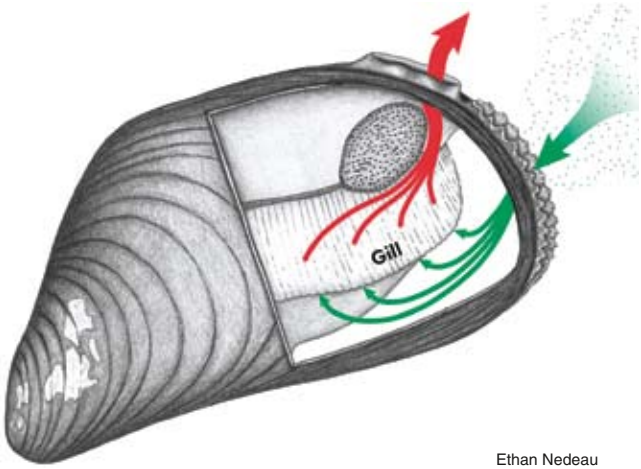
5 How are blue mussels serving as an indicator organism in Casco Bay?

Sonny McAlpin

Background

The impact of toxic chemicals on the health of natural resources and the humans who use them has been a serious concern for in the United States since the 1960's, when the devastating effects of DDT were first publicized. We now know that toxic chemicals, including metals, pesticides and other organic chemicals are found at varying concentration levels everywhere in our environment. A key question for health and resource managers is whether or not they are present at levels that can cause toxic effects in humans and other organisms (Maine DEP 2005). Regularly monitoring toxic chemicals levels in a common resident organism that serves as a "sentinel" or "indicator" organism can be an effective environmental management tool.

The common blue mussel, *Mylius edulis,* is an ideal indicator species for marine environments. It is sedentary as an adult and relatively long-lived, accumulating contaminants from the local environment as it feeds and through surface contact with the sediments (see Figure 5-1). The mussel is commonly found throughout the coastal areas of the Gulf of Maine, making it useful for regional as well as local contaminant assessment (GOMC 2004). In Maine, blue mussels are found in dense beds in the intertidal zone (between the high and low tide lines), where they can serve as good indicators of sediment contamination. Because they are primary consumers at the base of the food chain, elevated levels of toxic contaminants in the tissues of mussels may suggest that higher level consumers like fish and humans may be at risk from contaminants in the ecosystem.



Ethan Nedeau

Figure 5-1. *The common blue mussel serves as an excellent indicator of environmental contamination. As the mussel breathes and feeds, its gill filters out and retains particles, including contaminants, which can be digested and assimilated into its tissues.*

Monitoring Blue Mussels in Maine's Coastal Waters

In 1987, Maine DEP began a major long-term study (the Marine Environmental Monitoring Program) to assess the levels and locations of toxic contaminants along the coast, using the common blue mussel as the indicator species. Because regional and national programs also sample mussels (NOAA's Mussel Watch and the Gulf of Maine Council on the Marine Environment's Gulf Watch) these larger data sets help to provide a context for assessing the relative conditions in Maine. The goals of Maine DEP's blue mussel sampling program included:

- Defining background (or baseline) levels of toxic chemicals in Maine mussels and
- Determining what levels pose a health risk to humans and/or marine life

Sampling included mussels from 24 "reference sites" thought to represent a relatively unimpacted background condition, free from industrial and anthropogenic influences. These sites were used to describe normal background (baseline) levels. Normal was defined as plus or minus 2 standard deviations around the mean of concentrations found in mussels collected at the reference stations. Because the concentration of toxic chemicals in mussel tissue varies with season, age of mussels, location in the intertidal zone and reproductive state, the time of collection was standardized to an "index period" from late August to early October, with mussels selected from the low intertidal or shallow subtidal zone. The Maine DEP program divided the Maine coast into 8 regions, each reflecting an ecological system such as a large estuary, coastal or intertidal regime. One of the regions selected was Casco Bay, a semi-enclosed system with a deeply indented coastline and many islands (Maine DEP 2005).

Mussels were sampled for the metals aluminum (Al), arsenic (As), cadmium (Cd), copper (Cu), iron (Fe), nickel (Ni), lead (Pb), zinc (Zn), silver (Ag), and mercury (Hg) as well as pesticides, dioxins and furans, PAHs (polycyclic aromatic hydrocarbons), and PCBs (polychlorinated biphenyls) at multiple sites in Casco Bay. Since 1996, CBEP has supplemented the Maine DEP's Marine Environmental Monitoring Program and Surface Water Ambient Toxics Monitoring programs by sampling at additional Casco Bay sites.

Based on the mussel sampling data, the Marine Environmental Monitoring Program has established normal baseline reference concentrations for metals in mussels, with the exception of arsenic. Arsenic is compared to elevated levels as reported in NOAA (1988). Organics (PAHs, pesticides, and PCBs) are also compared to NOAA's 1998 reported elevated levels (Maine DEP 2005).

Key Results of Maine DEP and CBEP Mussel Sampling in Maine

Blue mussel soft tissue data is now available from approximately 65 sites sampled along the Maine coast during the period 1987 to 2003. When compared to the established baseline reference concentrations, some sites in Maine had contaminant levels above the Maine coastal norm. Most, however, did not. Mussels with elevated levels of toxic chemicals in their tissues were generally in the most heavily developed ports and harbors or were in the mouths of major industrial rivers, as seen in the overview of lead concentrations in sites sampled since 1987. Figure 5-2 provides an overview of the results of lead sampling sites in the Bay. Note that the elevated and highly elevated levels of lead are seen in areas with high levels of human activity.

CBEP sampling in 1996 and 1998 indicated elevated toxic chemicals at the following sites:

- Lead levels were elevated in Back Cove mussels while dioxins and furans were elevated in Freeport, New Meadows, Jewell Island, Back Cove, and the Harraseeket River; total PCBs were elevated in samples from Back Cove, Quahog Bay, and somewhat elevated in samples from Falmouth.
- Arsenic was elevated at Falmouth and Jewell Island,

For samples collected by CBEP and Maine DEP from 2001 to 2003, Table 5-1 indicates sites where metals were elevated above the State normal baseline. For other toxic chemicals, areas where elevated levels were detected are summarized as follows:

- PAHs were at baseline levels at all sites except the inner Fore River where they were highly elevated.
- PCBs and pesticides were at baseline or below at all other sites except the inner Fore River site, where PCBs were approaching elevated.

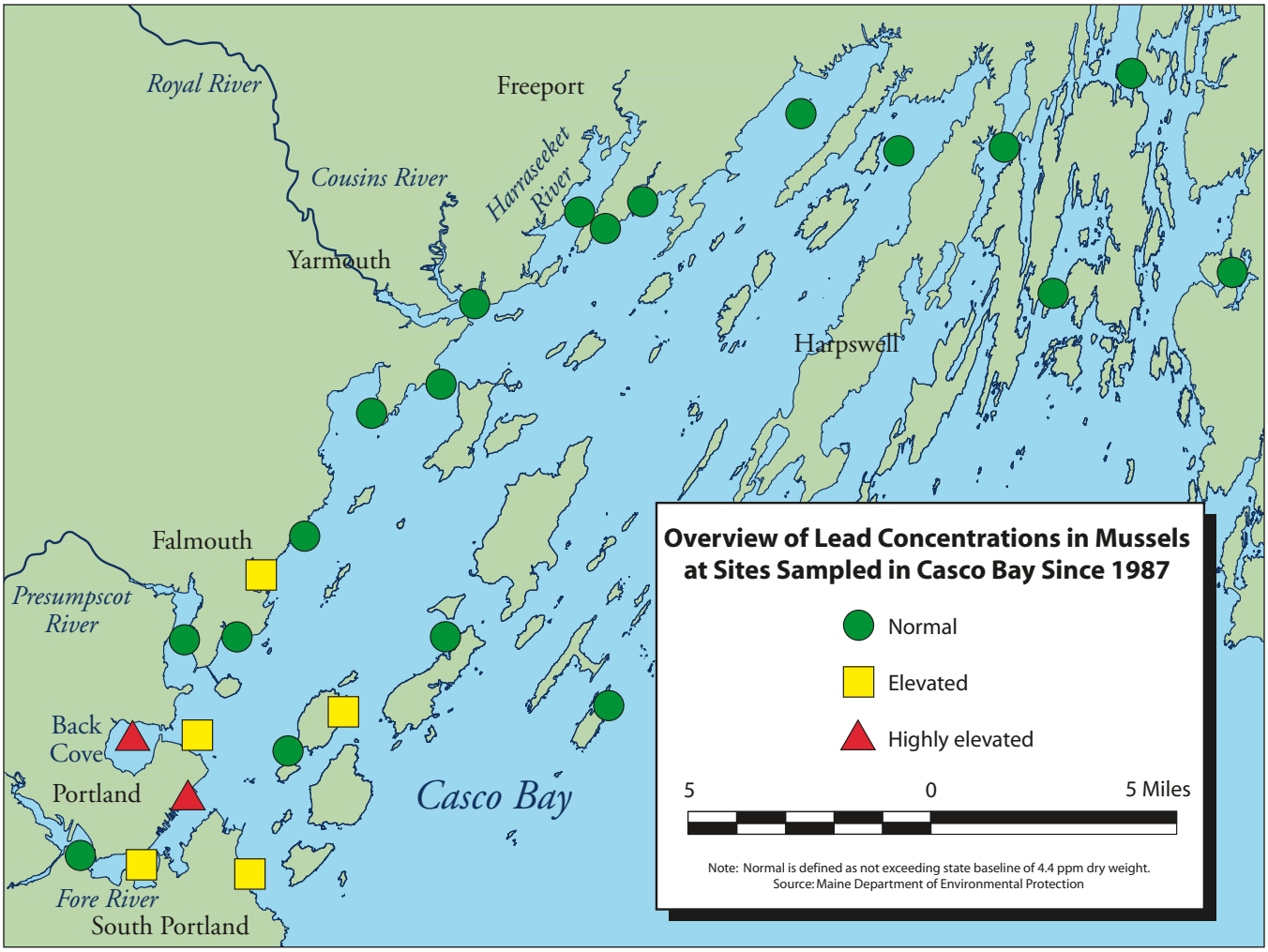


Figure 5-2. *Long-term monitoring of mussels in Casco Bay indicates that elevated levels of metals (such as lead) tend to be found in areas where human activity is concentrated.*

Changes in Toxics Concentrations Over Time

Sampling at the same locations several years apart allows us to look at the way concentrations of contaminants are changing over time. Six of the sites noted in Table 5-1 were also sampled for metals in 1988. The 1988 data was the result of a single sample while the 2001 and 2002 results are based on four replicate samples. Note that aluminum was not included in the 1988 analysis. Along with iron, aluminum is used to indicate the extent to which mussels are ingesting suspended sediments and is reported as elevated in the table to give an indication of the amount of sediment in the gut of the mussel.

Table 5-1: Maine Department of Environmental Protection

Metals Elevated Above Maine Normal Baseline Values Found in Mussels from Sampling Sites in Casco Bay 2001-2003

	Al	Cd	Cr	Cu	Ni	Pb	Zn	Ag	Hg
Great Diamond Island (Cocktail Cove)	X					X		X	
Long Island					X				
Mare Brook	X								
Inner Fore River						X	X		X
Maquoit Bay	X								
East End Beach						X	X		
Spring Point						X	X		
Mill Creek						X			
Outer Fore River						X			

Source: Maine Department of Environmental Protection

The six sites sampled in both 1988 and 2001/2002 are Great Diamond Island, Long Island, the Inner Fore River, East End Beach, Spring Point and Mill Creek. Each of these sites is characterized below, including changes in land use that may have altered the concentration or availability of toxic chemicals to resident blue mussel populations.

- **Great Diamond Island, Cocktail Cove** is a protected cove, heavily used by recreational boaters in the summer. The shoreline is ledge with gravel beaches. Increased development has changed land use dramatically since 1988. A restaurant and marina and new seasonal and year-round homes have increased boat traffic and nonpoint source runoff. In 1988, while levels of metals were within normal concentrations, the lead level was approaching the human health action level (Maine DEP 2005). A repeat sampling in 2001 indicated that lead concentrations were now twice as high. Arsenic and silver were also elevated, but were not sampled in 1988.

- **The Long Island** fuel terminal area (the shore adjacent to the former Navy fuel depot) at Ponce Landing has sand and gravel beaches with rocky outcrops. The area is now residential. In 1988, cadmium and zinc were elevated above normal and lead was elevated above the health screening level. The presence of toxics is likely related to the past history of the site (Maine DEP 2005). In 2001, metals were all in the normal range with the exception of nickel, which was elevated.

- **The Inner Fore River,** upstream of the I-95 Bridge is a soft mud-bottom area that receives freshwater inflows from the Stroudwater River. There is moderate commercial and residential development nearby. Historically, the water quality has been compromised by industry upstream. In 1988, metals were in the normal range with the exception of zinc, a common constituent of road runoff which derives from tire material. Both the Portland Jetport and the Maine Mall are nearby sources of polluted runoff (Maine DEP 2005). In 2002, the concentration of lead was twice as high, zinc had decreased but was still at the high end of the Maine coastal normal baseline, and mercury was in a range similar to the 1988 value.

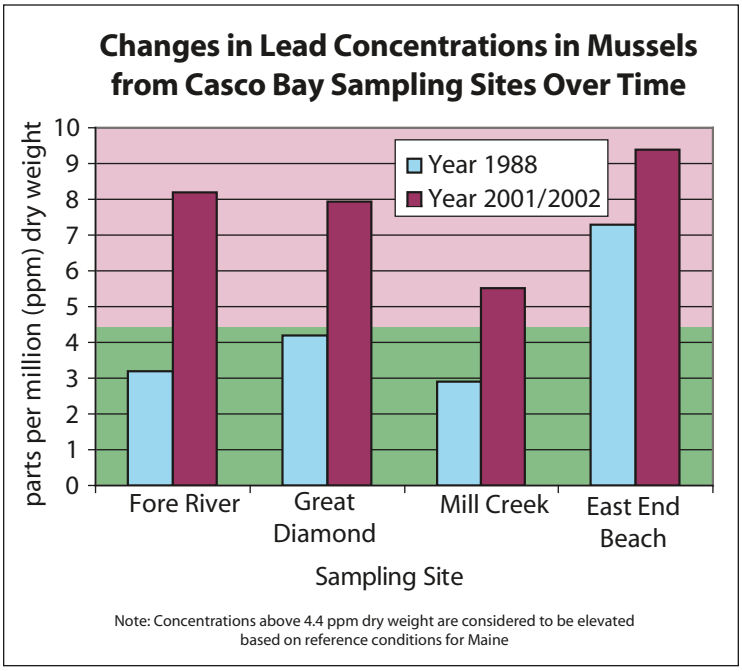
- Off of **East End Beach**, the sediment is composed of fine and coarse rubble, including fill from the old city dump. Water quality at the beach may be affected by urban runoff, leachate from the dump and possibly pollutants carried downstream by the Presumpscot River. The area is densely residential, with a municipal sewage treatment plant nearby. In 1988, both lead and zinc were elevated (Maine DEP 2005). In 2001, lead and zinc were still elevated, with slight increases in concentration. Cadmium increased to 2.66 ppm in 2001, elevated based on reference conditions for Maine (the coastal baseline norm is 2.56 ppm).

- **Spring Poin**t (South Portland) area has a narrow intertidal shoreline which is rocky and drops off steeply to deepwater. The adjacent area is residential with nearby industrial development. There are no direct discharges, but the area is likely impacted by urban runoff and pollutants from the inner harbor carried by the outgoing tide. In 1988, lead was elevated (Maine DEP 2005). In 2001, the lead level was still elevated but the concentration had declined since 1988, as it has in most areas of the Bay.

- **Mill Creek** (Mussel Cove) is an estuary comprised of intertidal mud flats. The Cove has a drainage areas of 5.4 square miles. Over the past 25 years, development along Route 1, including two shopping centers, has greatly increased the amount of impervious surface and stormwater runoff to the Cove. In 1988, metal concentrations were within normal baseline conditions, including a lead concentration of 2.90 ppm (parts per million) in the single replicate sample (Maine DEP 2005). In the 2001 sampling, lead concentrations increased to an average of 5.51 ppm in the four replicates, exceeding the level considered high for Maine.

The increases in lead levels that were seen at four of the sites (Inner Fore River, Great Diamond Island, Mill Creek and East End Beach in Portland) are all likely related to increased development and impervious surface (see Figure 5-3).

Figure 5-3



Marine and Estuarine Areas of Concern in Maine for Toxic Contamination.[1]

Location	Area
Cape Rosier	80 acres
Boothbay Harbor	410 acres
Fore River (Casco Bay)	1,230 acres
Back Cove (Casco Bay)	460 acres
Presumpscot River Estuary (Casco Bay)	620 acres
Piscataqua River Estuary	2,560

Based on sediment and mussel tissue analyses, Maine DEP has identified six areas of concern for toxics along Maine's coast, which are listed above. Three of these areas are in Casco Bay. As noted earlier, the most impacted areas tend to be in heavily developed ports and harbors or in the mouths of major industrial rivers (Maine DEP 2004).

[1]Acreage based on professional judgement.

Comparing Levels of Toxics in Casco Bay and Gulf of Maine Mussels

Gulfwatch is a joint United States/Canadian blue mussel monitoring program sponsored by the Gulf of Maine Council on the Marine Environment. The program is intended to help identify temporal and spatial trends in ecosystem exposure and exposure variability in the Gulf. Since 1993, Gulfwatch scientists have regularly sampled mussels along the coast of the Gulf of Maine. Five "benchmark" sites have been sampled every year. A total of 27 other sites have been sampled every 3 years on a rotating basis. There are also 6 multi-year sites that have been sampled every six years. Mussel tissues have been tested for 9 trace metals,16 pesticides, 24 PCB congeners (varying configurations of chemical structure) and 24 PAHs. Of the 38 sites that have been regularly monitored, three are in Casco Bay: these are located in Portland Harbor, the Presumpscot River estuary and the Royal River estuary.

Data from the first nine years (1993-2001) of Gulfwatch sampling have been analyzed and interpreted (GOMC 2006).

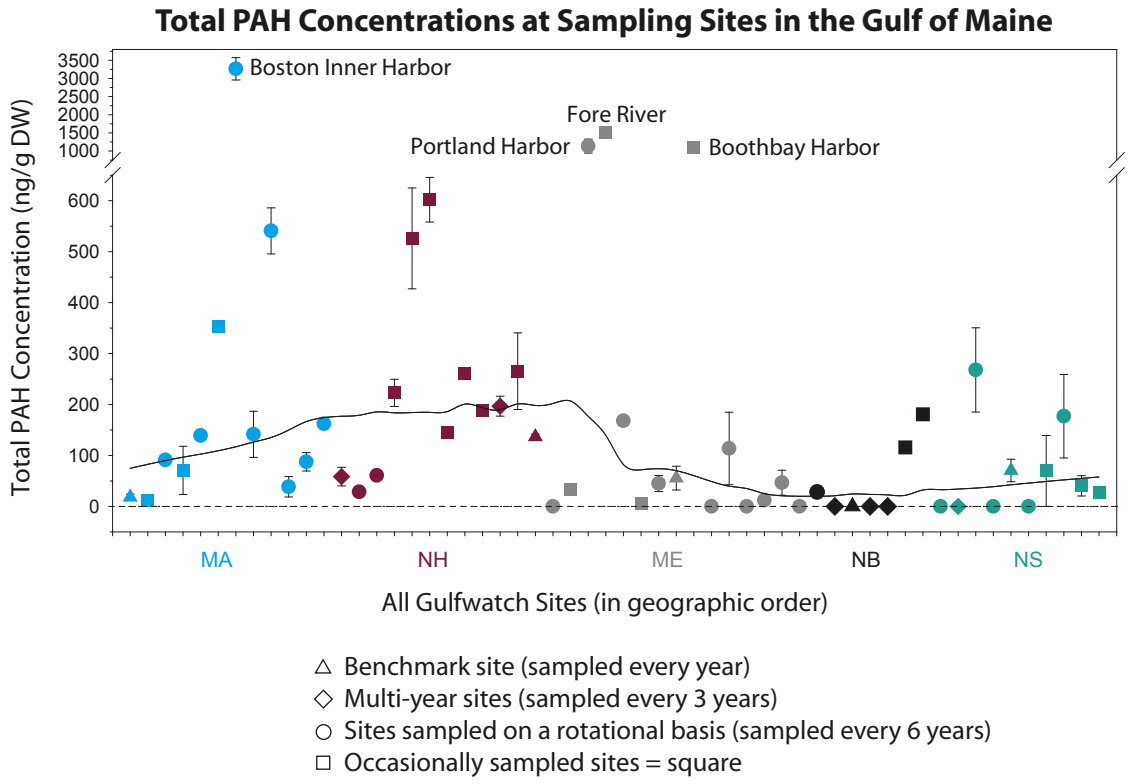
Statisitically significant spatial trends included:

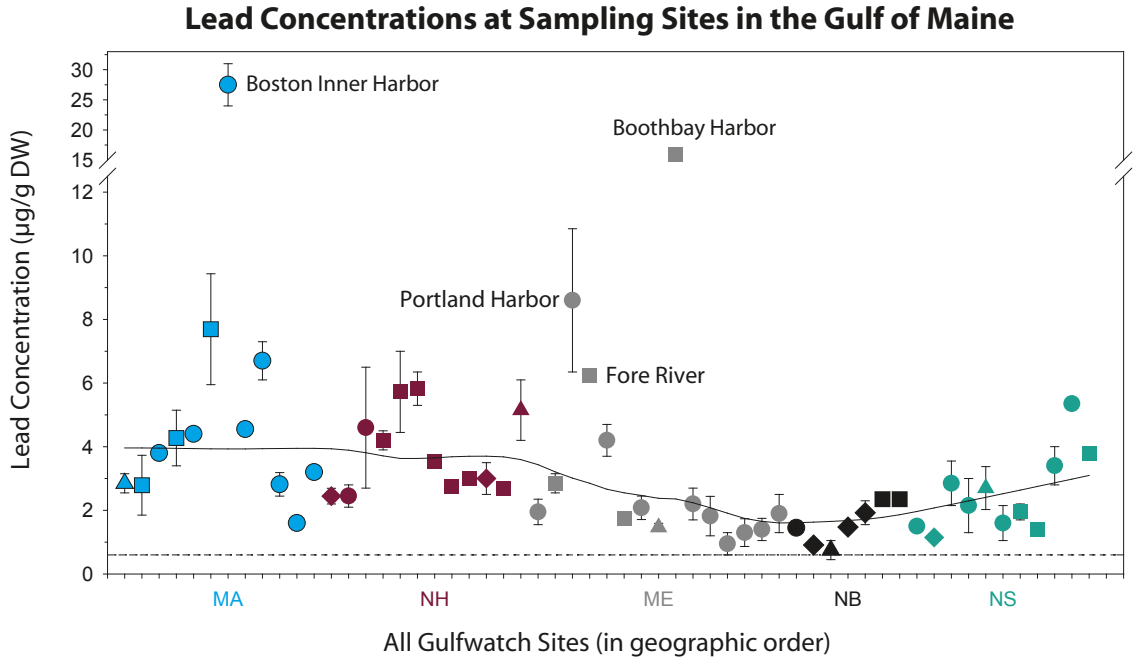
- Decreasing trends south to north for silver, chromium, copper, lead and zinc
- Decreasing trends south to north for total DDT and DDT metabolites p,p-DDE and p,p-DDD, and for total PCBs

Statistically significant temporal trends :

- Silver, chromium, iron, lead, zinc, p,p-DDE and total DDT declined at some of the benchmark sites.
- Total DDT increased in Sandwich, MA.

Figure 5-4. *Nine-year (1993-2001) median and median absolute deviations for the sum of total PAH concentrations in nanograms/gram dry weight (ng/g DW) and lead concentrations in micrograms per gram dry weight (µg/g DW) in mussel tissues at all Gulfwatch sites, in geographic order (south to north along the x axis from Massachusetts to Nova Scotia). Note the elevated levels of PAHs in Portland Harbor and the Fore River. The dashed line indicates the detection limit of the analytical method. The solid line is the Lowess smoother, a statistical smoothing function for scatter plots that results in a locally weighted regression line (GOMC 2006).*





Gulfwatch sites in Casco Bay with elevated concentrations of toxic chemicals

- Lead was detected at concentrations exceeding the federal action level (level at which a consumption advisory may be appropriate) of 11.5 parts per million at the Portland Harbor site in several samples (see Figure 5-4). There were increasing concentrations of lead at the Casco Bay sites, including Portland Harbor. This data is consistent with the results of the Maine DEP and CBEP monitoring studies (see Figures 5-2 and 5-3).
- The sites in Maine with the highest mussel tissue PAH concentrations were in Casco Bay. Mussel tissues from the Fore River site and the Portland Harbor site had 1500 and 1100 nanograms/gram (ng/g) dry weight respectively. The PAH median value for Maine as a whole was 45 ng/g (see Figure 5-4). CBEP and DEP sampling in 2001 to 2003 also showed highly elevated levels of PAHs in the Fore River.

Summary/Conclusions

Most areas in Maine that are away from human activity, past and present, contain background/baseline concentrations of toxic metals and organic chemicals. Based on the blue mussel as an indicator, elevated levels of toxic contaminants in Maine tend to be present in areas with an industrial history (*e.g.*, past manufacturing), in harbors, commercial ports, the mouths of river watersheds and in locations adjacent to population centers. This is also confirmed by regional mussel sampling conducted by the Gulfwatch Program. The geographic distribution of sediment contamination in the Bay (see Chapter 4) is generally confirmed by the analysis of mussel tissue by the Maine DEP, CBEP and Gulfwatch monitoring programs.

The concentration of toxic chemicals found in blue mussel tissues is one of the fourteen indicators used by the CBEP to evaluate the environmental health of Casco Bay in *State of the Bay* (CBEP 2005). Continued mussel monitoring in the Bay will be useful to establish temporal and spatial trends in ecosystem contaminant levels and to assess potential health risks to human seafood consumers. The health implications of elevated levels of contaminants in blue mussels from Casco Bay are discussed in Chapter 8.

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