TOXIC POLLUTION

CASCO BAY PLAN

TOXIC POLLUTION
in Casco Bay

To reduce toxic pollution in Casco Bay, the Management Committee established the following goal and objectives:

GOAL:

Reduce toxic pollution in Casco Bay.

OBJECTIVES:

- *The accumulation of toxics in the sediment and biota shall be reduced.*
- *Seafood harvested from Casco Bay shall be acceptable for consumption.*
- *Contamination in Casco Bay shall not have an adverse effect on the biological community.*

Introduction

Sediments can act as an indicator of overall environmental contamination in marine ecosystems because many toxic contaminants, which do not dissolve readily in water, become attached to sediments and organic material and settle to the bottom.

When scientists first took a careful look at the bottom sediments of Casco Bay in 1980, their findings occasioned some concern. What had been considered a relatively uncontaminated environment actually contained a broad array of toxic contaminants: polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAHs), lead, cadmium, copper, nickel, chromium, and zinc.

Further studies of the Casco Bay floor were conducted in 1989, 1991, and 1994, providing more data on the types, potential sources, and location of toxic pollutants. This chapter outlines the extent of the toxic pollution problem and prelimi-

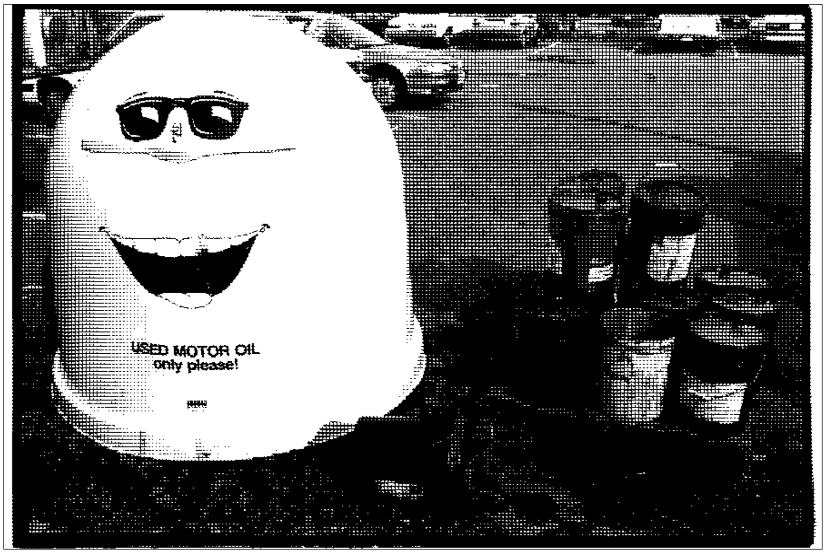


photo by Christopher Ayres

nary measures taken to address it, as well as recommendations for additional action. Toxic contaminants may become concentrated in plants and animals, a process known as bioaccumulation.

Types of Toxic Pollution

The toxicity of a substance depends on how it is structured, how much is present, and how readily it can be absorbed by living organisms. Mercury, for example, is relatively nontoxic in its elemental form, but highly toxic in other chemical forms. While essential for a healthy diet in low concentrations, metals such as copper, nickel, and zinc can be lethal in high doses. Some species absorb toxic chemicals more readily than others. Toxics can also combine to produce a "cocktail effect" that is more harmful than exposure to single substances. The presence of toxics in animal tissues is not necessarily hazardous to the animal.

There are two primary types of toxic pollutants: organic chemicals and heavy metals. The former are bonded forms of carbon, hydrogen, and other atoms. Many occur naturally and several hundred thousand have been developed by chemists for use in oils, paints, pesticides, cleaners, solvents, insulation, fire retardants, and other products. *Organic compounds found in the sediments of Casco Bay include PCBs, PAHs, pesticides, butyltins (organometallic compounds), dioxins (organochlorines), and furans.* Organic chemicals eventually break down into hydrogen and oxygen, but this breakdown is slow; during the interim, they can remain toxic.

Heavy metals are metallic elements that in pure form are literally heavy (dense), such as lead, mercury, arsenic, cadmium, silver, nickel, selenium, chromium, zinc, and copper. Many heavy metals found in Casco Bay result from contemporary or historical discharges from vehicles and industry. Others naturally occur in rocks and minerals and leach into the environment over time. Because metals are elements and generally do not break down further into less harmful chemicals, they can accumulate where they are released, provided they are not disturbed and moved elsewhere.

In 1991, the Casco Bay Estuary Project commissioned a baseline study to provide a "snapshot" of sediment contamination levels in Casco Bay, using state-of-the-art analytical methods (Kennicutt *et al.,* 1992).

As Table 5-1 indicates, the bay registered potentially toxic levels of PCBs and PAHs and high levels of four heavy metals compared to other estuaries nationally.

Two classes of organic chemicals — PCBs and PAHs — are present at potentially toxic levels to bottom-dwelling animals (benthos) in the inner Fore River of Casco Bay (Long and Morgan, 1990; and Kennicutt *et al.,* 1992). PAH levels are considered high in several locations when compared to other bays around the country (O'Connor, 1990).

Table 5-1

Toxic Chemicals in Casco Bay

TOXICITY	CHEMICAL	LOCATIONS
POTENTIALLY TOXIC LEVELS	PCBs Hydrocarbons (PAHs)	Fore River (Inner) Fore River (Outer)
HIGH COMPARED TO OTHER BAYS NATIONALLY	Hydrocarbons (PAHs)	Fore River Back Cove Inner Bay East Bay Cape Small Outer Bay
	Lead	Fore River Back Cove
	Cadmium	Back Cove East Bay
	Mercury	Inner Fore River Back Cove
	Silver	Back Cove

Sources: Kennicutt **et al.*****, 1992; O'Connor, 1990; Long and Morgan, 1990***

Four heavy metals — lead, cadmium, mercury, and silver — are considered "high" in some locations in Casco Bay when compared to bays nationwide (O'Connor, 1990). However, these metals are not present at a level that would be considered toxic to benthos in the bay (Kennicutt *et al.,*1992). Six — arsenic (As), chromium (Cr), copper (Cu), nickel (Ni), selenium (Se), and zinc (Zn) — are not considered "high" on a national scale (O'Connor, 1990).

The pesticide DDT is present in relatively low concentrations in Casco Bay. Other pesticides — aldrin, BHC, dieldrin, endosulfan (I, II, and sulfate), endrin, endrin aldehyde, heptachlor, heptachlor epoxide, toxaphene, and hexachlorobenzene — were not detectable (*i.e.,* less than 0.25 part per billion) or barely detectable (Kennicutt *et al.,* 1992).

Butyltins, PCDD/PCDF (*i.e.*, dioxins, furans), and planar PCBs were detected in sediments from all areas of Casco Bay in 1994; however, concentrations were relatively low when compared to other areas nationally (Wade *et al.,* 1995).

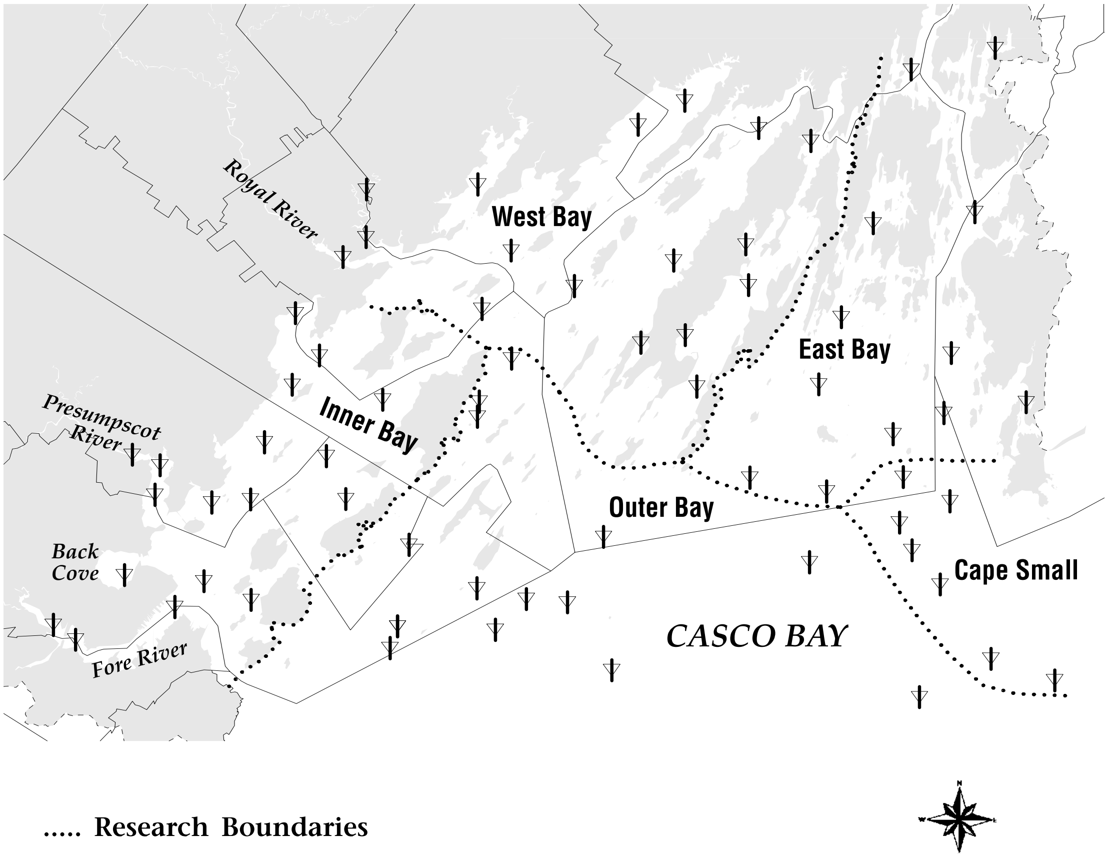
Figure 5-1 shows locations sampled in the 1991 study of sediment contamination in Casco Bay. This map shows place names and the regions referred to in Table 5-1 and the following text.

Sources of Toxic Pollution

When it rains or snows, the soil particles and organic matter in runoff water pick up oils, metals, pesticides, and other contaminants. The contaminants adhere to the soil or organic matter rather than mixing readily into water. Once in the bay, organic contaminants may float to the surface to avoid water, forming a sea-surface microlayer. Other contaminants adhere to sediments and particles of organic detritus. Initially, sediment and particles settle to the sea bottom near where they enter marine waters, though over time they may get dispersed by tides, currents, storms, or dredg-

Figure 5-1

Sediment Sample Locations, 1991



..... Research Boundaries

Sediment Sample Locations, 1991

Sources: Casco Bay Estuary Project and Texas A&M University

ing. Water that lies over contaminated sediments may even test as clean because the toxics tend not to be water-soluble.

The most common toxic pollutants in Casco Bay are PAHs, a class of organic compounds primarily found in fossil fuels such as oil or coal. Most PAHs found in the sediments of the bay come from combustion sources (i.e.*, car and truck exhausts, and industrial and residential chimneys)* (Kennicutt *et al.,*1992). PAHs enter the bay through combined sewer overflows and storm drains (particularly those that drain roads and parking lots), licensed discharges, old industrial sites or dumps (Hawes, 1993), spills, deposition of atmospheric pollution from urban sources in and upwind of Maine, and highly developed residential and industrial areas in the bay watershed (Kennicutt *et al.,* 1992).

Hydrocarbon pollution, another source of PAHs, is aggravated by the roughly 70 reported spills each year in Maine coastal waters. Most spills are small, averaging 20 gallons (Report of the Commission to Study Maine's Oil Spill Cleanup, 1990), with the average "most probable" spill in Portland Harbor being a 45-gallon diesel oil spill from a fishing vessel overfilling its tanks (Maine and New Hampshire Area Contingency Plan). The largest recorded oil spill in Casco Bay was the *Tamano* spill in July 1972, which spilled an estimated 100,000 gallons of #6 (heavy industrial) fuel. The oil's principal impact was felt on Long Island and other islands in the bay.

Metals in Casco Bay are concentrated in and around Portland Harbor. Sources are numerous, including vehicle emissions, licensed discharges, air deposition, and historic industrial sites. Discharge of toxic pollutants in the bay region began in the 19th century with manufacturing facilities, such as railroad and shipbuilding yards, tanneries, and metal foundries, which released heavy metals into waters and emitted oil-related compounds from smokestacks. At the time, there was no knowledge of how toxic pollutants affected the environmental or public health, and therefore no treatment.

Evidence of these early industries remains in the bay. At the site of a former coal gas works plant, which operated in Portland for almost a century, coal tar can still be seen oozing into the Fore River estuary. Sediments collected near this site have a visible oily sheen and register high levels of combustion-derived oils (PAHs). Digging and construction on historically contaminated sites can unearth and redistribute toxic chemicals through runoff. DDT and chlordane, two banned pesticides, can still be found in the bay, possibly due to leakage from old dumps, illegal disposal by residents or businesses, runoff from residential areas, and deposition from air.

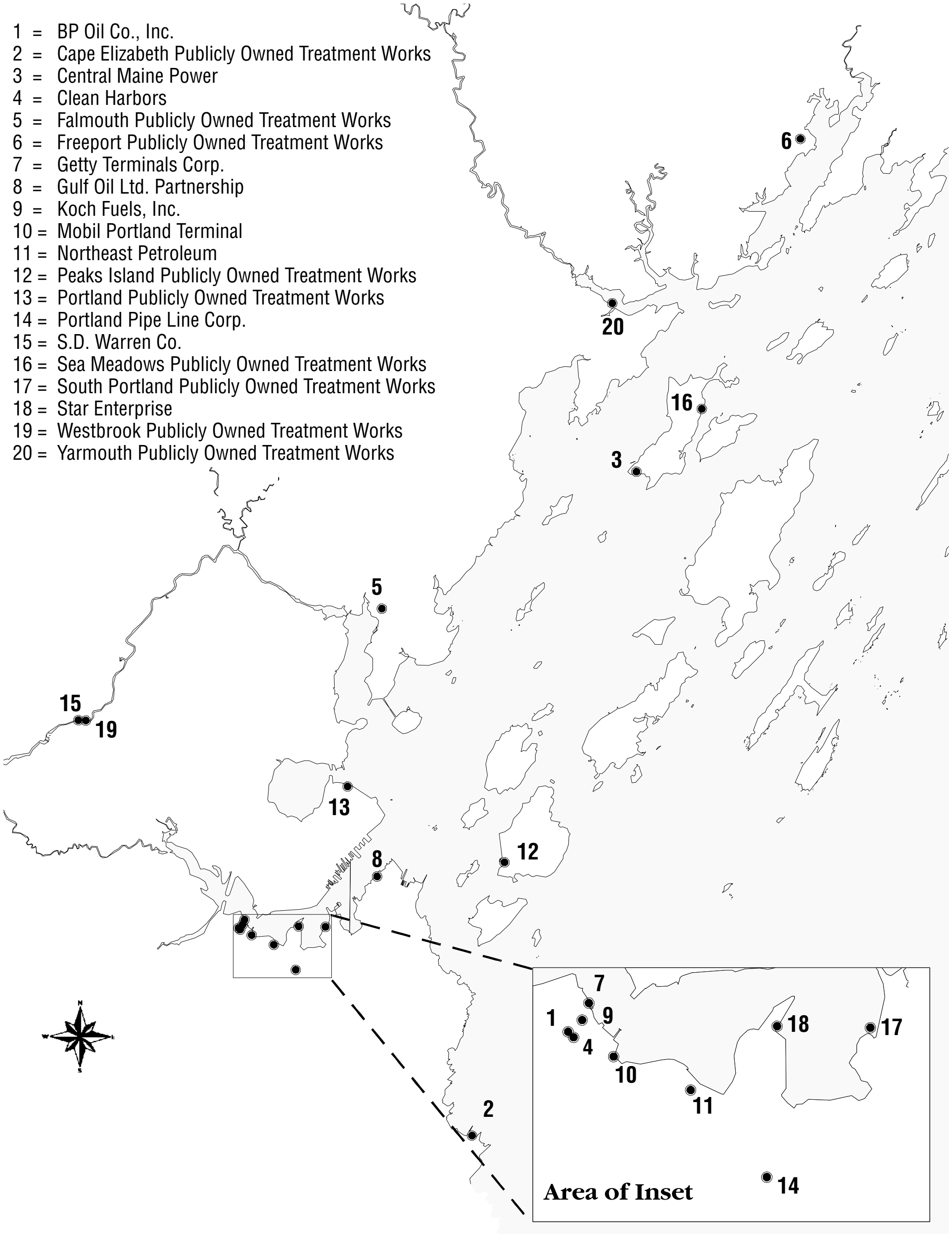
With the advent of electrical power production in the late 19th century, potentially carcinogenic (*i.e.,* cancer-causing) PAHs were emitted from smokestacks and PCBs were used in electric transformers. Later, Portland became a prominent center for unloading and storage of oil, with no booms used until the 1970s to contain spilled oil. Numerous gasoline stations were constructed with underground tanks, many of which have disintegrated over the years (releasing oil, lead, and other toxic by-products). Although PCBs were banned in the 1970s because of their carcinogenic properties, they are still found at high levels in the inner Fore River. Although the sources of this contamination are unknown, they could include old dumps and filled-in areas (*e.g.,* in 1989, PCBs were found in an old dump at Portland's sewage-treatment plant site).

Most point (pipe) discharges into Casco Bay and its watershed are licensed by the Maine Department of Environmental Protection and the U.S. Environmental Protection Agency. There are 17 licensed facilities that are considered significant dischargers in the Casco Bay watershed. They include (in descending order of flow of water that has the potential to contact pollutants — "process wastewater"): S.D. Warren Company paper mill in Westbrook; the sewage treatment plants in Portland, South Portland, and Westbrook; the Central Maine Power Station on Cousins Island in Yarmouth; the sewage treatment plants in Freeport, Falmouth, and Yarmouth; GTE Products Corporation in Standish; and eight oil/water stormwater separator discharges at the oil terminals in South Portland. The majority of these discharges are concentrated in the Portland area (National Oceanic and Atmospheric Administration, 1994).

There are 24 additional minor licensed discharges in the watershed, including industrial facilities, power plants, and small sewage treatment plants. Minor discharges include sewage treatment for populations of less than 10,000 people and less than one million gallons of flow per day. The sewage treatment plants at Peaks Island and Cape Elizabeth, cooling water at Burnham & Morrill and Bath Iron Works, and industry with small non-toxic discharges are examples of minor discharges. Also a number of other industries discharge into sewage treatment plants and some are required to pretreat their wastes prior to dis-

Figure 5-2

National Pollution Discharge Elimination System Outfall Locations



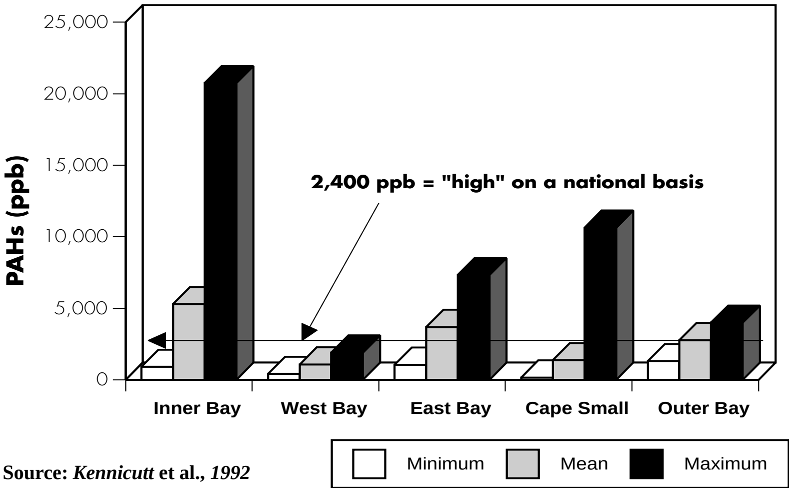
Source: Casco Bay Estuary Project

charge into the municipal sewer.

Licensed discharges contribute a variety of pollutants to Casco Bay and its watershed including PAHs, oil and grease, heavy metals, chlorine, suspended solids, organic material, organic matter, fecal coliform bacteria, nitrogen, and phosphorus. The National Oceanic and Atmospheric Administration (1994) estimated typical pollutant discharge concentrations (*i.e.,* not monitored) for the major licensed discharges into Casco Bay. They estimated that sewage treatment plants contribute the greatest relative amounts of lead, cadmium, arsenic, iron, fecal coliform bacteria, nitrogen, phosphorus, and oil and grease. Zinc and mercury contributions are split among sewage treatment plants, power plants, and paper mill facilities, while copper and chromium contributions are principally split between power plant and paper mill facilities. Both paper mills and

Figure 5-3

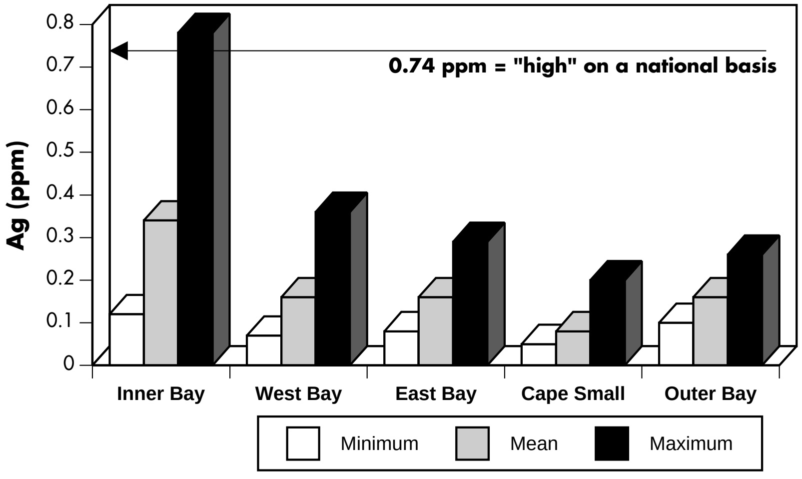
PAHs in Sediments



Source: ***Kennicutt* et al., *1992***

Figure 5-4

Silver in Sediments

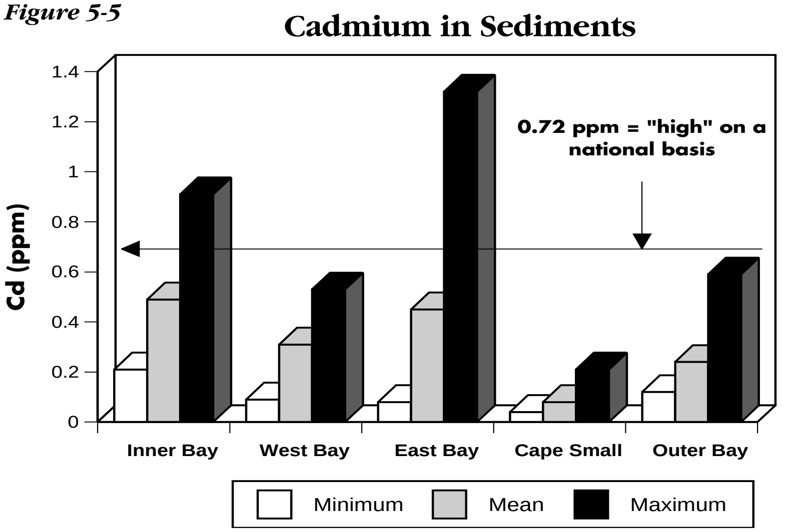


Sources: ***Kennicutt* et al., *1992; O'Connor, 1990***

sewage treatment plants are sources of suspended solids and organic materials that have the potential to deplete oxygen in rivers or the bay. PAHs are discharged from oil/water separators at the oil terminals; however, their contribution could not be estimated because the discharges are linked to storms and the characteristics of the site. Sources of dioxin and furans include papermaking (*e.g.,* the bleach Kraft paper mills on the Presumpscot, Kennebec, and Androscoggin rivers), industrial processes, and sewage treatment, as well as incineration and forest fires (a minor source).

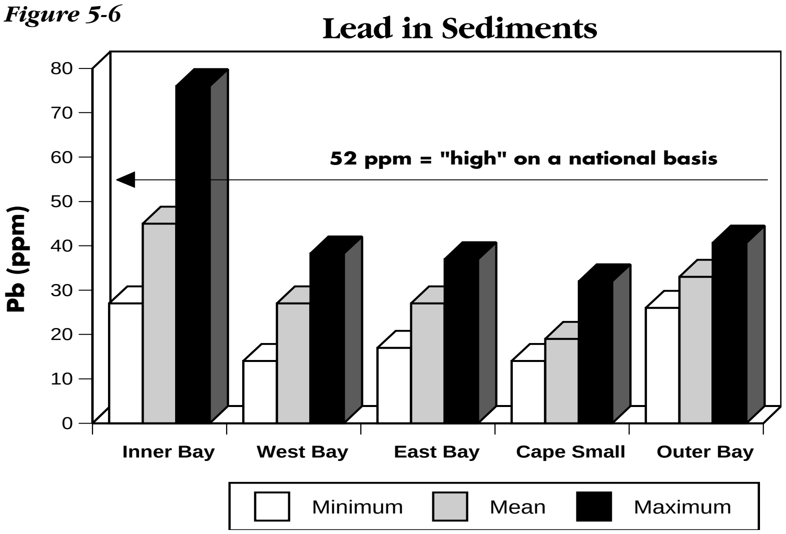
Air deposition is another likely source of PAHs, dioxins, pesticides, heavy metals, and nutrients. Air emissions in Maine are licensed and the results of an ongoing emissions inventory will assist in determining local contributions. The East Coast

Figure 5-5



Sources: ***Kennicutt*** **et al.,** ***1992; O'Connor, 1990***

Figure 5-6



Sources: ***Kennicutt*** **et al.,** ***1992; O'Connor, 1990***

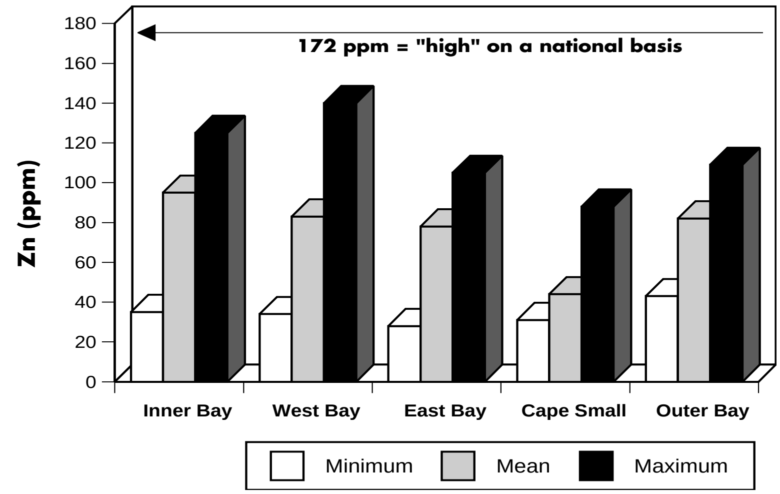
of the United States and the industrial sources in western Pennsylvania and Ohio also are potential sources of pollutants deposited from the air into Casco Bay.

Concentrations of Toxic Pollution

A comprehensive sediment contamination study completed for the Casco Bay Estuary Project in 1991 assessed the presence of 60 contaminants at 65 locations (Kennicutt *et al.,* 1992). *The study found toxic pollutants in virtually all sites with recent accumulations of mud,* although these conditions do not occur throughout the bay.

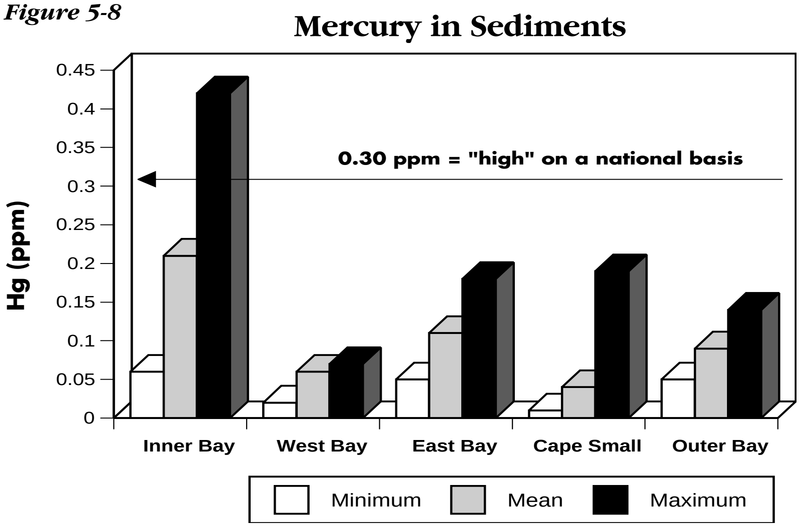
The graphs in Figures 5-3 through 5-11 synthesize information from the 65 sediment sampling sites in five regions of the bay. One sample of sediment was taken at each of the 65 locations. The maximum, minimum, and mean con-

Figure 5-7



Sources: ***Kennicutt* et al., *1992; O'Connor, 1990***

Figure 5-8

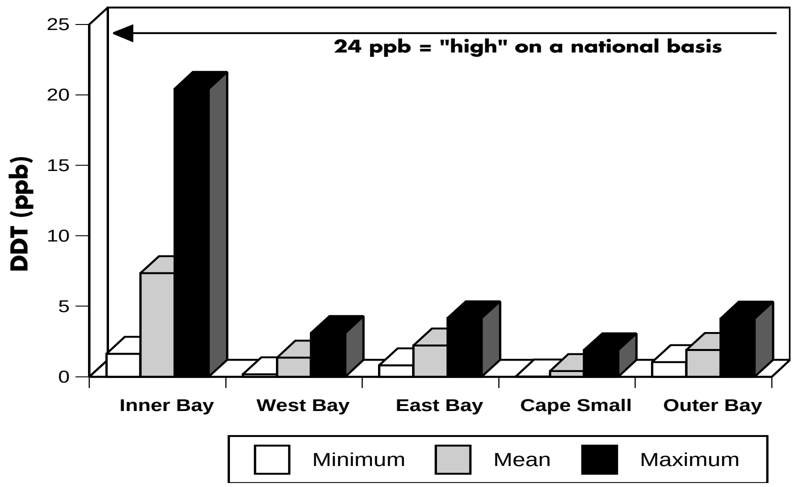


Sources: ***Kennicutt* et al., *1992; O'Connor, 1990***

centrations for each region are graphed so that general comparisons may be made among regions.

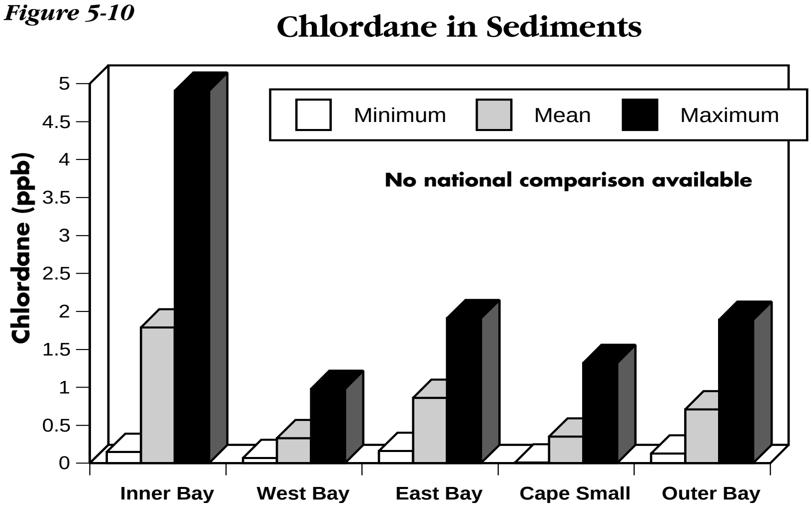
As the graphs indicate, concentrations of contaminants can vary widely within a region. They may even vary within a small area of sediment (*e.g.,* a sample taken for PCB analysis from 1 square foot of mud in the Fore River was 10 times higher than two other samples taken in the same vicinity). The terms "high" and "low" noted in the text refer to concentrations of contaminants in Casco Bay, not to their toxicity concentrations (*i.e.,* some contaminants are very toxic in low levels, while others are not toxic even at high levels; quotation marks around "high" denote comparisons on a national basis) (O'Connor, 1990).

Figure 5-9



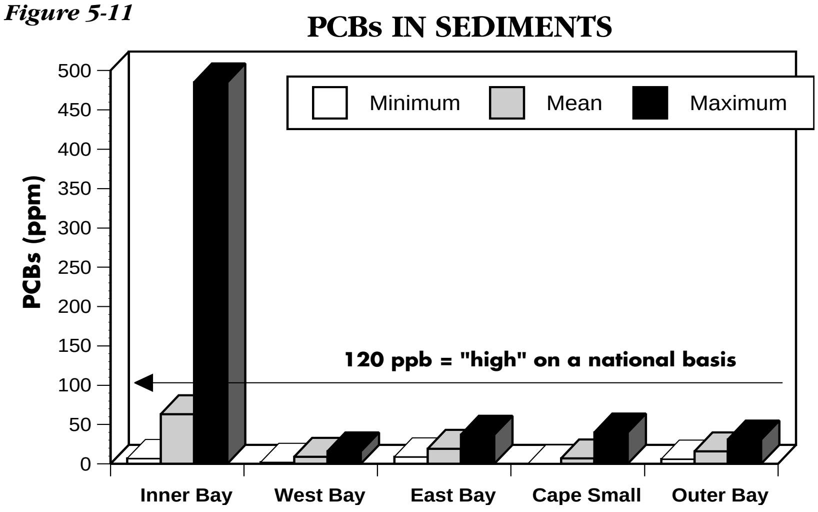
Sources: ***Kennicutt*** **et al.,** ***1992; O'Connor, 1990***

Figure 5-10



Source: ***Kennicutt*** **et al.,** ***1992***

Figure 5-11



Sources: *Kennicutt* et al., *1992; O'Connor, 1990*

Oils and PAHs

The highest concentrations of PAHs — the most widespread contaminants in the bay — occur in the Fore River, Back Cove, Presumpscot estuary, and the rest of Inner Bay (Kennicutt *et al.,* 1992). Mean concentration of PAHs declines the farther one gets from Portland *(see Figure 5-3),* except for "hot spots" of elevated contaminant levels in East Bay, Outer Bay, and Cape Small. Most of these sites contain "modern mud," sediment that has been moved by storms and currents from other areas in or near the bay. The National Status and Trends Program, run by the National Oceanic and Atmospheric Administration, considers PAH levels above 2,400 parts per billion (ppb) to be "high" by national standards (no "high" values were adjusted for variances in sediment type) (O'Connor, 1990). The highest concentrations of PAHs in Casco Bay reach 20,748 ppb (Kennicutt *et al.,*1992).

Heavy Metals

Concentration of heavy metals varies throughout Casco Bay. Five heavy metals — silver (Ag), cadmium (Cd), lead (Pb), zinc (Zn), and mercury (Hg) — have "elevated" levels due to human activities, with mean concentrations running highest in the Inner Bay *(see Figures 5-4 through 5-8).* Maximum concentrations of mercury, lead, and silver occur in Inner Bay; the maximum for cadmium is in East Bay; and the maximum for zinc is in West Bay. Using different analytical methods, a 1991 study by Larsen and Gaudette (1995) found elevated levels of lead, copper, cadmium, and zinc in the Inner Bay and elevated levels of cadmium in the East Bay. The National Status and Trends Program considers the following values "high": 0.74 part per million silver, 0.72 part per million cadmium, 52 parts per million lead, 172 parts per million zinc, and 0.30 part per million mercury (O'Connor, 1990). Five metals — arsenic (As), chromium (Cr), copper (Cu), nickel (Ni), and selenium (Se) — do not appear to be elevated by human activities and are distributed naturally by type of sediment and type of mineral present (Kennicutt *et al.,*1992).

Pesticides

DDT and chlordane have relatively low concentrations (near or below the detection limit of the analytical equipment) in most of Casco Bay. Maximum concentrations for both DDT and chlordane were in Back Cove *(see Figures 5-9* *and 5-10)*, with the highest mean concentrations in the Inner Bay, intermediate concentrations in East and Outer bays, and the lowest mean concentration in West Bay and Cape Small. Nationally, 24 parts per billion is considered "high" for DDT (O'Connor, 1990). In addition to the relatively high percentage of undegraded DDT in the bay, there are also by-products produced as DDT degenerates in the environment. DDT is gradually metabolized into DDE and DDD. DDD predominates in the Inner Bay samples, while DDE predominates elsewhere (DDT in Figure 5-9 is total DDT, which includes DDD, DDE, and undegraded DDT).

All components of chlordane were not measured in the National Status and Trends Program (Kennicutt *et al.,*1992). However, when similar components are compared, concentrations of chlordane in Casco Bay are lower than most other East Coast estuaries. Other pesticides were not detectable or barely detectable (Kennicutt *et al.,* 1992).

PCBs

PCB concentrations are highest in the Inner Bay, particularly the Fore River (see Figure 5-11), and lowest in Cape Small and West Bay. Concentrations elsewhere are far lower than Inner Bay and correlate to materials in the sediments (especially organic carbon). A "high" level for PCBs, as defined by the National Status and Trends Program, is 120 parts per billion (O'Connor, 1990). The levels in Casco Bay range from 0.4 to 485 parts per billion, with only one sampling site above 120 parts per billion.

Dioxins, Furans, and Butyltins

Concentrations of dioxins, furans, and butyltins were highest near their potential sources, primarily in the Inner and East bays (the latter being due to possible contamination from the Kennebec River). PCDD/PCDF, and especially 2, 3, 7, 8-TCDD, appeared in higher concentrations near the Presumpscot River when compared to other sites in the bay.

Ecological Effects

While the biological impacts of toxic pollution have not yet been studied by the Casco Bay Estuary Project, this section summarizes potential effects on living resources. Toxics have the potential to bioaccumulate and magnify up the food chain. The *Casco Bay Monitoring Plan* includes recommendations for more specific assessment of biological impacts from toxic contaminants.

Bottom-Dwelling Animals

Contaminants collect in "modern mud" (*i.e.*, mud accumulated over the last century); therefore, bottom-dwelling animals that dwell in mud habitats tend to be exposed to the highest levels of contaminants. Animals such as shrimp-like amphipods are particularly sensitive to contaminants and may be unable to live in polluted sediments.

Bottom-dwelling (or benthic) animals play an important role in the food chain. They recycle the organic matter from dead plants and animals that drifts to the bottom. Bacteria act as decomposers, releasing nutrients from organic matter so it can be incorporated into new plant life. These bacteria are fed on by bottom-dwellers such as small shrimp-like crustaceans, worms, mollusks (*e.g.,* clams), and echinoderms (*e.g.,* starfish) who — in turn — are consumed by groundfish (*e.g.*, flounder, cod, and haddock), lobsters, and crabs.

While thorough studies of toxic impacts on benthic life in Casco Bay have not been completed, there is some evidence of damage. Animals that would be expected to occur in the flats of Back Cove are missing, potentially due to such factors as oil-related contaminants, heavy metals, combined sewer overflow discharges, sedimentary disturbances, or a combination of factors (Watling, 1995). Benthic life in the inner Fore River has been dramatically impaired. In bottom samples taken in 1989, some hardy worms were present in much smaller numbers than expected, but mollusks, crustaceans, and other species were absent. Some of the worms collected had oil on their "feet" (parapodia), probably due to petroleum-related contaminants (Doggett, 1995).

Fisheries

Sediment contamination can have serious ramifications for fisheries and marine life in Casco Bay. Fish and crustaceans can absorb toxics directly by exposure to contaminants in the water, and indirectly by eating contaminated food — particularly bottom-dwelling organisms that live and feed among the "modern mud" sediments on the bay's bottom.

Elevated levels of toxic contaminants in fish and crustaceans can inhibit growth and reproduction, disrupt life processes of the young, change sex ratios, and cause cancer or even death. Toxic contaminants decrease natural immunities, making animals more susceptible to disease and attack by micro-organisms (*e.g.*, fin rot in fish, shell degradation in crustaceans, and tumors in flounder). Some fat-soluble chemicals, such as DDT, are liberated during migration and reproduction, affecting adults, embryos, and newborns. Some species of spawning fish, such as salmon, trout, shad, and alewives, can detect toxic pollutants (*e.g.,* chlorine) and avoid contaminated rivers, but this rerouting can disrupt their migration.

Blue mussels sampled in the outer Fore River had elevated levels of lead in their tissues, while those in the Presumpscot River had elevated levels of mercury (Sowles, 1993). These findings confirm that mussels are accumulating metals, but do not indicate what harm is being done. Mussels are used nationally as an indicator species of toxic pollution.

Livers of flounder caught off the Kennebec River in 1984 were found to have elevated levels of lead, copper, zinc, and PCBs (O'Connor, 1990). Experiments have shown that flounder are prone to develop tumors after eating worms contaminated by PAHs (McElroy *et al.*, 1989), and that the presence of contaminants cause them to generate additional toxic by-products which further stimulate tumor growth. These results have not been duplicated since 1984 due to the scarcity of flounder. Fishermen have reported tumors in flounder caught off Casco Bay, but the cause of the tumors has not been determined.

Wildlife

Mammals and birds that feed on benthic organisms or fish may absorb concentrated amounts of contaminants. *Some of the tidal mudflats that represent the most important feeding areas for shorebirds, waterfowl, and wading birds — the Fore River, Back Cove, and Presumpscot River — also have the highest concentration of contaminated sediments in the bay.* Until approximately 20 years ago, these areas received high levels of untreated waste from residences, businesses, and industry.

Human Health

*Various toxic pollutants (*e.g.*, PCBs, DDT, some PAHs, and dioxin) concentrate in the liver, fat, and tissue of animals and can cause significant human health impacts in the species that eat them.* Bioaccumulative toxic chemicals can cause cancer, adverse reproductive effects, birth and developmental effects, organ damage, and deleterious impacts on the nervous, immune, and endocrine systems. When toxic contaminants pose an unacceptable health risk, a consumption advisory is issued by the state toxicologist. However, the absence of an advisory does not imply the absence of a problem because advisory levels assume that each species represents a person's total exposure to that contaminant — an inaccurate assumption because data and analysis are not available to determine risk. With the exception of testing for dioxin in lobsters and clams, there has been no risk assessment of potential health hazards from eating seafood in Casco Bay.

Dioxin levels in clams in the Presumpscot River were approximately one-third higher than clams sampled from Scarborough, but only half as high as clams sampled in the Kennebec/Androscoggin and Penobscot rivers (Mower, 1995). The levels in clams at all sites sampled were not high enough to issue a consumption advisory. Dioxin levels in lobster meat were elevated only slightly, but were greatly elevated (20 to 30 times greater than the meat) in the tomalley (the lobster's liver and pancreas). In February 1994, an advisory was issued cautioning against consumption of tomalley for all lobsters caught in Maine waters (Mower, 1995). Testing results from the summer of 1994 determined that this advisory will remain in effect indefinitely.

A freshwater fish consumption advisory that was issued for the Presumpscot River south of Westbrook in 1990 was lifted in 1992 because of reduced dioxin levels in fish tissues (Mower, 1995).

Economic Effects

The economic cost of polluted sediments can be seen in reduced stocks of (and market for) fish and seafood. *If contaminants reduce the growth and reproductive success of marine organisms, the productivity of fisheries can decline.* It is hard to assess the impact of contaminants on fisheries, however, due to the complexity of the marine ecosystem.

Beyond an actual decline in stocks, there is the risk of diminished consumer confidence. When studies reveal contamination in sediments, some consumers become concerned and reduce or eliminate seafood purchases, although no studies have tracked consumer responses around Casco Bay.

Economic impacts can also be felt outside the fishing industry. Dredging projects may be delayed or limited by prohibitively expensive disposal options because toxic sediments must be disposed of at hazardous waste landfills. While dredging is required to keep ports and harbors accessible (*e.g.*, in Portland, Yarmouth, and Freeport), upland disposal is at least 10 times more expensive than disposal at sea.

Remediation of contaminated sites in other settings has proven extremely costly. While no remediation is recommended for toxic sediments in Casco Bay at this time, efforts to reduce or eliminate toxic accumulation could prevent costly restoration bills in the future (*e.g.,* the clean-up of PCBs in New Haven Harbor, Massachusetts).

Trends

By the 1970s, heavy industrial production around Portland was in decline, and the passage of the National Environmental Policy Act set the stage for protecting Casco Bay's environment. Federal funds were allocated for sewage treatment, industries were required to treat their discharges, and regulations were enacted to improve solid waste disposal.

During the past quarter-century, the cleanup appears to have begun to produce results. *Preliminary data indicates that metal contamination declined in the mid-1970s, probably in response to use of unleaded gasoline and construction of sewage treatment plants* (indicated by a sediment core taken in inner Casco Bay near Clapboard Island) (Gaudette, 1995). Also, *Historic Sources of Pollution in Portland Harbor* shows that Portland and South Portland lost most of the major heavy industry (*e.g.*, foundries, machine shops, and railroad houses and yards) that were sources of heavy metals.

Results of the 1991 sediment contamination study conducted for the Casco Bay Estuary Project confirm previous studies conducted in 1980 and 1989 (Larsen *et al.,* 1983; and Doggett, 1995), which indicate similar contamination in geographic distribution (*e.g.*, highest levels of contamination in Inner Bay; low levels elsewhere with some "hot spots"). A study conducted by Larsen and Gaudette (1995) showed significant declines in cadmium, chromium, lead, and zinc. Nickel was unchanged and copper increased in concentration.

Steps taken to reduce the rate of contamination entering the bay include:

- industrial and municipal cooperation with discharge permit limits and pre-treatment programs
- reduction of combined sewer overflows
- better oil-spill prevention
- cleanup of some hazardous waste sites
- implementation of best management practices in road construction, major development, farming, and forestry
- elimination of leaded gasoline
- increased awareness among citizens and boaters regarding safe disposal of toxic materials
- discontinued use of shoreside dumps

To continue reducing levels of sediment contamination, more attention must now be focused on nonpoint sources such as runoff from roads and parking lots. If measures to reduce pollution are taken, the ecosystem will eventually cleanse itself. Contaminated sediments will become "biologically unavailable" as new sediments wash off the land and cover them, and chemical and degradative processes reduce their toxicity. And as cleaner sediments enter the bay, existing contaminants will be made less toxic through further dilution.

Regulatory Measures

No regulations directly address contaminated sediments, except those on dredging administered by the Maine Department of Environmental Protection and the U.S. Army Corps of Engineers. Permits are required from both agencies, along with physical, chemical, and biological testing of the material to be dredged. Most sites in Maine undergo physical and chemical testing at a minimum, and may be required to test toxicity to animals. Under the Maine Department of Environmental Protection Natural Resource Protection Act, the applicant may have to change the timing of the project, notify local fisheries interests, and test for additional contaminants.

Regulations that indirectly address contaminated sediments include water quality classification laws, which consider toxics when issuing licenses for wastewater discharges and the toxicity-testing on animals required for large-volume dischargers. State laws such as the Sensible Transportation Act and the Growth Management Act also play a role in activities and development that relate to contaminated sediment.

Recommendations

While existing regulations have helped, in recent decades, to reduce the volume of toxic contaminants entering Casco Bay, further action is needed. The following measures outline some steps to reduce toxic pollution in Casco Bay. The title of each action is listed below. Following the title is the action number. The actions are described more fully in Chapter 7. Actions that directly relate to this chapter appear in bold typeface; other actions that support this chapter appear in regular typeface.

■ Public Education

- Fund high school students' research. (#1)
- Focus post-secondary educational programs on Casco Bay. (#2)
- Conduct a comprehensive campaign to promote sound household practices. (#3)
- **Educate boaters about low-impact practices, nontoxic boat products, and the need to protect sensitive habitats. (#4)**
- Hold "State of the Bay" conferences. (#7)

■ Technical Assistance

- Provide training in best management practices for contractors, public works crews, road commissioners, and municipal boards and staff. (#4)
- **Establish a reduction and management program for toxic pollutants in Casco Bay communities and small businesses. (#5)**
- **Develop and implement action plans for sub-watershed areas. (#6)**
- **Conduct pollution prevention audits for businesses/industries that affect Casco Bay. (#8)**

■ Regulatory/Enforcement Plan

- Adopt minimum standards for stormwater quality in state and municipal regulatory programs. (#3)

■ Planning and Assessment

- **Develop a comprehensive management strategy for dredge material. (#2)**
- **Develop biological/environmental indicators. (#6)**
- **Develop sediment quality criteria and sediment quality discharge limits that apply to Casco Bay. (#7)**