CASCO BAY ESTUARY PROJECT

Toxic Pollution in Casco Bay

Toxic contaminants, such as hydrocarbons and lead found in Casco Bay, are important to monitor because of their tremendous potential to harm human health and natural ecosystems. Monitoring to detect their presence, any "hot spots," and trends in their availability will help policy-makers decide where and when to focus efforts at pollution control and remediation. Monitoring is vital to assessing the health of Casco Bay, its resources, and surroundings. Understanding the level of toxic contamination will help us improve and maintain Casco Bay water quality.

The Casco Bay Estuary Project has focused attention on assessing the presence of toxic contaminants within Casco Bay and on developing an action plan to minimize their presence and monitor any trends. Monitoring toxic contamination is the priority recommendation for the implementation phase of the *Casco Bay Plan*.

This fact sheet outlines what we know about the extent of Casco Bay's toxic pollution problem through recent studies, preliminary measures taken to address it, and recommendations for additional action.

Preliminary monitoring studies provide a baseline against which to measure further research results. Three types of studies have been used to determine the presence of toxics in Casco Bay: tissue analysis, sediment testing, and current source assessment.

Analyzing tissues

Checking for the presence of toxic contaminants in animal tissue indicates whether toxics were taken up by organisms ("bioaccumulated") or concentrated as they traveled up the food chain ("biomagnified"). In the Casco Bay watershed, lobsters, clams, mussels, and some species of fish were analyzed for toxics by the Maine Department of Environmental Protection.

Testing recent sediments

Toxic contaminants can accumulate in sediments. In estuarine waters like Casco Bay, where freshwater rivers meet saline coastal waters, dissolved metals and organic chemicals attach to sediment and organic or plant material and settle to the bottom. If toxics are found in recently deposited estuarine sediments, they are likely to be found elsewhere in the ecosystem. The Casco Bay Estuary Project has funded two studies looking at toxic concentrations in sediments.

Assessing current sources

Sampling discharges, stormwater runoff, and atmospheric deposition for toxic contamination gives us an understanding of the current "loading" of toxics into the ecosystem. Many "point" sources of pollution

(discharge pipes from industry, municipal wastewater treatment plants, and other specific discharge points) are regulated and periodically tested for contaminants. However, it is not clear how much toxic pollution is contributed by "nonpoint" sources. (Nonpoint source pollution is an indirect discharge which can come from numerous sources, and is usually a result of stormwater runoff.) Also, many pesticides and combustion-related contaminants are transported by air and deposited throughout the region. Limited testing has been done in Maine on airborne toxics.

Types of Toxic Pollution

There are two primary types of toxic pollutants: organic chemicals and heavy metals. **Organic chemicals** are bonded forms of carbon, hydrogen, and other atoms. Many occur naturally, while thousands of others have been developed for use in oils, paints, pesticides, cleaners, solvents, insulation, fire retardants, and other products. Organic chemicals eventually break down into hydrogen and oxygen, but this breakdown is slow; in the interim, they can remain toxic.

Organic compounds found in the sediments of Casco Bay include:

- *PCBs (polychlorinated biphenyls)*
- *PAHs (polynuclear or polycyclic aromatic hydrocarbons)*
- *pesticides*
- *butyltins (organo-metallic compounds)*
- *dioxins (organo-chlorines)*

While others may be present, the above compounds were selected for study due to their toxicity and persistence.

Heavy metals are elements and generally do not break down into less harmful forms. They tend to accumulate where they are released, provided they are not disturbed, covered, or moved elsewhere. While essential for a healthy diet in low concentrations, heavy metals such as copper, nickel, and zinc can be lethal in high doses. Mercury can be very toxic, as it tends to bioaccumulate in living tissue.

Heavy metals are metallic elements such as lead, mercury, arsenic, cadmium, silver, nickel, selenium, chromium, zinc, and copper.

How bad is the bay?

Casco Bay is not pristine. The bay registered potentially toxic levels of PCBs and PAHs (hydrocarbons) and high levels of four heavy metals, compared to other estuaries nationally. Elevated levels of dioxin and butyltins were also found. Although other contaminants were found in Casco Bay, their concentrations were at lower levels than in other more urban bays. Long-term monitoring of Casco Bay is key to determining whether the bay is becoming healthier or more polluted, and where to direct targeted actions to prevent further contamination.

Sources of Toxic Pollution

Toxic contaminants come from a myriad of sources. They can enter the bay in urban areas through combined sewer overflows, and treated and untreated sewage and stormwater discharged by a sewage treatment plant. Storm drains, particularly those that drain roads and parking lots, and runoff from highly developed residential and industrial areas in the watershed, add more toxics. Leaching from old industrial sites or dumps, emissions and discharges from industrial and municipal operations and wastewater treatment plants, and deposition of atmospheric pollution from urban sources in and upwind of Maine all add to the burden.

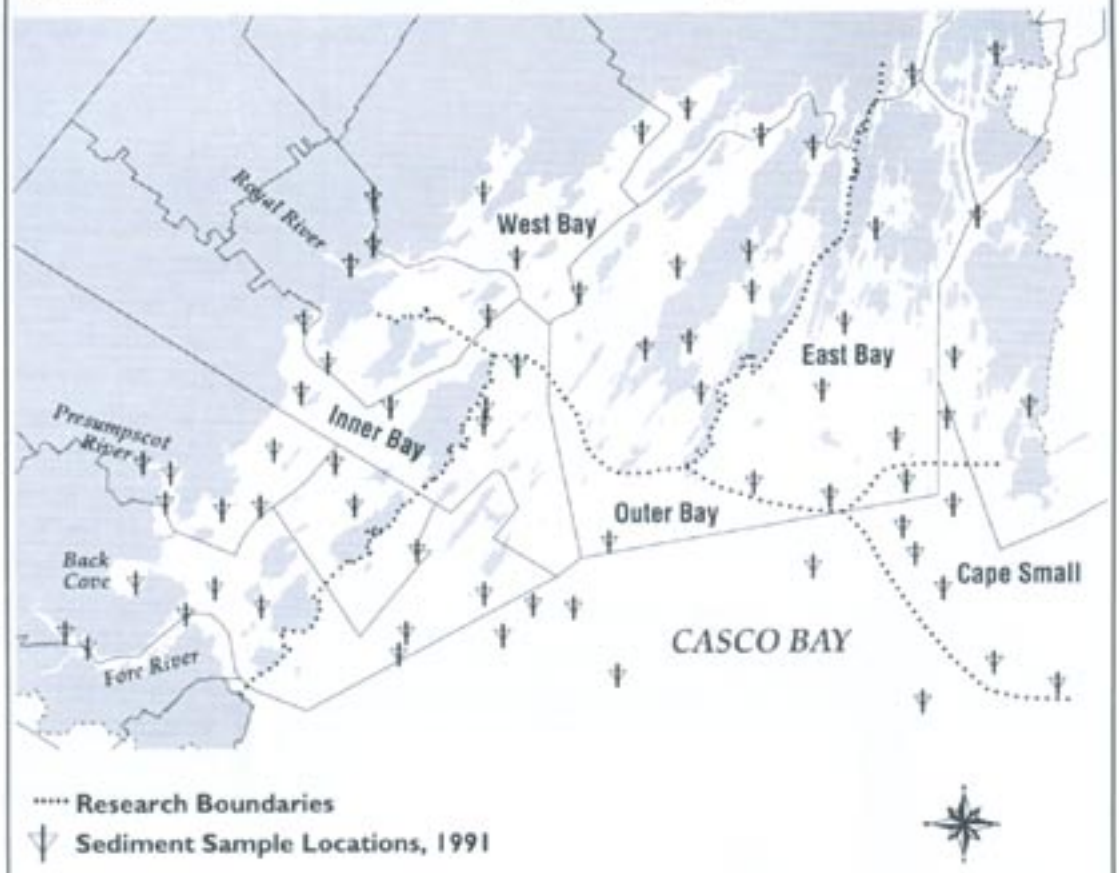
The most prevalent toxic pollutants in Casco Bay are PAHs, or polynuclear aromatic hydrocarbons, which are primarily the product of fossil fuel combustion (i.e., car and truck exhausts, industrial smokestacks, and residential chimneys) as well as fuel spills.

Hydrocarbon pollution is aggravated by the roughly 70 reported fuel spills each year in Maine coastal waters. Most spills are small, averaging 20 gallons, with the typical spill in Portland harbor being a 45-gallon diesel oil spill from a fishing vessel overfilling its tanks.

With the exception of cadmium, **heavy metals** in Casco Bay sediments are primarily concentrated in and around Portland harbor. Sources are numerous, including vehicle emissions, industrial and wastewater discharges, and historic industrial sites. They also naturally occur in rocks and minerals and leach into the environment over time.

PCBs (polychlorinated biphenyls) were used as coolants and insulators in electrical transformers and capacitors between 1930 and the late 1970s, when they were banned as suspected carcinogenics. PCBs are still present in some electronic components. Sources of PCBs for Casco Bay include discharges from stormwater and unregulated sources, and atmospheric deposition.

FIGURE 1 **Sediment Sample Locations, 1991**



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

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 pollutants in the air.

TBT, or tributyltin, is the active ingredient used in marine paints to prevent fouling of submerged boat bottoms by barnacles and algae. Fouling is a nuisance and slows down boats, increasing their use of fuel. **Butyltins** include tetrabutyltin (4BT), tributyltin (TBT), dibutyltin (DBT), and monobutyltin (MBT).

Sources of **dioxin** include paper making (for example, the bleach kraft paper mills on the Presumpscot, Kennebec, and Androscoggin rivers), incineration, industrial processes, and forest fires (a minor source). In Casco Bay, researchers measured PCDD/PCDF or polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans.

TABLE 1 **Toxic Chemicals in Casco Bay**

Toxicity	Chemical	Locations
Potentially Toxic Levels	PCBs	Fore River (Inner)
	PAHs (Hydrocarbons)	Fore River (Outer)
High Compared to Other Bays Nationally	PAHs (Hydrocarbons)	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

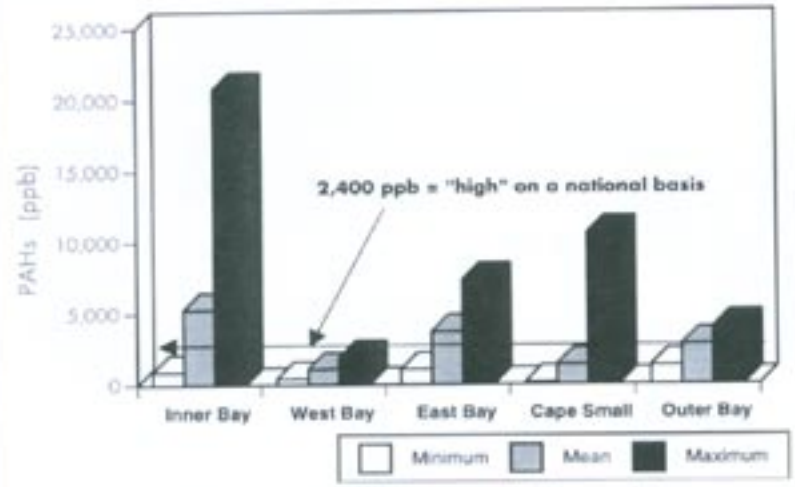
Concentrations of Toxic Pollution

The Casco Bay Estuary Project commissioned two baseline studies conducted with recently developed analytical techniques to provide a "snapshot" of sediment contamination levels in Casco Bay and to clarify information compiled from previous studies. Initial studies were performed in 1991, with more chemicals tested in 1994. Figure 1 shows sediment sample locations for these studies. The toxic chemicals were chosen on the basis of their potential toxicity to biological resources and persistence in the environment. Some contaminants are very toxic at low levels while others are not toxic even at high levels. Quotation marks around "high" on the following figures denote comparisons on a national basis.

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

FIGURE 2

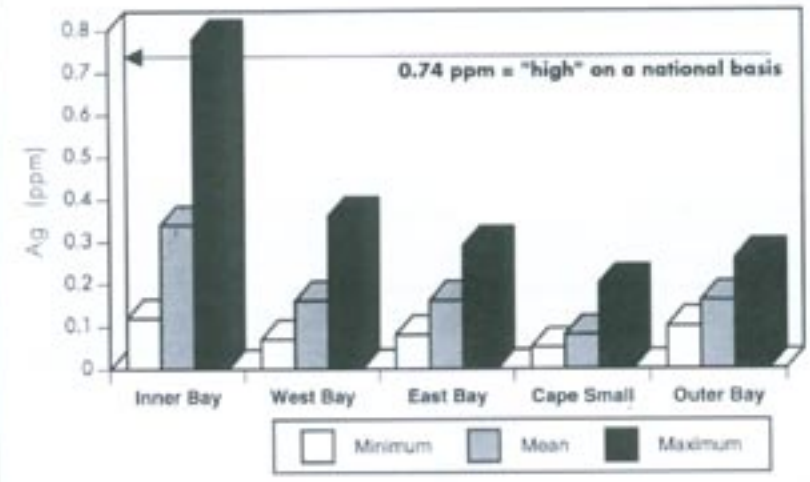
PAHs in Sediments



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

FIGURE 3

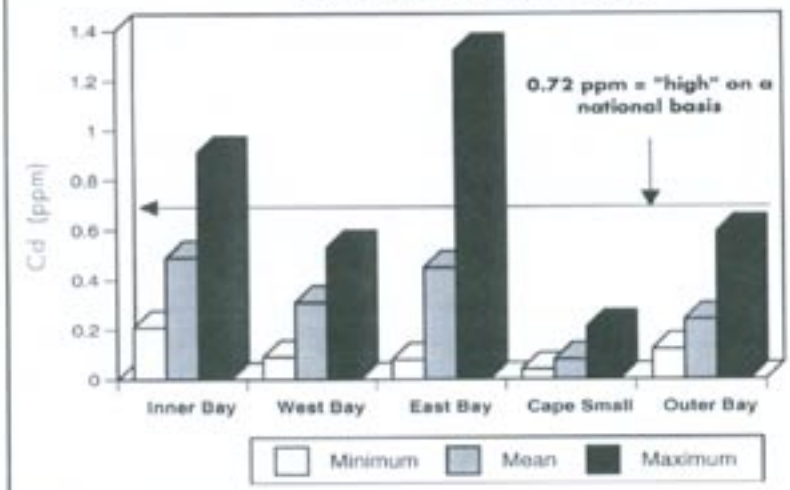
Silver in Sediments



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

FIGURE 4

Cadmium in Sediments



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

These studies also found toxic pollutants in virtually all sites with recent accumulations of mud, although these conditions do not occur throughout the bay.

Oils and PAHs

PAHs (hydrocarbons) were the most widespread contaminants in Casco Bay. The highest concentrations of PAHs occur in the Fore River, Back Cove, Presumpscot River estuary, and the rest of the inner bay (Figure 2). The average concentration of PAHs declines the farther one gets from Portland, except for "hot spots" of elevated contaminant levels in the east and outer bays, and Cape Small. PAH levels are considered high in several locations, especially in the inner bay, when compared to other bays around the country. Levels found in 1991 were generally lower than those thought to produce toxic responses in marine bottom-dwelling organisms. Another study, however, found levels of PAHs high enough to produce toxic responses in the more industrialized Portland harbor areas with known historic discharges.

PAHs are present at potentially toxic levels to bottom-dwelling animals (benthos) in the inner Fore River of Casco Bay

Heavy Metals

Five heavy metals—silver, cadmium, lead, zinc, and mercury—have elevated levels due to human activities, with average concentrations running highest in the inner bay. All of these, with the exception of zinc, are considered "high" in some locations in Casco Bay when compared to bays nationally (Figures 3-7). These metals, however, are not present at a level that would be considered toxic to bottom-dwelling organisms in the bay.

"High" levels of mercury, lead, and silver were found in the inner bay; the maximum cadmium level was found in the east bay and the maximum for zinc was in the west bay. Five metals—arsenic, chromium, copper, nickel, and selenium—do not appear to

be elevated by human activities. Using different analytical methods, a 1991 study found elevated levels of lead, copper, cadmium, and zinc in the inner bay and elevated levels of cadmium in the east bay (Larson and Gaudette, 1995).

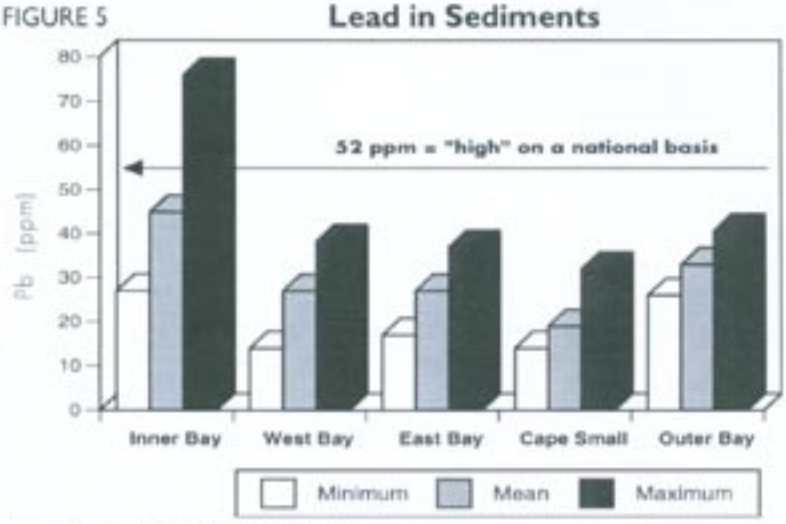
Elevated levels of lead and mercury were found in blue mussels near industrial sources in the inner bay, Presumpscot River estuary, and Back Cove. However, in locations adjacent to these sites, where contaminated tissues were expected, blue mussels had concentrations of heavy metals that were within baseline or at non-contaminated levels (Maine Department of Environmental Protection, 1996).

Pesticides

DDT and chlordane have relatively low concentrations (near or below the detection limit of the analytical equipment) in most of Casco Bay (Figures 8 and 9, page 6). Maximum concentrations for both DDT and chlordane were found in Back Cove, with the highest average concentrations in the inner bay, intermediate levels in the east and outer bays, and lowest in the west bay and Cape Small. DDT concentrations were below those known to cause toxic responses in most benthic organisms. There was a relatively high percentage of undegraded DDT in the bay, raising the specter of long-range transport of the toxic from areas where its use is not banned.

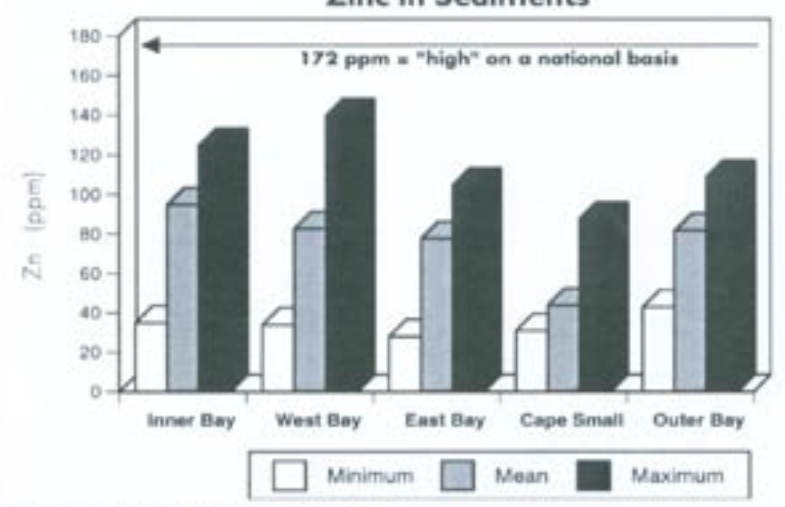
Other pesticides—aldrin, BHC, dieldrin, endosulfan (I, II, and sulfate), endrin, endrin aldehyde, heptachlor, heptachlor epoxide, toxaphene, and hexachlorobenzene—were either not detectable (less than 0.25 parts per billion) or barely detectable.

FIGURE 5



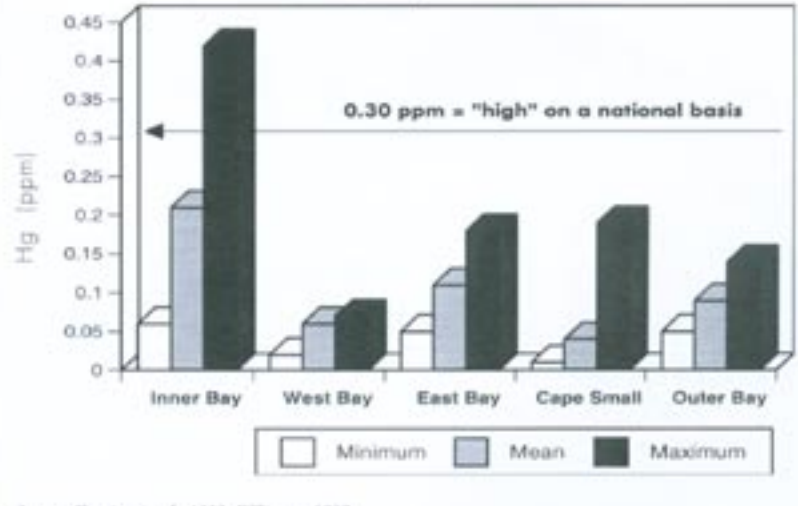
Source: Kennicutt et al., 1992; O'Connor, 1990

FIGURE 6



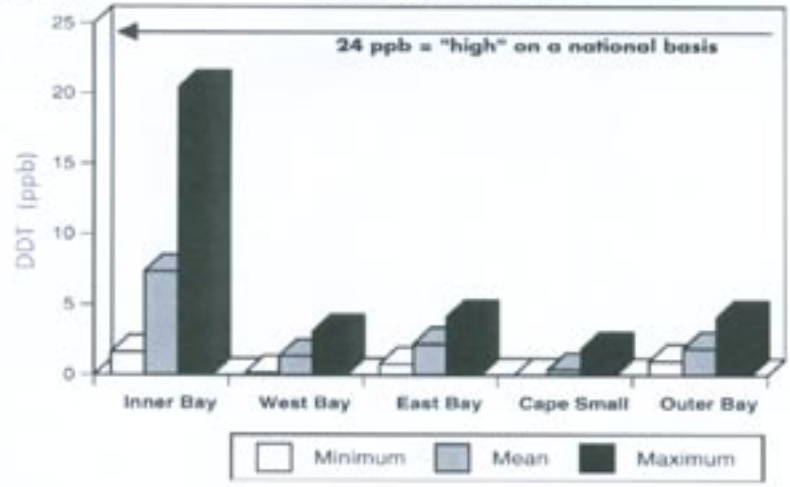
Source: Kennicutt et al., 1992; O'Connor, 1990

FIGURE 7



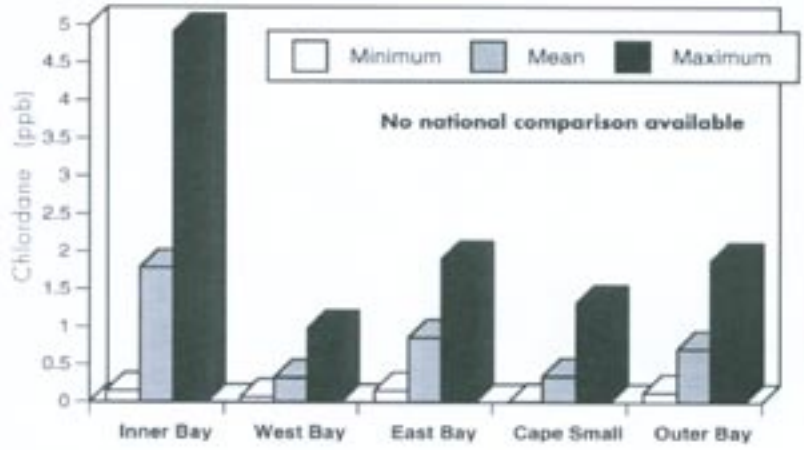
Source: Kennicutt et al., 1992; O'Connor, 1990

FIGURE 8



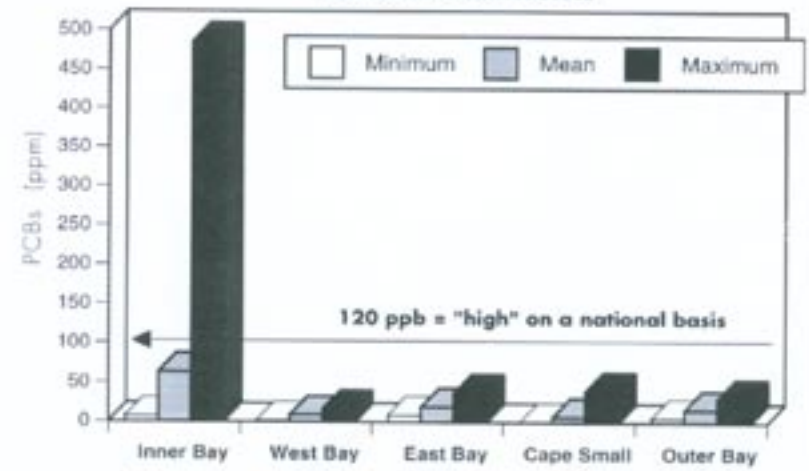
Source: Kennicutt et al., 1992; O'Connor, 1990

FIGURE 9



Source: Kennicutt et al., 1992

FIGURE 10



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

PCBs

PCB concentrations are highest in the inner bay, particularly the Fore River, and lowest in Cape Small and the west bay (Figure 10). PCBs were detected in sediments throughout the bay at low levels, with some exceptions.

PCBs at one sampling site in the inner Fore River of Casco Bay were present at potentially toxic levels to bottom-dwelling animals.

Concentrations elsewhere are far lower than in the inner bay and correlate to materials in the sediments (especially organic carbon). Concentrations of PCBs also increased with increasing concentrations of dioxins.

Butyltins, Dioxins, and Furans

Butyltins, dioxins, and furans were detected in sediments from all areas of Casco Bay in 1994 (Figures 11 and 12, page 7). While concentrations are relatively low when compared to other areas nationally, these toxics are persistent, they bioaccumulate, and they can be toxic at very low concentrations.

Butyltin concentrations were highest from samples taken near marinas, shipyards, and anchorages. Despite the fact that these concentrations are not considered "high" on a national basis, similar levels detected in a Louisiana estuary sediment study were considered high enough to have an adverse impact on the biological community.

Concentrations of dioxins, furans, and butyltins were highest near their potential sources, primarily in the inner and east bays.

Dioxins (PCDD/PCDF and especially 2,3,7,8-TCDD) appeared in sediments in higher concentrations near the Presumpscot River when compared to other sites in the bay. The Presumpscot River has a paper mill ten miles upstream where detectable concentrations of 2,3,7,8-TCDD have been found in the effluent (Maine Dept. of Environmental Protection, 1995). High levels in the east bay may be due to contamination from the Kennebec and Androscoggin rivers or air deposition, including local combustion sources.

The Maine Department of Environmen-

tal Protection has analyzed fish and shellfish tissue for dioxins in selected rivers and coastal areas through the Dioxin Monitoring Program.

Since 1990, levels of dioxin in Presumpscot River fish have dropped by about 90%. While a health advisory had been in place warning against eating Presumpscot River fish, today that advisory has been lifted indicating significant progress.

Clams from the Presumpscot River estuary (one of six locations along the Maine coast) contained dioxin levels within human health guidelines for meats, however dioxin levels in tomalley (lobster liver and pancreas) exceed health guidelines. This was not unexpected, since it has long been known that tomalley concentrates contaminants by up to 80 times the level found in muscle tissues. Dioxin levels in the Presumpscot River estuary lobsters were about average when compared to the levels found at the other five locations tested. Several New England states including Maine, have issued health advisories recommending that women who are pregnant, breast feeding, or of child-bearing age avoid eating lobster tomalley.

FIGURE 11

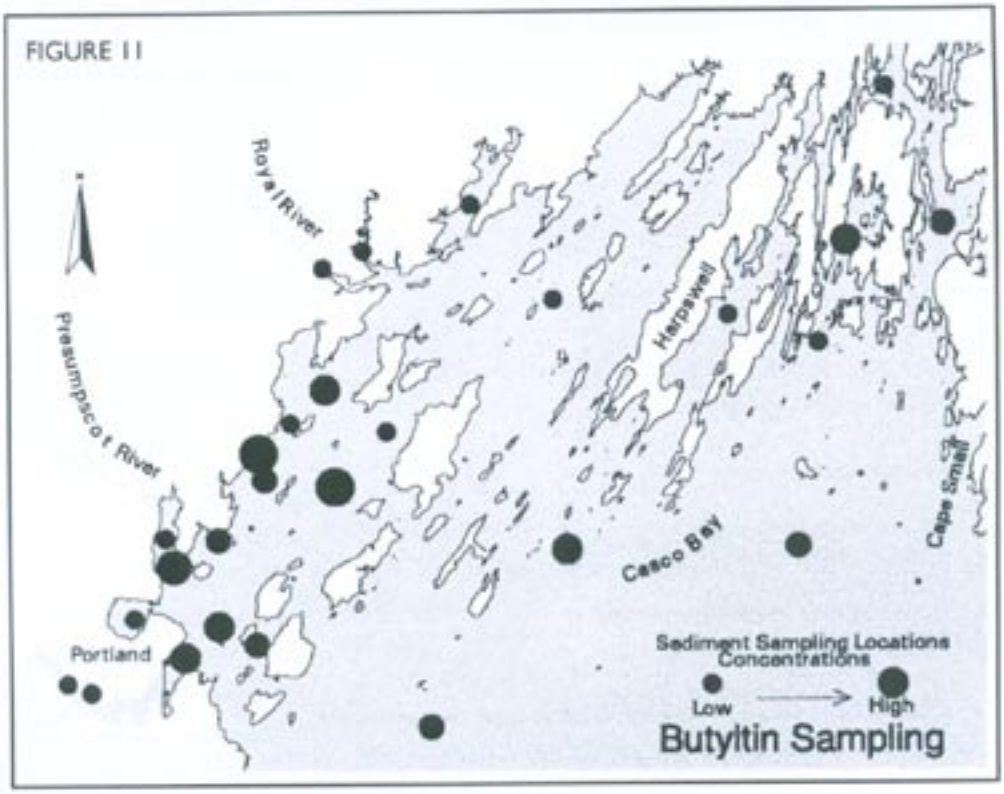
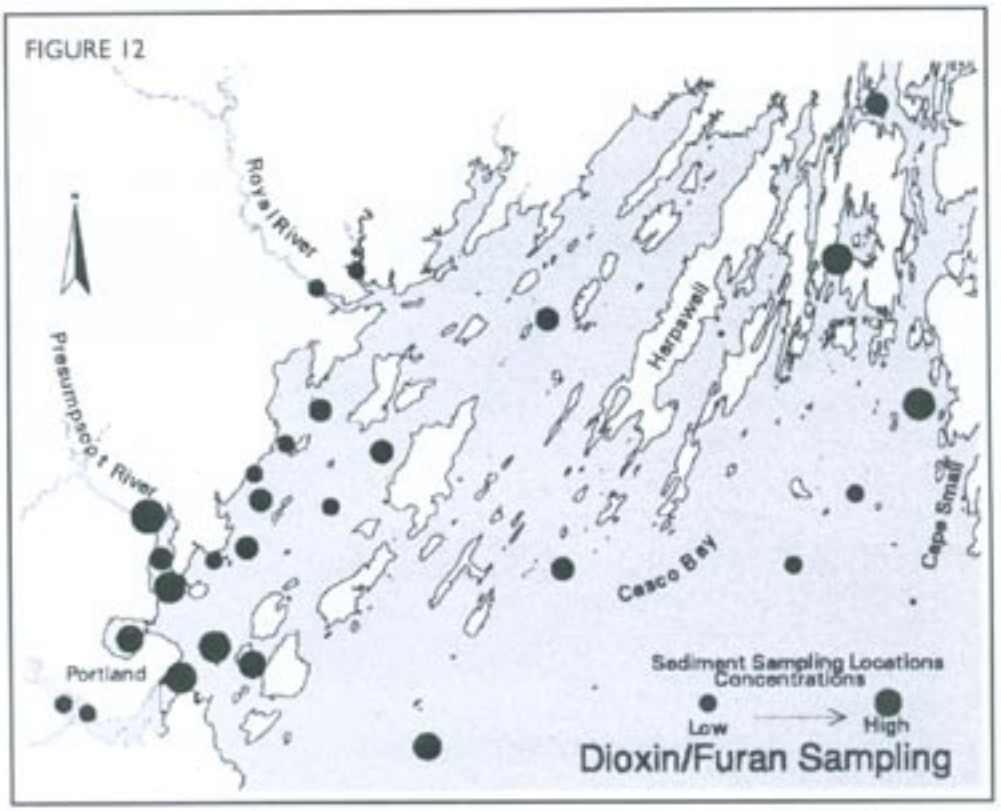


FIGURE 12



While substantial progress has been made, dioxins continue to be discharged to the river at low levels and are present in bottom sediments in and around the estuary. Periodic monitoring of this and other contaminants must be continued to assure that toxic contaminants continue to decline to protect Casco Bay's rich marine life as well as our own human health.

Ecological Effects

Toxic compounds can affect individual animals, which in turn can have profound effects on the ecosystem. Toxics have potential effects on living resources, particularly marine life, wildlife, and humans.

Various toxic pollutants (for example, PCBs, DDT, some PAHs, and dioxin) concentrate in the liver, fat, and tissue of animals and humans, seriously affecting their health. These effects, in turn, can inhibit growth and reproduction, disrupt life processes of the young, change sex ratios, and decrease natural immunities, increasing susceptibility to disease and attack by micro-organisms. Some fat-soluble chemicals, such as DDT, are liberated from fat during migration and reproduction, affecting adults, embryos, and newborns. Some species of spawning fish may detect toxic pollutants and avoid contaminated rivers, but this rerouting can disrupt their migration.

Toxic pollutants can cause:
- *Cancer*
- *Adverse reproductive effects*
- *Birth and developmental effects*
- *Organ damage*
- *Problems with nervous, immune and endocrine systems*

Bottom-dwelling (or benthic) animals play an important role in the food chain. Because contaminants collect in mud that has been recently deposited, benthic animals living in mud habitats can 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. Fish and crustaceans can absorb toxics directly by exposure to contaminants in the water and indirectly by eating contaminated food, particularly benthic organisms that pass sediments through their bodies to extract food.

Mammals, fish, and birds that feed on benthic organisms may absorb and accumulate concentrated amounts of toxic materials by eating many contaminated meals. Some of the tidal mud flats 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.

While thorough studies of toxic impacts on benthic life in Casco Bay have not been completed, there is some evidence of damage. Animals expected to occur in the flats of Back Cove are missing, and benthic life in the inner Fore River has been dramatically impaired. Potential sources of such damage include oil-related contaminants, heavy metals, combined sewer overflow discharges, sedimentary disturbances, or a combination of factors.

When toxic contaminants pose an unacceptable health risk, a consumption advisory is issued by the state toxicologist. The absence of an advisory, however, does not imply the absence of a problem because samples may not be available, and because advisory levels assume that each species consumed represents a person's total exposure to that contaminant—an inaccurate assumption. With the exception of testing for dioxin in lobsters and clams, there has been no risk assessment of potential health hazards from eating seafood from Casco Bay.

Economic Effects

The economic cost of polluted sediments can affect many sectors:

- If contaminants reduce the settlement, 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.

- When studies reveal contamination in sediments, consumers become concerned and reduce or eliminate seafood purchases, affecting fisheries markets and, consequently, those who make their living fishing.

- Dredging projects may be delayed or limited by prohibitively expensive disposal options because contaminated sediments may have to be disposed of at hazardous waste landfills or capped (covered with clean material) at sea.

- Remediation of contaminated sites in other settings has proven extremely costly. While no reme-

diation 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.

Future Research – Monitoring Casco Bay

During the past quarter-century, pollution prevention appears to have begun to produce results. *Preliminary data indicate that metal contamination in Casco Bay sediments declined in the mid-1970s.* A 1991 study showed significant declines in cadmium, chromium, lead, and zinc, though nickel levels were unchanged and copper increased in concentration (Larson and Gaudette, 1995).

To continue reducing levels of sediment contamination, more attention must now be focused on nonpoint sources such as runoff from roads and parking lots, atmospheric deposition, and the continued reduction in pollutants discharged from industrial processes. 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. Also, as cleaner sediments enter the bay, existing contaminants will be made less toxic through further dilution.

To reduce toxic pollution in Casco Bay, the Management Committee of the Casco Bay Estuary Project 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*

Monitoring is vital to assessing the health of Casco Bay, its resources, and its surroundings. The Casco Bay Estuary Project has developed a five-year monitoring program to address information needs and

Control of Toxic Inputs

While much still needs to be done, efforts to control toxic inputs in the past two decades have included the following:

- Significant regulation and public financing of wastewater disposal through wastewater treatment plants, prohibition of new overboard discharge systems, reduction of combined sewer overflows, industrial pretreatment programs, and stormwater management, have greatly reduced overall inputs of heavy metals and PAHs.
- Pollution prevention efforts by the Maine Department of Environmental Protection and local industry have led to the decreased use of chlorine and other toxics in industrial processes.
- Consumer use of TBT and other butyltins has been regulated at both the state and federal levels. Antifouling paints sold in Maine must meet stringent standards for reduced leaching rates. Only vessels over 25 meters in length are allowed to use TBT-containing paint, and these paints also have regulated release amounts.
- Manufacture of PCBs has been banned.
- Use of DDT and chlordane has been banned and other pesticides have been more stringently regulated.
- An understanding of the risks of our pervasive use of petroleum has increased. Oil spill prevention efforts are extensive in Casco Bay. There is better stewardship of underground storage of petroleum, and consumers are educating themselves on proper disposal of used oil and oil products.
- Numerous underground tanks have been removed.
- Some hazardous waste sites have been capped or remediated to slow the leaching of toxics to ground and surface waters.
- The use of best management practices in road construction, major development, farming, and forestry has decreased the potential for erosion.
- The sale of leaded gasoline, a significant source of airborne lead deposition, has been eliminated.
- Citizens and boaters are being educated about safe disposal of toxic materials.
- Solid waste management has eliminated shore-side dumps and closure and capping of old landfills has decreased the potential for toxic leaching.

gaps. The plan proposes to assess changes in toxic contamination in Casco Bay by:

- Tracking levels of pollutants entering the bay via combined sewer overflows and stormwater runoff
- Sampling sediments from sites sampled in previous studies
- Analyzing tissue of blue mussels, lobster, and waterfowl for contaminants
- Conducting a bioassay using larval bivalves, worms, or amphipods
- Studying the benthic (bottom) animal community populations
- Analyzing cooked seafood for levels of contaminants posing a public health threat

The findings of this work will help map out important steps to improve and maintain the quality of Casco Bay waters.

In addition, the lack of knowledge about the loading, magnitude, and potential sources of toxic contamination from air deposition makes policy formulation difficult. The Casco Bay Estuary Project has applied for research funds to assess the contribution of this problem.

REFERENCES

For more detail and data sources for research described above, request the Project's studies by Kennicutt *et al.* (1992), Wade *et al.* (1995), or Hawes (1993), and the *Casco Bay Plan*. Copies of these reports are filed in area libraries. For more information contact the Casco Bay Estuary Project.

Kennicut, M.C. II, T.L. Wade, and B.J. Presley. 1992. Texas A & M University. *Assessment of Sediment Contamination in Casco Bay.* Casco Bay Estuary Project.

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Long, E.R. and L.G. Morgan. 1990. *The Potential for Biological Effects of Sediment-Sorbed Contaminants Tested in the National Status and Trends Program.* NOAA Technical Memo No. 5 OMA 52.

O'Connor, T.P. 1990. *Coastal Environmental Quality in the United States, 1990. Chemical Contamination in Sediment and Tissues.* A Special NOAA 20th Anniversary Report, Coastal and Estuarine Assessment Branch, Ocean Assessments Division, Office of Oceanography and Marine Assessment, National Ocean Services, NOAA, Rockville, MD.

Wade, T.L., T.J. Jackson, L. Chambers, and P. Gardinali. 1995. Texas A & M University. *Assessment of Butyltins, PCDD/PCDF and Planar PCB Contaminants in Sediments from Casco Bay.* Casco Bay Estuary Project.

What You Can Do

While existing regulations help to reduce the volume of toxic contaminants entering Casco Bay, further action is needed. The following measures outline steps you can take to reduce toxic pollution in Casco Bay:

- Refuel boats and vehicles carefully to avoid spillage
- Dispose of used motor oil and antifreeze properly - never pour them down storm drains
- Buy unbleached paper products
- Conserve fuel and resources
- If you must use pesticides, apply them sparingly and properly

- Dispose of toxic household materials, such as batteries or unwanted paint, appropriately
- Use non-toxic household cleaners and products

For more information, request the Casco Bay Estuary Project's fact sheet "A Clean Bay Begins at Home," which outlines specific products and actions to reduce toxic inputs into the bay.

Want to know more?

The mission of the Casco Bay Estuary Project is to preserve the ecological integrity of Casco Bay and ensure the compatible human uses of the bay's resources through public stewardship and effective management. For more information, call or write:

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