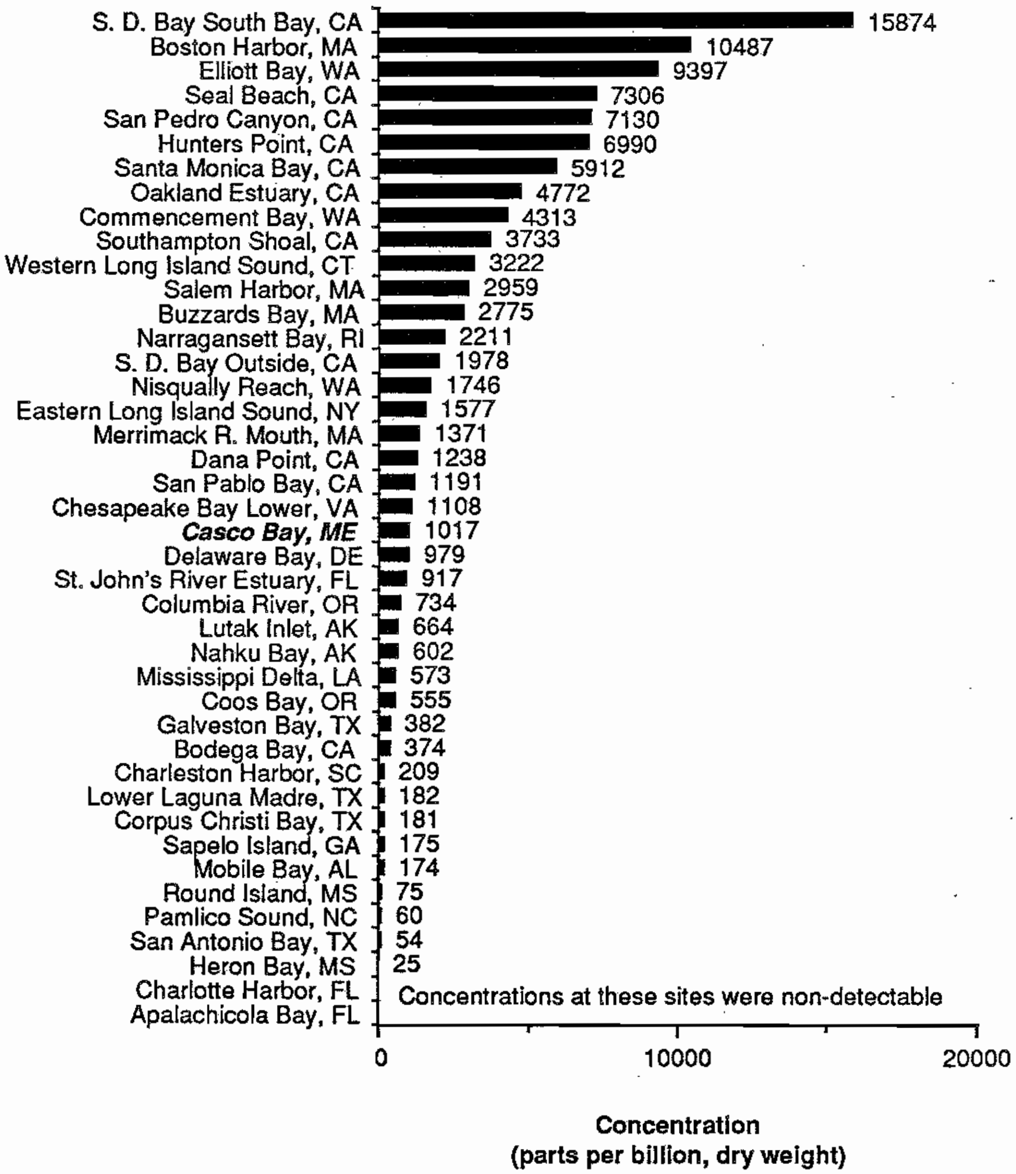
Concentrations of Mercury in Fish Liver Tissue Sampled in NOAA's Status & Trends Program



Source: NOAA (1987c)

Figure 4-22

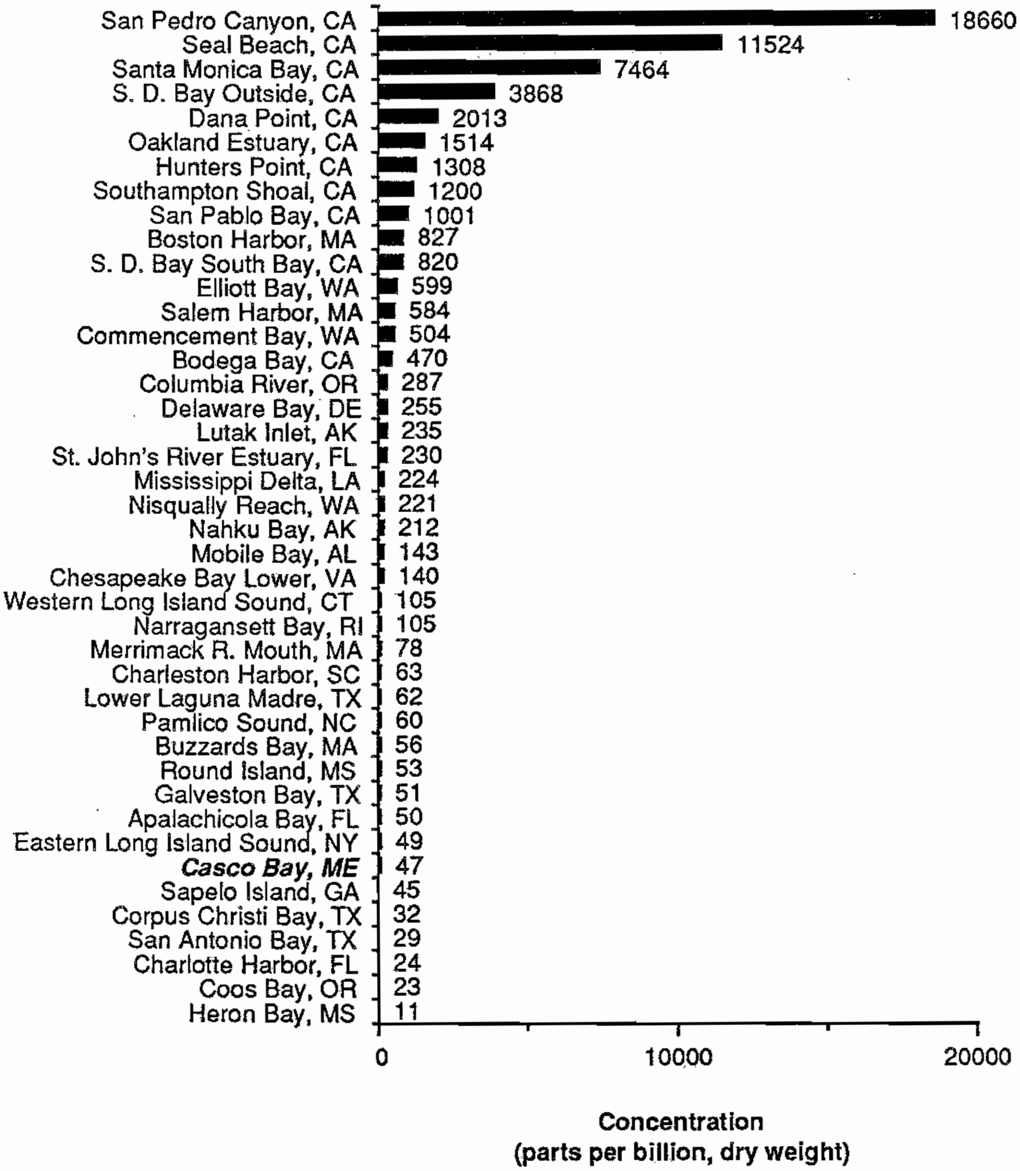
Concentrations of PCBs in Fish Liver Tissue Sampled in NOAA's Status & Trends Program



Source: NOAA (1987c)

Figure 4-23

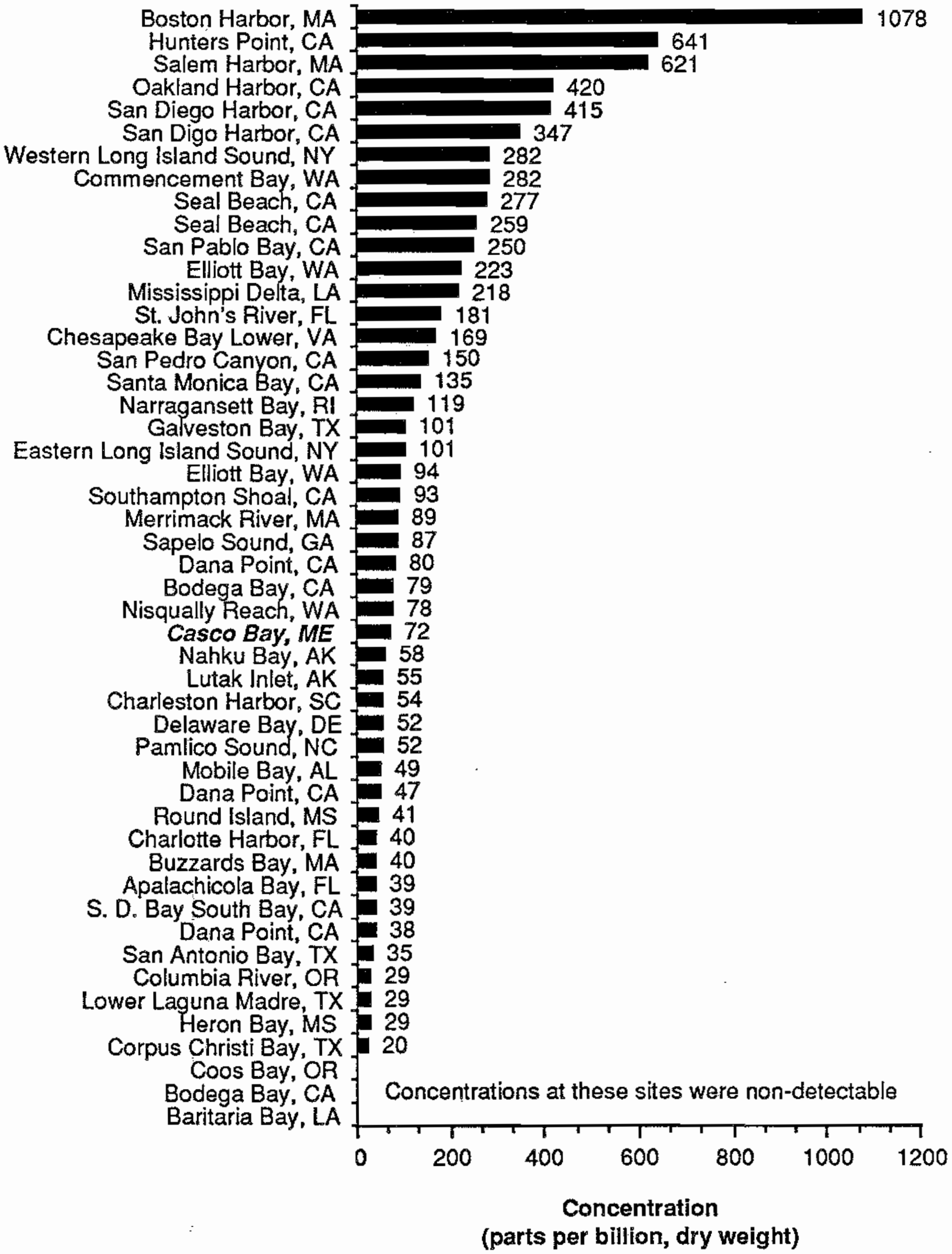
Concentrations of DDT in Fish Liver Tissue Sampled in NOAA's Status & Trends Program



Source: NOAA (1987c)

Figure 4-24

Concentrations of Total Chlorinated Pesticides in Fish Liver Tissue Sampled in NOAA's Status & Trends Program



Source: NOAA (1987c)

V. SOURCES OF POLLUTION IN CASCO BAY

As the preceding chapters make clear, the pollutants generated by the many activities that take place on the shores of Casco Bay do not simply go away. They show up in the water, the sediments, and even the marine life of the Bay. In this chapter we shift our attention from the Bay itself to the land and people around it, to examine the many sources of the pollutants in Casco Bay and possible ways of reducing the flow of pollutants into the Bay.

In the jargon of pollution control experts, sources of water pollution are divided into point sources and nonpoint sources. Point sources are facilities or locations where a specific pipe or other discharge site can be identified. Sewage treatment plants, industrial discharge pipes, and power plant cooling water discharges are examples of point sources. Publicly-owned sewage treatment facilities often take the place of additional point sources by treating more than just sanitary waste. In many systems industries discharge their wastes to the sewage collection system instead of discharging them directly to surface waters. These wastes are sent to the treatment plants, which are not specifically designed to treat industrial discharges, for treatment and discharge.

Nonpoint sources, on the other hand, are not as easily located — or, for that matter, as easily controlled. Rainwater carrying sediments from a field to a water body, and runoff carrying oil from the streets and parking lots of a city into a harbor, are examples of nonpoint sources.

In many urban areas the distinction between point and nonpoint sources is blurred when we discuss the runoff that pours off the streets each time it rains. Some of this urban runoff drains directly into a nearby stream, lake, or harbor, but much of it is collected by the city's drainage system. When this storm runoff is discharged via a stormwater discharge pipe, it has become a point source discharge.

The situation is further complicated in older cities where the storm drainage system and the sanitary sewer system are one and the same. In these "combined" sewerage systems, the same interceptor pipes carry both stormwater and sewage. When it rains, enormous volumes of runoff pour into the system, which is not designed to carry the entire combined volume of runoff and sewage. To prevent a surcharge of the system, which would result in flooding and/or sewage backups, such systems are designed with relief points, where the excess volume is discharged as "combined sewer overflows," or CSOs, which contain a mixture of raw sewage and street runoff.

Casco Bay is affected by discharges from every type of source described in the preceding paragraphs. Sewage treatment facilities, industrial discharges, urban runoff (both point runoff and nonpoint runoff), and CSOs, as well as discharges from tankers and other vessels and oil spills, contribute to the pollutant load that the Bay is asked to assimilate, day in and day out.

A. Point Sources

Table 5-1 shows the daily volumes of different types of wastewater that are dumped into Casco Bay and its immediate tributaries from point sources.

1. Sewage

From Table 5-1 we see that Casco Bay receives nearly 30 million gallons of treated sewage every day. Municipal facilities account for over 24 million gallons per day, or 81 percent of the total. The Portland Water District's treatment plants in Portland (15.1 million gallons per day) and Westbrook (2.2 million gallons per day) and the City of South Portland's facility (5.5 million gallons per day) are the largest municipal dischargers. Among non-municipal dischargers of sanitary wastes, S.D. Warren Company in Westbrook is by far the largest contributor, with a flow of 5 million gallons per day that accounts for 87 percent of the non-municipal total and 17 percent of the overall total. The four largest sanitary waste dischargers to Casco Bay — Portland, South Portland, S.D. Warren, and Westbrook — together discharge nearly 28 million gallons of treated sewage every day, all in the Greater Portland area.

The Portland and South Portland discharges deserve greater scrutiny. In addition to sanitary wastes, Portland's treatment system also receives industrial discharges from 107 firms, five of which fall under federal pretreatment requirements (Crawford, 1988). (Certain industries must treat their wastes before they discharge them to the sewer system, i.e., "pre-treat" them, under the federal Clean Water Act. Large cities or those with significant industrial contributions to their sewage flow, such as Portland, must have their own program to regulate these pretreaters.) Industrial contributions account for about one eighth of the flow in the Portland system (NOAA, 1987a). Portland and South Portland also have combined sewer systems. These systems, as noted above, discharge raw sewage and stormwater during times of wet weather. CSO discharges, which are difficult to quantify, are not included in Table 5-1. During wet weather, approximately 60 different CSO discharge points discharge raw sewage and stormwater from the Portland and South Portland systems into the Fore River, Back Cove, Portland Harbor, Casco Bay, the Presumpscot estuary, and other waters. These completely untreated discharges, although they are intermittent, can have serious water quality impacts, and are in fact blamed by many, including the Maine Department of Environmental Protection (1988), for the bulk of the water quality problems in the Portland/South Portland area.

2. Industrial Wastewater

One major discharger also contributes the bulk of the industrial wastewater discharged to Casco Bay (Table 5-1). S.D. Warren Company, a significant contributor of sanitary wastewater, also accounts for a large proportion of the total industrial discharge of over 23 million gallons per day. As the largest industrial dischargers, S.D. Warren discharges over 21 million gallons of industrial wastewater into Casco Bay every day. This represents 89 percent of the total industrial waste flow into the Bay.

3. Cooling Water

Casco Bay also receives large volumes of cooling water from power plants and industries (Table 5-1). In fact, the volume of cooling water discharged far exceeds the volume of sewage and industrial waste discharged to the Bay. However, cooling water discharges, while not monitored for pollutants as are sewage and industrial discharges, are not thought to contain significant concentrations of harmful pollutants. Operators of power plants sometimes use biocides to kill organisms in their intake water that tend to attach to the inside surfaces of pipes and interfere with water flow, and small amounts of metals (e.g., copper) may be added to the water as it passes through the plant. The concentrations of these substances in the discharge will likely be very low, but because of the enormous volumes discharged from some plants (such as the Central Maine Power facility in Yarmouth), the total amount discharged could conceivably be significant.

4. Oily Stormwater Discharges

The numerous oil-related facilities in the Portland area, as well as certain other facilities, discharge treated stormwater runoff under permits issued by the U.S. Environmental Protection Agency and the Maine Department of Environmental Protection (Table 5-2). The pollutant of concern in these permits is oil, and the runoff is treated in oil-water separators before being discharged. Like CSOs, these discharges are very difficult to quantify, but they are monitored from time to time for oil and grease, a measure of the total amount of oil in the discharge. The oil-water separators provide only a gross level of treatment, and cannot remove all of the oil present in the runoff. They are subject to various operational problems and imperfections, and can vary significantly in performance. Because of the extreme variability in the concentration of oil in the discharge, and the fact that the volume of the discharge is all but impossible to calculate, the amount of oil that flows into Casco Bay through these discharge points is unknown.

5. Bilge Waters and Spills

Portland is by far Maine's busiest port, handling a total of 308,631 metric tons of cargo in 1987. In the same year, nearly 61 million barrels of oil moved through the port in tankers and barges (excluding the movements of small harbor tankers that service vessels in the harbor) (Maine Department of Transportation, 1988). Over 80 percent of the petroleum products received in Maine ports are handled at the docks and terminals on Casco Bay. Sixty-five percent of the state's oil storage capacity at marine terminals is located on Casco Bay; over 90 percent of the Casco Bay total, or 60 percent of the state total, is west of Great Chebeague Island (Crawford, 1988). The bilge wash from the 154 tankers that visited the port in 1987 (Maine Department of Transportation, 1988) likely contributed significant amounts of oil to the waters of Casco Bay, although Clean Harbors Inc. of South Portland, a new company, currently handles bilge wash disposal.

B. Nonpoint Sources

Runoff from those parts of the coast where stormwater is not collected in sewer systems reaches the Bay as a potential nonpoint source of pollution.

Runoff from urban areas will contain a mixture of oil, heavy metals, nutrients, and organic material; runoff from non-urban areas will contain fewer toxic pollutants but higher amounts of some nutrients. Pesticides may be entering Casco Bay in runoff from agricultural and forested areas throughout the watershed.. Spills from oil pipelines represent another hard-to-quantify nonpoint source.

C. Pollutant Loadings

It is not possible to obtain precise values for the total amounts of various pollutants that enter the Bay from the many point and nonpoint sources mentioned above. Pollutant concentrations and discharge volumes are quite variable; often, they can only be estimated. However, it is possible to make "educated guesses" that can give us at least an idea of the relative contributions of different types of sources to the total pollution picture in Casco Bay.

The National Coastal Pollutant Discharge Inventory (NCPDI), maintained by NOAA, is a data base and computational framework that can be used to generate just this sort of information. When specific information about a given pollutant concentration or flow is not available, NCPDI relies on the best information that is available, e.g., "typical" concentrations and calculated runoff volumes. The results are a screening tool intended to assist in the assessment of relative pollutant contributions.

Table 5-3 presents estimates for annual pollutant loadings to Casco Bay from the NCPDI data base. It shows that Casco Bay receives a staggering load of toxic contaminants each year: nearly 77 tons of toxic metals, including nearly 24 tons of lead, over 7 tons of chromium, nearly 34 tons of zinc, and more than 1,500 tons of petroleum hydrocarbons. A closer look at the table allows us to pinpoint the major source categories for each contaminant.

Power plants account for a large part of the flow into the Bay, but because the concentrations of pollutants in the discharges are very low, the total pollutant contribution from power plants is quite low.

Point sources other than power plants, however, are significant contributors of most pollutants. Wastewater treatment plants and industries together account for more than 30 percent of the total annual loading to Casco Bay for all metals except lead, and for more than 40 percent of the total for all metals except arsenic, lead and copper. For cadmium, chromium, copper, and lead, the contributions of wastewater treatment plants and industries are roughly comparable.

Point sources are also significant contributors of petroleum hydrocarbons to Casco Bay, with almost half of the total loading attributable to wastewater treatment plants. Wastewater treatment plants pour over 750 tons of petroleum hydrocarbons into Casco Bay each year — over half of the total received by the Bay. As noted above, most of the point source pollutant loads enter the Bay in the Portland area.

Table 5-3 also reveals the large extent to which nonpoint sources, especially urban runoff, contribute to the pollution of the Bay. Urban runoff accounts for nearly all of the bacterial contaminants entering Casco Bay. A large part of the Bay's annual toxic load is also attributable to urban runoff. Urban runoff contributes nearly half of the petroleum hydrocarbons, over 80 percent of the lead, and a significant fraction of the arsenic, cadmium, copper, chromium, and mercury entering Casco Bay each year. As was the case for point source loadings, nearly all of the nonpoint loading occurs in the Greater Portland area.

Table 5-3 suggests a critical consideration for those concerned with reducing the flow of contaminants into Casco Bay: controlling point sources is important, but will not get the whole job done. Controlling pollutant loadings from urban runoff — that is, controlling discharges from CSOs and stormwater discharges, as well as runoff from oil facilities and other industrial areas — is at least as important as controlling pollution from large point sources.

A hard look at the pollution problems of Casco Bay will also have to consider the heavy tanker and barge traffic that makes Portland the largest oil port in Maine. These point sources are not even considered in Table 5-3, but may play a important role in the Bay's hydrocarbon pollution picture.

The area that will reap the greatest immediate benefit from better controls of both point and nonpoint sources is the area that is in the greatest need of help, the area that has borne the greatest burden so far — the Portland vicinity.

However, the ultimate benefits of better pollution control will go well beyond the Portland area. As many of the results in Chapters II, III and IV suggest, contamination problems in Casco Bay are not limited to Portland. Sediments and fish taken from outer Casco Bay also had high levels of many contaminants; shellfish closures are not limited to Portland and South Portland.

Most importantly, by

addressing the growing problem of pollution in Casco Bay now, the people that live and work on and around Casco Bay can avoid the fate of those that live further south. The results presented in the preceding chapters stand as a warning against complacency and inaction: the situation in Casco Bay is not as different from the situation in Salem and Boston and Providence as one might think. As the shores and islands of Casco Bay come under increasing pressure to follow the path of the much more urbanized and densely populated coastal areas of southern New England, the need for action will become even more critical. By acting promptly and aggressively, citizens and government officials can begin to reclaim Casco Bay and prevent the sort of environmental disasters that have befallen too many of their neighbors to the south.

Table 5-1

Point Source Discharges to Casco Bay

Waste Type	Daily Flow (millions of gallons)
Sewage/Sanitary Wastewater	29.8
Industrial Wastewater	23.5
Cooling Water	526.4

Sources: NOAA (1987a); U.S. Environmental Protection Agency (1988); Douglas Miller, Portland Water District (personal communication)

Table 5-2

Dischargers of Treated Stormwater Runoff to Casco Bay

Discharger	Receiving Water
Amoco Oil (South Portland)	Portland Harbor
BP Oil (South Portland)	Fore River
Brunswick Naval Air Station	Mere Brook
Central Maine Power (Portland)	Casco Bay
(South Portland)	Fore River
(Yarmouth)	Casco Bay
Chevron USA (South Portland)	Casco Bay
Clean Harbors/Williams Terminal	South Portland tidewaters
Cumberland Farms (South Portland)	Casco Bay
Exxon Co., USA (South Portland)	Fore River
General Electric (South Portland)	South Portland Harbor
Getty (South Portland)	South Portland Harbor
Greater Portland Resource Recovery	Stroudwater River
Gulf Oil (Portland)	Portland Harbor
Koch Fuels (South Portland)	Fore River/S. Portland H.
Merrill Industries	Fore River
Mobil Oil (South Portland)	Fore River/S. Portland H.
Northeast Petroleum (South Portland)	Fore River
Phoenix Resources (South Portland)	Casco Bay
Portland Pipe Line (South Portland)	Anthoine Creek
Texaco (South Portland)	Fore River
U.S. Naval Air Station	Casco Bay
U.S. Navy Fuel Depot (Harpswell)	Casco Bay
Webber Oil (Portland)	Portland Harbor

Sources: NOAA (1987a); U.S. Environmental Protection Agency (1988)

Table 5-3

Estimated Annual Pollutant Loadings to Casco Bay
from the National Coastal Pollutant Discharge Inventory

Pollutant	Units	WWTPs	Industries*	Power Plants**	Urban Runoff	Other Runoff	Totals
Flow	10^9 gallons	8.78	12.86	190.0	20.15	47.45	279.24
Biochemical Oxygen Demand	tons	867.7	1435.0	—	1467.2	739.7	4509.6
Total Suspended Solids	tons	1047.6	3110.4	46.8	16,815	67,376	88395.8
Nitrogen	tons	367.4	332.9	—	262.7	416.3	1379.3
Phosphorus	tons	305.9	135.1	—	43.8	13.9	498.7
Fecal Coliform Bacteria	cells	4.1×10^{10}	3.5×10^5	—	3.5×10^{16}	—	3.5×10^{16}
Metals							
Arsenic	tons	0.410	0.046	0.109	0.599	0.176	1.340
Cadmium	tons	0.156	0.173	0.014	0.236	0.027	0.606
Chromium	tons	1.781	2.103	0.094	1.988	1.409	7.375
Copper	tons	1.691	1.487	1.720	4.351	0.674	9.923
Lead	tons	1.623	1.076	0.016	19.081	2.013	23.809
Mercury	pounds	37.8	14.7	3.7	31.6	0.01	87.81
Zinc	tons	5.074	8.565	1.093	17.788	1.225	33.745
Petroleum Hydrocarbons	tons	756.7	12.2	0.05	738.6	—	1507.6
PCBs	pounds	0.01	—	—	10.8	—	10.8
Chlorinated Pesticides	pounds	32.3	—	—	8.9	66.0	107.2

* Process, sanitary, and cooling water flows.
** Process and cooling flows (no sanitary flows from power plants).
*** Total includes only only those sources listed by NOAA (1987a); atmospheric deposition is not included.

Sources: NOAA (1987a); U.S. Environmental Protection Agency (1988); some loadings calculated from values provided by Daniel Farrow, NOAA (personal communication)

VI. RECOMMENDATIONS

Effective action by citizens and government can turn the tide in Casco Bay. Instead of a slow, downward spiral toward environmental degradation, Casco Bay can experience a recovery from the problems that are already present and continue to serve as a vital, productive resource for the whole region.

A comprehensive solution for the problems that are beginning to appear in Casco Bay would include dozens of specific steps by federal, state, and local governments, and by individual citizens. Following are some broader recommendations that emphasize a small number of actions that can be taken in the short term to begin to build both a better knowledge base about the Bay and the momentum that will be required to ensure the protection of Casco Bay over the long term.

- The state and EPA should take immediate action against the problem of combined sewer overflows in the Portland/South Portland area. The Portland Water District, the City of South Portland, and the City of Portland should be required to develop plans that will result in the reduction or elimination of pollutant flows from their combined total of nearly 60 overflow points.

- The Portland Water District should take effective steps to reduce the levels of fecal coliform bacteria in the discharge from its Portland plant. The plant has consistently violated the limits in its discharge permit for bacteria for over three years..

- The state should set up a Casco Bay Environmental Trust Fund, to which penalties from state, federal, or citizen-initiated enforcement actions against firms or municipalities that violate water pollution laws would be directed. The Fund would finance studies and remedial actions around the Bay.

- The state and EPA should immediately begin to devote additional resources to the problems of inner Casco Bay, especially Portland and South Portland Harbors. They should develop a detailed plan for improving the water quality of that area so that it meets state water quality standards.

- The U.S. Food and Drug Administration should institute systematic monitoring of fish and shellfish in markets and in the ocean, in order to maintain public confidence in the safety of seafood and to establish an early warning system. In addition the federal government should set safety standards for the many unregulated contaminants now found in fish and shellfish, including lead, cadmium, various hydrocarbons, and non-chlorinated pesticides. The New England states should expand their spot checking to ensure that the federal standards are being met.

- The state government and Maine's congressional delegation should request that Casco Bay be made part of EPA's national estuary program, so that the comprehensive study of the Bay could receive federal funds as well as state funds.

- The National Oceanic and Atmospheric Administration should add Casco Bay to its Mussel Watch program. This would provide consistent comparative monitoring of contaminant levels in these sentinel organisms.

- The Departments of Environmental Protection and Marine Resources, and the U.S. Environmental Protection Agency's regional office in Boston, should initiate a comprehensive study of the Bay and of the many factors, especially human activities, that affect environmental quality in the Bay.

REFERENCES

Armstrong, P.B., C.M. Hanson and H.E. Gaudette. 1976. Minor elements in sediments of Great Bay estuary, New Hampshire. Environmental Geology 1: 207-214

Boehm, P.D., W. Steinhauer and J. Brown. 1984. Organic pollutant biogeochemical studies: northeast U.S. marine environment. Final Report for Contract #NA-83-FA-C-00022, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Sandy Hook Laboratory, Highlands, N.J.

Broutman, M.A. and D.L. Leonard. 1986. National Estuarine Inventory: Classified Shellfish Growing Waters by Estuary. Rockville, Maryland: Strategic Assessment Branch, National Oceanic and Atmospheric Administration.

Capuzzo, J.M., A. McElroy and G. Wallace. 1987. Fish and Shellfish Contamination in New England Waters: An Evaluation and Review of the Available Data on the Distribution of Chemical Contaminants. Washington, D.C.: Coast Alliance.

Christie, N.D. 1976. A numerical analysis of the distribution of a shallow littoral sand macrofauna along a transect at Lamberts Bay, South Africa. Trans. R. Soc. S Afr. 42: 149-172.

Conservation Law Foundation of New England. 1988. Lost Harvest: Sewage, Shellfish, and Economic Losses in the New Bedford Area. Boston.

Crawford, T. 1988. Possible sources of polycyclic aromatic hydrocarbon: Pollution in surficial sediments of Casco Bay, Maine and the U.S. Clean Waters Act. Unpublished manuscript.

Crowley, M. 1986. "Penobscot Bay benthos not in pristine shape." The Republican Journal, July 3, 1986, pp. 1,2.

Farrington, J.W. 1983. Bivalves as sentinels of coastal chemical pollution: The Mussel (and Oyster) Watch. Oceanus 26(2): 18-29.

Farrington, J.W., J.M. Capuzzo, T.M. Leschine, and M.A. Champ. 1982a. Ocean dumping. Oceanus 25: 39-50.

Farrington, J.W., E.D. Goldberg, R.W. Risebrough, J.H. Martin, and V.T. Brown. 1983. U.S. "Mussel Watch" 1976-1978: An overview of the trace-metal, DDE, PCB, hydrocarbon, and artificial radionuclide data. Environmental Science and Technology 17: 490-496.

Farrington, J.W., R.W. Risebrough, P.L. Parker, A.C. Davis, B. de Lappe, J.K. Winters, D. Boatwright and N.M. Frew. 1982b. Hydrocarbons, polychlorinated biphenyls, and DDE in mussels and oysters from the U.S. coast, 1976-1978 — the Mussel Watch. Technical Report WHOI-82-42, Woods Hole Oceanographic Institution, Woods Hole, Mass.

Field, J.G. 1971. A numerical analysis of changes in the soft bottom fauna along a transect across False Bay, South Africa. Journal of Experimental Marine Biology and Ecology 7: 215-253.

Goldberg, E.D., V.T. Bowen, J.W. Farrington, G. Harvey, J.H. Martin, P.L. Parker, R.W. Risebrough, W. Robertson, E. Schneider and E. Gamble. 1978. The Mussel Watch. Environmental Conservation 5(2): 101-125.

Goldberg, E.D., M. Koide, V. Hodge, A.R. Flegal and J. Martin 1983. U.S. Mussel Watch: 1977-78 results on trace metals and radionuclides. Estuarine, Coastal and Shelf Science 16: 69-93.

Grieg, R.A., R.N. Reid and D.R. Wenzloff. 1977. Trace metal concentrations in sediments from Long Island Sound. Marine Pollution Bulletin 8: 183-188.

Grieg, R.A. and G. Sennefelder. 1985. Metals and PCB concentrations in mussels from Long Island Sound. Bulletin of Environmental Contamination and Toxicology 35: 331-334.

Johnson, A.C., P.F. Larsen, D.F. Gadbois and A.W. Humanson. 1985. The distribution of polycyclic aromatic hydrocarbons in the surficial sediments of Penobscot Bay (Maine, USA) in relation to possible sources and to other sites worldwide. Marine Environmental Research 15:1-16.

Laflamme, R.E. and R.A. Hites. 1978. The global distribution of polycyclic aromatic hydrocarbons in recent sediments. Geochimica et Cosmochimica Acta 42: 289-303.

Lannin, J. 1986. "Lead in crabs raises fears of coastal pollution." Maine Sunday Telegram, January 5, 1986.

Larsen, P.F. 1979. The shallow-water macrobenthos of a northern New England estuary. Marine Biology 55: 69-78.

Larsen, P.F. and L.F. Doggett. 1978. Benthos study of the Sheepscot River estuary. Bigelow Laboratory Technical Report 10-78, Bigelow Laboratory for Ocean Sciences, West Boothbay Harbor, Maine.

Larsen, P.F., D.F. Gadbois, A.C. Johnson and L.F. Doggett. 1983a. PCB monitoring in the Casco Bay region of the Gulf of Maine. Marine Pollution Bulletin 14(1): 32.

Larsen, P.F., D.F. Gadbois, A.C. Johnson and L.F. Doggett. 1983b. Distribution of polycyclic aromatic hydrocarbons in the surficial sediments of Casco Bay, Maine. Bulletin of Environmental Contamination and Toxicology 30: 530-535.

Larsen, P.F., D.F. Gadbois, A.C. Johnson and R.F. Maney. 1984. On the appearance of PCBs in the surficial sediments of Casco Bay, Maine. Marine Pollution Bulletin 15(12): 452-453.

Larsen, P.F., A.C. Johnson and L.F. Doggett. 1983c. Environmental benchmark studies in Casco Bay - Portland Harbor, Maine, April 1980. NOAA Technical Memorandum NMFS-F/NEC-19. Northeast Monitoring Program, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Center, Woods Hole, Mass.

Larsen, P.F., V.S. Zdanowicz, A.C. Johnson and L.F. Doggett. 1983d. Trace metals in New England marine sediments: Casco Bay, Maine, in relation to other sites. Chemistry in Ecology 1: 191-200.

Lyons, W.B., P.B. Armstrong and H.E. Gaudette (in press). Sedimentary trace metal concentrations in northern New England estuaries. Sea Grant Publication. Durham, New Hampshire: University of New Hampshire.

Lyons, W.B. and W.F. Fitzgerald. 1980. Trace metal fluxes to near-shore Long Island Sound sediments. Marine Pollution Bulletin 11: 157-161.

Mackay, N.J., R.J. Williams, J.L. Kacprzac, M.N. Kazacos, A.J. Collins and E.H. Auty. 1975. Heavy metals in cultivated oysters (Crassostrea commercialis = Saccostrea cucullata) from the estuaries of New South Wales. Australian Journal of Marine and Freshwater Research 26: 31-46.

Maine Department of Environmental Protection. 1988. State of Maine 1988 Water Quality Assessment. Bureau of Water Quality Control.

Maine Department of Marine Resources. 1987. Maps of shellfish closures within Casco Bay. Obtained from Kerry M. Lyons.

Maine Department of Transportation. 1988. Monthly traffic summaries for Portland, 1987. Obtained from Leroy Sawtelle.

Maurer, D., L. Watling, P. Kinner, W. Leathem and C. Wethe. 1978. Benthic invertebrate assemblages of Delaware Bay. Marine Biology 45: 65-78.

Murchelano, R.A. 1985. Fish as sentinels of environmental health. Unpublished manuscript.

Murchelano, R.A., L. Despres-Patanjo and J. Ziskowski. 1986. A histopathologic evaluation of gross lesions excised from commercially important North Atlantic marine fishes. NOAA Technical Report NMFS-37. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Center, Woods Hole, Mass.

Murchelano, R.A. and R.E. Wolke. 1985. Epizootic carcinoma in the winter flounder, Pseudopleuronectes americanus. Science 228: 587-589.

National Oceanic and Atmospheric Administration. 1981. Annual NEMP Report on the Health of the Northeast Coastal Waters of the United States, 1980. NOAA Technical Memorandum NMFS-F/NEC-10. Northeast Monitoring Program, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Center, Woods Hole, Mass.

National Oceanic and Atmospheric Administration. 1983. Annual NEMP Report on the Health of the Northeast Coastal Waters of the United States, 1981. NOAA Technical Memorandum NMFS-F/NEC-20. Northeast Monitoring Program, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Center, Woods Hole, Mass.

National Oceanic and Atmospheric Administration. 1985. Annual NEMP Report on the Health of the Northeast Coastal Waters of the United States, 1982. NOAA Technical Memorandum NMFS-F/NEC-35. Northeast Monitoring Program, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Center, Woods Hole, Mass.

National Oceanic and Atmospheric Administration. 1987a. National Coastal Pollutant Discharge Inventory data. Personal communication with Daniel R.G. Farrow, Strategic Assessment Branch.

National Oceanic and Atmospheric Administration. 1987b. National Estuarine Inventory Data Atlas — Volume 2: Land Use Characteristics. Rockville, Md.: Strategic Assessment Branch.

National Oceanic and Atmospheric Administration. 1987c. National Status and Trends Program for Marine Environmental Quality: Progress Report — A Summary of Selected Data on Chemical Contaminants in Tissues Collected During 1984, 1985, and 1986. NOAA Technical Report NOS OMA 38. Rockville, Md.: Office of Oceanography and Marine Assessment.

National Oceanic and Atmospheric Administration. 1987d. National Status and Trends Program for Marine Environmental Quality: Progress Report and Preliminary Assessment of Findings of the Benthic Surveillance Project — 1984. Rockville, Md.: Office of Oceanography and Marine Assessment.

National Oceanic and Atmospheric Administration. 1987e. Unpublished data from National Status and Trends Program, Benthic Surveillance Project. Personal communication from Jeannette Bass.

National Oceanic and Atmospheric Administration/U.S. Food and Drug Administration. 1985. 1985 National Shellfish Register of Classified Estuarine Waters. Rockville, Maryland/Washington, D.C.

National Research Council. 1985. Oil in the Sea: Inputs, Fates and Effects. Washington, D.C.: National Academy Press.

New England River Basins Commission. 1981. Presumpscot River Basin/Casco Bay Overview. Boston, Mass.

O'Connor, J.S. 1972. The macrofauna of Moriches Bay, New York. Biol. Bull. 142: 84-102.

Olsen, L.A. 1984. Effects of contaminated sediment on fish and wildlife: review and annotated bibliography. U.S. Fish and Wildlife Service, FWS/OBS-82/66.

Palmieri, J., H. Livingston and J.W. Farrington. 1984. U.S. "Mussel Watch" Program: Transuranic Element Data from Woods Hole Oceanographic Institution 1976-1983. Technical Report WHOI-84-28/CRC-84-5. Woods Hole, Mass.: Woods Hole Oceanographic Institution/Coastal Research Center.

Pearce, J.B. and A.C. Johnson. 1986. A not so distant warning. Habitat 3(7): 30-33.

Plante, J.M. 1986. Commercial Fisheries News, March 1986.

Resources for Cape Ann. 1982. The Costs of Pollution: The Shellfish Industry and the Effects of Coastal Water Pollution. Gloucester, Mass.

Rosenberg, R. 1973. Succession in benthic macrofauna in a Swedish fjord subsequent to the closure of a sulphite paper mill. Oikos 24: 244-258.

Rowe, G.T., P.T. Polloni and J.I. Rowe. 1972. Benthic community parameters in the lower Mystic River. Int. Rev. ges. Hydrobiol. 57: 573-584.

Sindermann, C.J. 1980. The use of pathological effects of pollutants in marine environmental monitoring programs. In A.D. McIntyre and J.B. Pearce (eds.), Biological Effects of Pollution and Problems of Monitoring, Rapports et Proces-Verbaux des Reunions, Volume 179, pp. 129-134. Copenhagen: Conseil International pour L'Exploration de la Mer.

Susani, L. 1986. Liver Lesions in Feral Fish: A Discussion of their Relationship to Environmental Pollutants. NOAA Technical Memorandum NOS OMA 27. Rockville, Md.: National Oceanic and Atmospheric Administration, National Ocean Service.

U.S. Environmental Protection Agency. 1988. Discharge permit data obtained from Permits Processing Section, Region I, Boston.

U.S. Food and Drug Administration. 1986. National Shellfish Sanitation Program, Manual of Operation — Part 1: Sanitation of Shellfish Growing Areas. Austin, Texas: Interstate Shellfish Sanitation Conference.

Zdanowicz, V.S., D.F. Gadbois and M.W. Newman. 1986. Levels of organic and inorganic contaminants in sediments and fish tissues and prevalences of pathological disorders in winter flounder from estuaries of the northeast United States, 1984. In Oceans '86 Conference Record, Volume 2, pp. 578-585. Washington, D.C.: Marine Technology Society.