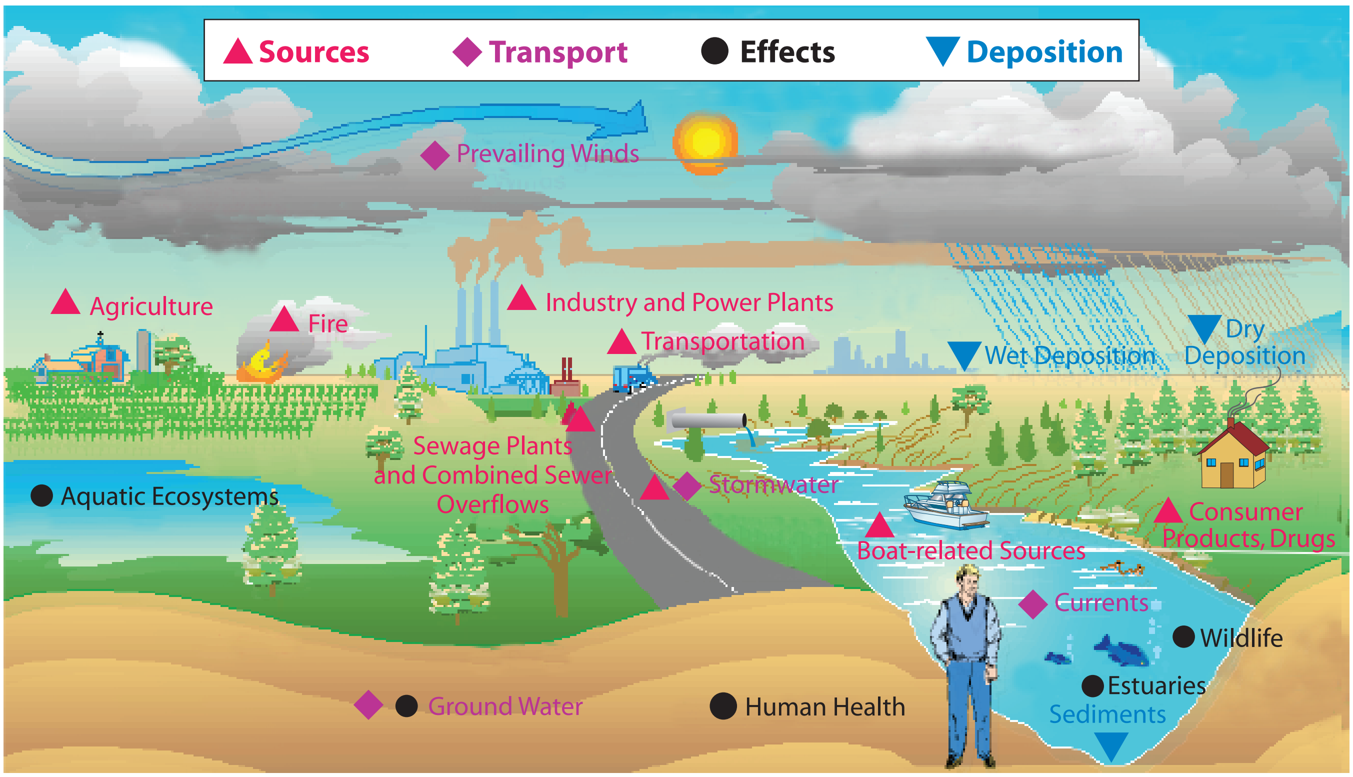
SECTION FOUR

Toxic Pollution



Toxic Chemical Pathways. Major toxic chemical pathways including sources, transport mechanisms, deposition, and effects are illustrated. Whether the toxics enter the watershed from point sources such as pipes, smokestacks, and internal combustion engines, or are transported and deposited by rain (wet deposition), wind (dry deposition) and stormwater runoff, toxic chemicals are finding their way into freshwater and marine aquatic ecosystems.

Adapted from National Science and Technology Council Committee on Environment and Natural Resources, Air Quality Research Subcommittee, 1999.

Introduction

Toxic chemicals are the major stressor impairing Maine's marine and estuarine waters (DEP 2008). The toxic chemicals addressed by CBEP's indicators include two primary types of pollutants: (1) heavy metals and (2) organic chemicals like polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), pesticides, and dioxins and furans – bonded forms of carbon, hydrogen and other atoms. Those organic chemicals break down slowly into their component parts, but as they do, they and their metabolites (breakdown products) can be toxic to living organisms. Since the 2005 *State of the Bay* report and the 2007 report *Toxic Pollution in Casco Bay*, CBEP has added a new class of contaminant chemicals to the indicators it monitors: "contaminants of emerging concern," chemicals that have not traditionally been monitored or regulated. Those include persistent organic chemicals like polybrominated diphenyl ethers (PBDEs) and perflourinated chemicals (PFCs) as well as pharmaceuticals and personal care products (PPCPs). Such contaminates are being found worldwide in aquatic environments, including Casco Bay.

Major pathways by which toxic chemicals enter the environment are illustrated in the diagram above. Sources of the toxic chemicals found in Casco Bay include the following:

- **PAHs**, the most common toxic contaminants in the Bay, come primarily from combustion of fossil fuels and wood, but oil, fuel spills, and asphalt are also sources.

- **PCBs** are potent carcinogens formerly used in electric transformers and other industrial applications. While they were banned in the 1970s, they are still found in old landfills and dumps, and are present at high levels in the Fore River.
- **Planar PCBs** are the most toxic form of PCBs, and commercial PCB mixtures are their source (Tanabe *et al.* 1987).
- **Pesticides** are largely carried from lawns and fields to water bodies through stormwater runoff. Although banned since 1972, the pesticide DDT and its toxic breakdown products still persist in the environment.
- **Dioxins and furans** are formed when organic material is burned in the presence of chlorine. Incineration, pulp paper manufacturing, coal-fired utilities, diesel vehicles and metal smelting are all sources of dioxin in the environment. Although the pulp mill discharging waste into the Presumpscot River stopped doing so in 2000, dioxins and furans still reach the Bay through atmospheric deposition.
- **PBDEs** are organic contaminants used as flame retardants in a variety of consumer products. They enter the environment through runoff, municipal waste incineration and sewage outflows, as well as by leaching from consumer products, sewage sludge applied to land as bio-solids, and industrial discharges (Kimbrough *et al.* 2009).
- **PFCs** are heat-resistant, slippery industrial chemicals that are used, for example, as water, stain and grease repellants (*e.g.*, Teflon). They are released into the environment through manufacturing processes, as well as through industrial and consumer use.
- **PPCPs** include over-the-counter and prescription drugs, as well as personal hygiene and beauty products like soaps, hairspray and sunscreen. When consumers wash off, excrete, or discard such products down drains, they can pass through septic systems and wastewater treatment plants into the environment.
- **Butyltins** are toxic organometallic compounds, molecules in which metal is bonded to a carbon atom in an organic molecule. Butyltins enter the Bay's sediments primarily from marine anti-fouling paints.
- **Heavy metals** are dense metallic elements such as lead, mercury, arsenic, cadmium, silver, nickel, selenium, chromium, zinc and copper. Because they do not break down over time, metals delivered from point sources, stormwater runoff, or atmospheric deposition can accumulate in the environment. In addition, metals can bind with organic chemicals forming organometallic compounds such as methyl mercury and butyltin, which can be highly toxic. Sources of heavy metals include vehicle emissions, industrial processes, coal combustion, weathering of metal pipes, and incineration (CBEP 1996).

The following three indicators report on toxic chemical monitoring programs that CBEP and its partners and collaborators are undertaking in Casco Bay.

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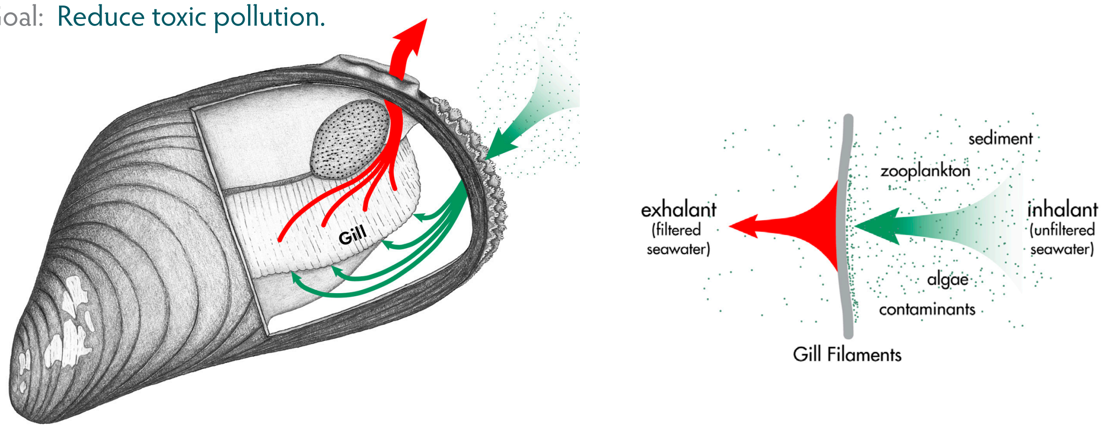
Are there toxic chemicals in the tissues of Casco Bay blue mussels?

CBEP Goal: Reduce toxic pollution.



Ethan Nedeau

The common blue mussel is an excellent indicator of environmental contamination. As a mussel breathes and feeds, its gill filters out and retains small particles, including biologically available contaminants, which can be ingested and assimilated into its tissues.

Why Is It Important to Monitor the Levels of Toxic Chemicals in Blue Mussels in Casco Bay?

The common blue mussel, *Mytilus edulis*, is long lived and sedentary as an adult, accumulating local contaminants through feeding and surface contact. It is common throughout Gulf of Maine coastal areas where it is found in densely populated beds in the intertidal zone—the area between low and high tides. Casco Bay is one of the most productive areas in Maine for wild mussels. The blue mussel is thus a useful "sentinel" species for the Bay. Because many toxic compounds biomagnify (become more concentrated in organisms higher up the food chain), elevated levels of contaminants in the tissues of blue mussels—which are near the base of the food chain—suggest that top-level consumers, including fish and humans, may be at risk from contaminants in the ecosystem.

Andreas Trepte

Data on toxic compounds in mussels from Casco Bay come primarily from statewide and regional monitoring programs. Maine DEP began using *Mytilus edulis* as an indicator species of toxic exposure in 1987, and has analyzed their soft tissues from approximately 65 sites along the Maine coast over the past 23 years. CBEP has periodically provided funding to add additional sites in Casco Bay to the program. Gulfwatch, a joint US/Canada blue mussel monitoring program, began sampling US and Canadian waters in 1991.

Status of Casco Bay Mussels

DEP SWAT Program 2007–2009 Sample Collection

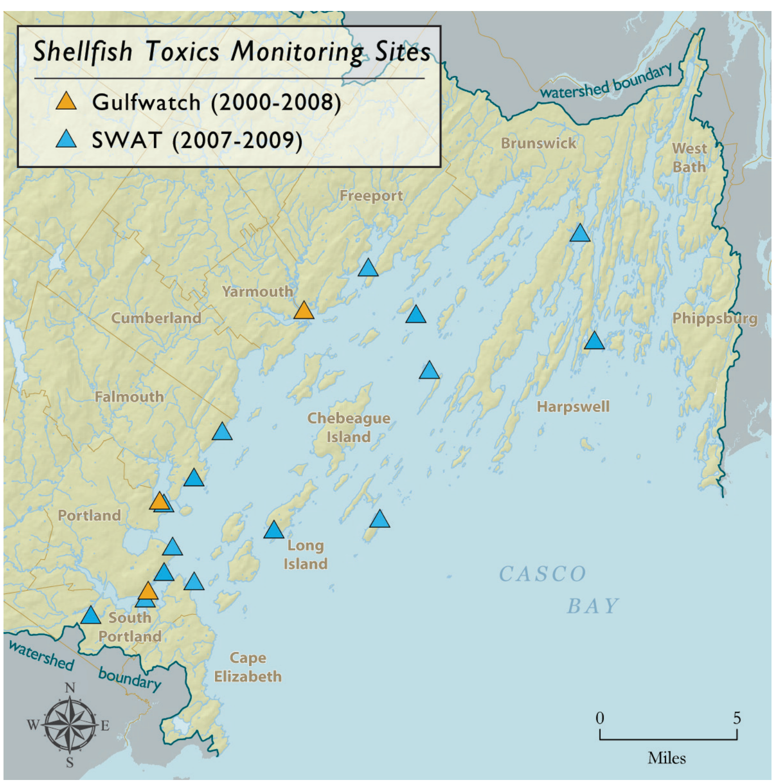
Samples were collected by DEP from sites in Casco Bay in 2007, 2008 and 2009 (see map on p. 39). Sampling was done from mid-October to mid-December each year, at four sites along the shoreline at each of the sampling locales. Mussels selected for analysis were in the 50 - 60 mm size range (DEP 2010). All samples were analyzed for aluminum (Al), arsenic (As), cadmium (Cd), copper (Cu), iron (Fe), nickel (Ni), lead (Pb), zinc (Zn), silver (Ag) and mercury (Hg), PAHs, PCBs pesticides, dioxins and furans. Samples with elevated levels are noted in the table. Note that elevation of Al and Fe (which are common and relatively non-toxic constituents of clay and soil minerals) often corresponds to high intake of suspended sediment and may relate to gut contents rather than tissue levels.

Pesticides sampled include the sum of DDTs (dichloro-diphenyl-trichloroethylene) and breakdown products. While the highest DDT levels were seen in Long Island, all Maine samples were considered to be in the low range nationally, based on National Status and Trends Mussel Watch data (NOAA 2008). Dieldrins and chlordanes were also in the low range in Maine samples. Elevated levels for the sum of organochlorine pesticides as compared to

Toxics Elevated[1,2] in Mussels Collected from Sampling Sites in Casco Bay 2007 – 2009
(Note that only East End Beach was sampled twice during this period)(DEP 2010)

Year Sampled	Sampling Location	Al	Fe	Cr	Cu	Ni	Pb	Zn	Hg	PCBs[3]	PAHs[4]	Organo-chlorine Pesticides[5]
2007	Spring Point, S. Portland				X[2]		X[2]					X[2]
	Middle Fore River, S. Portland				X[2]		X[2]	X[1,2]		X[2]	X[2]	X[2]
	East End Beach, Portland				X[2]		X[2]					X[2]
	Jewell Island, Punch Bowl											
	Falmouth Anchorage				X[2]							
	Harraseeket River, Freeport				X[2]							
	Mare Brook, Harpswell Cove				X[2]							
2008	Presumspcot River, Falmouth				X[2]		X[1,2]		X[2]			X[2]
	Middle Bay, Harpswell											
2009	Inner Fore River, Portland	X[1,2]	X[2]	X[1,2]	X[2]	X[2]				X[2]	X[2]	X[2]
	East End Beach, Portland	X[1,2]	X[2]	X[1,2]		X[2]	X[2]			X[2]		X[2]
	Mill Creek, Falmouth											
	Long Island											X[2]
	Maquoit Bay Freeport											
	Quahog Bay, Harpswell					X[2]						

1 Elevated based on Maine Reference Conditions, mean + 2 standard deviations (DEP 2005)
2 Elevated based on Gulf of Maine-wide Gulfwatch 85th percentile value, *i.e.*, 85% of samples fall below the 85th percentile value (GOMC 2009)
3 Sum of 19 PAHs
4 Sum of 35 PCB congeners
5 Sum of Organochlorine pesticides



other data from the Gulf of Maine are noted in the table. In 2009, samples were also collected for additional pesticides: organophosphates, triazines, pyrethroids and organonitrogens. Those pesticides were not at detectable levels in the Maine samples tested (DEP 2010).

Temporal Trends in Casco Bay

Where data from the same sites are taken over time, it may be possible to compare the levels of pollutants, and observe whether there is any apparent temporal trend. Maine DEP undertook an analysis of temporal trends for selected metals in mussel samples collected from 1987 to 2008 (DEP 2009). Three Casco Bay sites were included: East End Beach in Portland, and Spring Point and Middle Fore River, both in South Portland. The results indicated that:

- Cadmium showed a stable or decreasing trend.
- Copper was relatively stable through time.
- Zinc was relatively stable through time (DEP 2009).

Changes in Lead Concentration in Mussels from Casco Bay Sampling Sites Over Time

DEP SWAT sampling over time at several Casco Bay sites suggests that while there was an initial increase in lead levels from 1988 to 2001/2002, there has been a decline in lead levels in more recent samples. Units are micrograms per gram dry weight. The Gulfwatch mussel sampling program (see table below) has observed a regional decline in lead levels over the past decade.

Comparison of lead levels in past and recent samples suggests that for some sites in Casco Bay, lead levels have declined over time. (See the bar graph above.)

Trends in Mussel Toxics Across the Gulf of Maine: Gulfwatch Data

Gulfwatch is a joint US/Canada blue mussel monitoring program funded through the Gulf of Maine Council on the Maine Environment. Since 1991, the program has monitored mussels to help identify temporal and spatial trends in ecosystem exposure to toxic compounds throughout the Gulf. Three sites sampled from 2000-2009 lie within the Casco Bay watershed: Portland Harbor (sampled five times in that period), Presumpscot River (sampled three times) and Royal River (sampled twice).

Metals

Concentrations for most metals appear to have decreased over time in the Gulf. In addition, concentrations are generally higher to the south and west, and lower heading downeast. At the Portland Harbor site, most metal concentrations, including lead, decreased from 2000 to 2008 (see the table below). To the extent comparisons can be made, metals at the other sites (data not shown) showed either no change or a decline over time.

PAHs

PAHs in the region (based on the sum of 24 PAHs) were highest for the two sites located in Boston Harbor and Long Island-Boston Harbor. For the most part, sample locations for the remainder of the Gulf of Maine contained relatively low levels of PAHs. However, the fourth highest total PAHs in the Gulf of Maine were observed at Portland Harbor (see the graph on p. 41). Similar high levels of PAHs were noted in the 1993–2001 data analysis (GOMC 2006).

Chlorinated Pesticides and PCBs

With respect to chlorinated pesticides, values were quite high in Massachusetts, with the largest concentrations observed in Boston's Inner Harbor. Casco Bay samples ranged from a low at the Royal River site to a high at Portland Harbor. In general, concentrations of pesticides decrease with increases in latitude. Similarly, the concentrations of all PCBs summed together decrease with increases in latitude. Highest values were observed in Massachusetts at Neponset River and Boston's Inner Harbor. Casco Bay samples ranged from a low at the Royal River to a high at Portland Harbor.

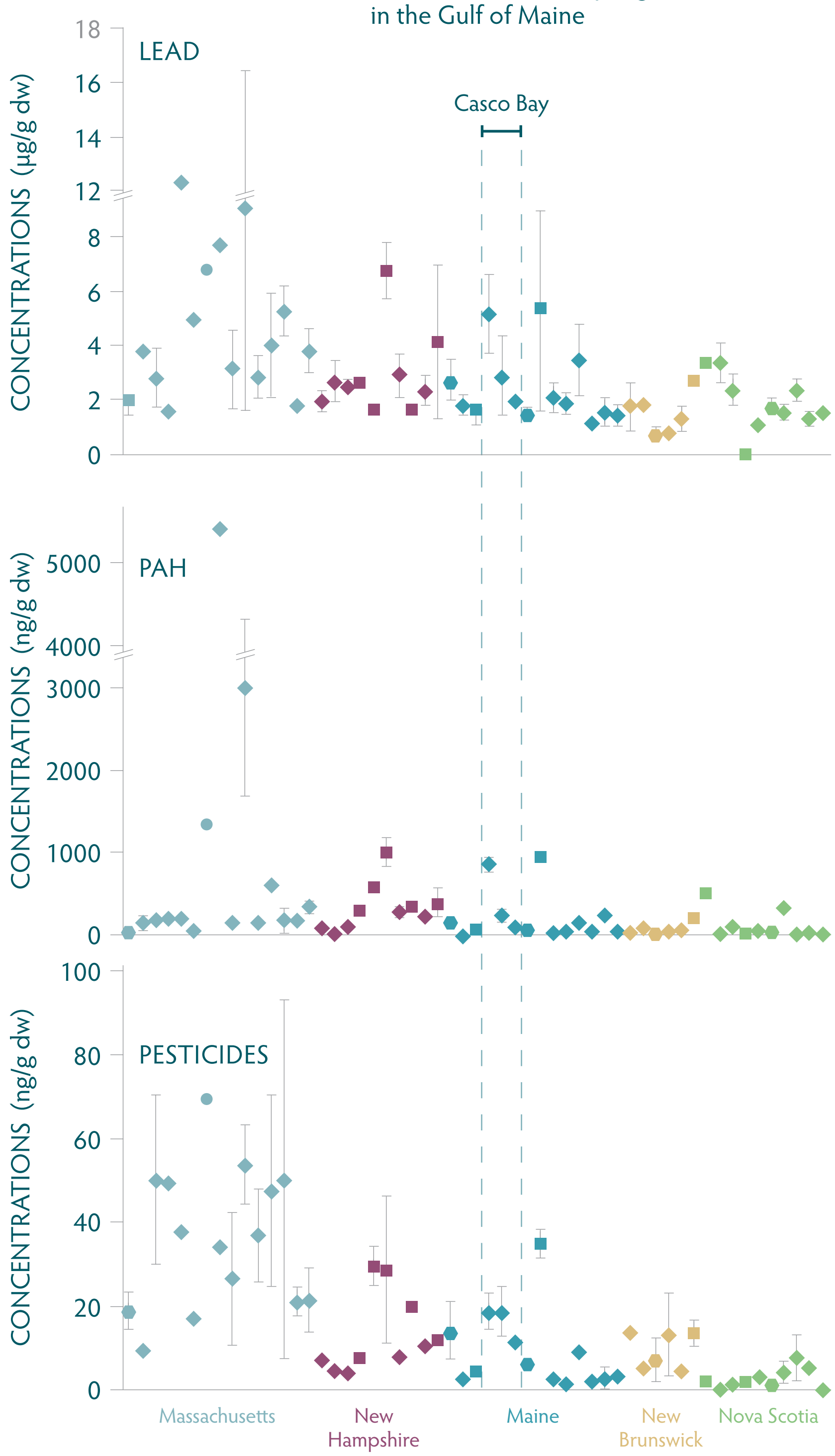
Gulfwatch Data for Metals in Portland Harbor

Year	Hg	Ag	Cd	Pb	Ni	Zn	Al	Cr	Fe	Cu
2000		0.1	1.78	11.5	2.45	357.5	370	2.3	737.5	12.3
2003	0.30	0.09	1.48	2.33	7.62	107.8	467		668.8	
2005	0.29	0.05	1.89	6.58	1.39	159.5	464	1.8	761.3	8.6
2007	0.2	0.02	1.39	4.34	0.95	146	250	1.7	444	7.6
2008	0.2	0.02	1.48	5.16	1.06	139	483	1.4	606	8.08

Most metals have decreased over time (units are μg/g dry weight).

Corey Templeton

Concentrations of Toxics at Sampling Sites in the Gulf of Maine



Eight-year (2000-2008) median and median absolute deviations[1] in concentrations in mussel tissues at all Gulfwatch sites, in geographic order (south to north along the x axis from Massachusetts to Nova Scotia).

- ⬢ Benchmark site (sampled every year)
- ◆ Multi-year sites (sampled every 3 years)
- ● Sampled every 6 years
- ■ Occasionally sampled sites

[1] In statistics, the median absolute deviation (MAD) is defined as the median of the absolute deviations from the data's median: MAD = $median_i (|X_i - median_i(X_i)|)$ In words, 50% of observations lie within the range defined by the MAD.

Conclusions

Most areas of Casco Bay and the Maine coastline that are located away from human activity have measurable but not elevated levels of toxic chemicals (based on Maine reference conditions and Gulfwatch 85th-percentile values). Elevated levels tend to occur where past manufacturing has left a legacy of pollutants in the sediment; in harbors and commercial port areas; at the mouths of rivers; and in developed areas where runoff is carried into coastal waters from impervious surfaces (see Indicator 2). In the polluted Inner Fore River, for example, historical upstream industry, inflow from the Stroudwater River, and runoff from the Portland Jetport and the Maine Mall all contribute to the toxic body burden of resident mussels. At East End Beach, another affected area, urban runoff, leachate from a dump, riverine inputs from the Presumpscot, and nearby dense residential development all contribute to pollution levels.

The human activity-related pattern of mussel contamination seen by Maine DEP's mussel sampling efforts and by the Gulfwatch regional sampling program is also observed in the distribution of sediment contamination in the Bay (see Indicator 10). There is some positive news. The Gulfwatch data suggest that metal levels in mussels (and in the ecosystem) are declining across the Gulf of Maine, including Casco Bay. The Maine DEP data also support the conclusion that lead levels have dropped at several Casco Bay sites over time.

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Are the levels of toxic chemicals in Casco Bay sediments changing over time?

CBEP Goal: Reduce toxic pollution.

Why Is It Important to Measure the Levels of Toxic Chemicals in Casco Bay Sediments?

When the sediments of Casco Bay were first analyzed in 1980, scientists were surprised to learn that contamination by heavy metals and organic contaminants was widespread. Toxic chemicals enter the Bay through multiple pathways (see the diagram on p. 36), often becoming attached to sediment particles. Once in the sediments, toxics can either break down over time or become buried under newer layers of sediment, where burrowing or deposit-feeding organisms, or dredging by humans, can return them to the surface. Pollution exposure adversely affects the benthic (bottom) community, making organisms sick, reducing the number of species present, and increasing the predominance of hardy, pollution-tolerant organisms.

Organisms that inhabit the benthic sediments play an important role in the marine food chain, recycling organic matter and serving as a food source to groundfish, lobsters, and crabs. By ingesting smaller organisms that have accumulated toxic chemicals from the sediments, fish and larger crustaceans may experience inhibited growth and reproduction, increased vulnerability to disease, and even death (US EPA 2006). Humans who consume seafood contaminated by toxic chemicals can be at risk as well. For example, the dioxins present in Casco Bay, a legacy of the pulp and paper industry, have resulted in elevated levels in the livers – the tomalley – of lobsters. A public health advisory against eating tomalley has been in effect in Maine since 1992 (DEP 2004). Monitoring sediments for pollutant concentrations, toxicity, and benthic community structure over time allows us to assess the extent and impacts of pollution contamination, and to measure the success of management strategies to reduce pollutant loads.

Steve Karpiak

Bottom-dwelling organisms like lobsters are exposed to toxic chemicals in the sediments. DEP advises consumers not to eat lobster tomalley.

Status

Contaminants

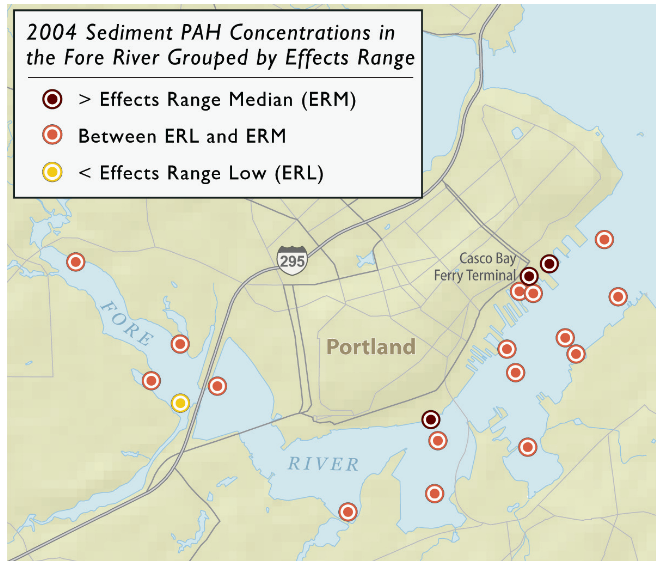
CBEP began monitoring the sediments in the Bay in 1991, conducting a baseline assessment at 65 sites. The site selection process took into consideration good areal coverage of the Bay, different sediment types and bottom communities, water depth, circulation patterns, and areas known to be historically affected by pollution. Surface sediments were analyzed for heavy metals, PAHs, PCBs and pesticides (Kennicutt *et al*. 1992). In 1994, 28 of the original sites and five new sites were analyzed for butyltins, doxins/furans, and coplanar PCBs (Wade *et al*. 1995). In 2000 and 2001, in partnership with EPA's National Coastal Assessment (NCA), CBEP resampled the sediments at the original locations for toxic pollutants, as well as for sediment toxicity and community structure. The results indicated that, in general, the most widespread contaminants in the Bay are petroleum and its byproducts, particularly high molecular weight PAHs derived from high-temperature combustion of petroleum products (*e.g*, vehicle exhaust). The sampling also indicated that PCBs were highly elevated in the inner Bay near Portland; and that none of the pesticides measured was highly elevated in the Bay. Trace metals were generally highest in the Inner Bay but few samples were much elevated above background levels. Butyltins, dioxins/furans, and planar PCBs were found throughout the Bay, with the highest levels in the Inner Bay.

Toxicity

Based on CBEP and NCA sampling, the concentrations of metals, PCBs (at almost all sites), pesticides, butyltins, doxins/furans and planar PCBs are lower in Casco Bay than levels known to cause harmful effects to organisms. PAH concentrations in the inner part of the Bay were between the levels identified by the National Status and Trends Program (NST) as Effects Range Low (possible biological

Sampling was conducted in 2004 in the Fore River by Friends of Casco Bay, supported by a Natural Resource Damage Assessment grant and funds from CBEP. Low and high molecular weight PAHs come from different sources, and their ratio can be used to help identify the likely source of the PAHs. For example, at the Casco Bay Ferry Terminal the primarily high molecular weight PAH signature indicates post-combustion sources such as vehicle exhaust and industrial combustion, rather than the low molecular weight signature of oil spills and urban runoff. The PAHs are likely carried via the CSO at the site (FOCB 2005).

effects) and Effects Range Median (probable biological effects) (Wade *et al.* 1995). The toxicity of additional PAH samples collected in the Fore River in 2004 is described in the map at right.



Trends

Scientists from Texas A & M University compared the pollutant concentration data from the 1991/1994 Casco Bay sediment sampling to the 2000/2001 data. They concluded that most toxic chemicals decreased or stayed the same during that time period, indicating that pollution control strategies are working in Casco Bay (see the summary table to the right and the TBT maps; Wade and Sweet 2005). Since many toxic compounds decay very slowly – or not at all – in the sediments, it is assumed that the declining levels observed primarily reflect the burial of toxics by cleaner, more recent sediments. The NCA program and CBEP collected sediment samples again in summer 2010. When the results of the 2010 sampling are available, CBEP will fund an analysis of spatial and temporal trends from 1991 to 2010.

Change in Concentration of Toxic Chemicals from 1991/1994 to 2000/2001 in Casco Bay Sediments

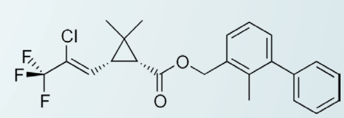
Decreased	No Overall Change	Increased
Cadmium	Arsenic	Silver
Chromium	Copper	
Mercury	Lead	
Nickel	Zinc	
Selenium		
Total pesticides, 4,4-DDE, 4-4DDD and total DDTs		
Tributyl tin and total butyl tin		
Total PCBs		
Planar PCB 126	Planar PCB 77	
	Dioxins/Furans	
Low molecular weight PAHs	Total PAHs	High molecular weight PAHs

Source: Wade and Sweet 2005

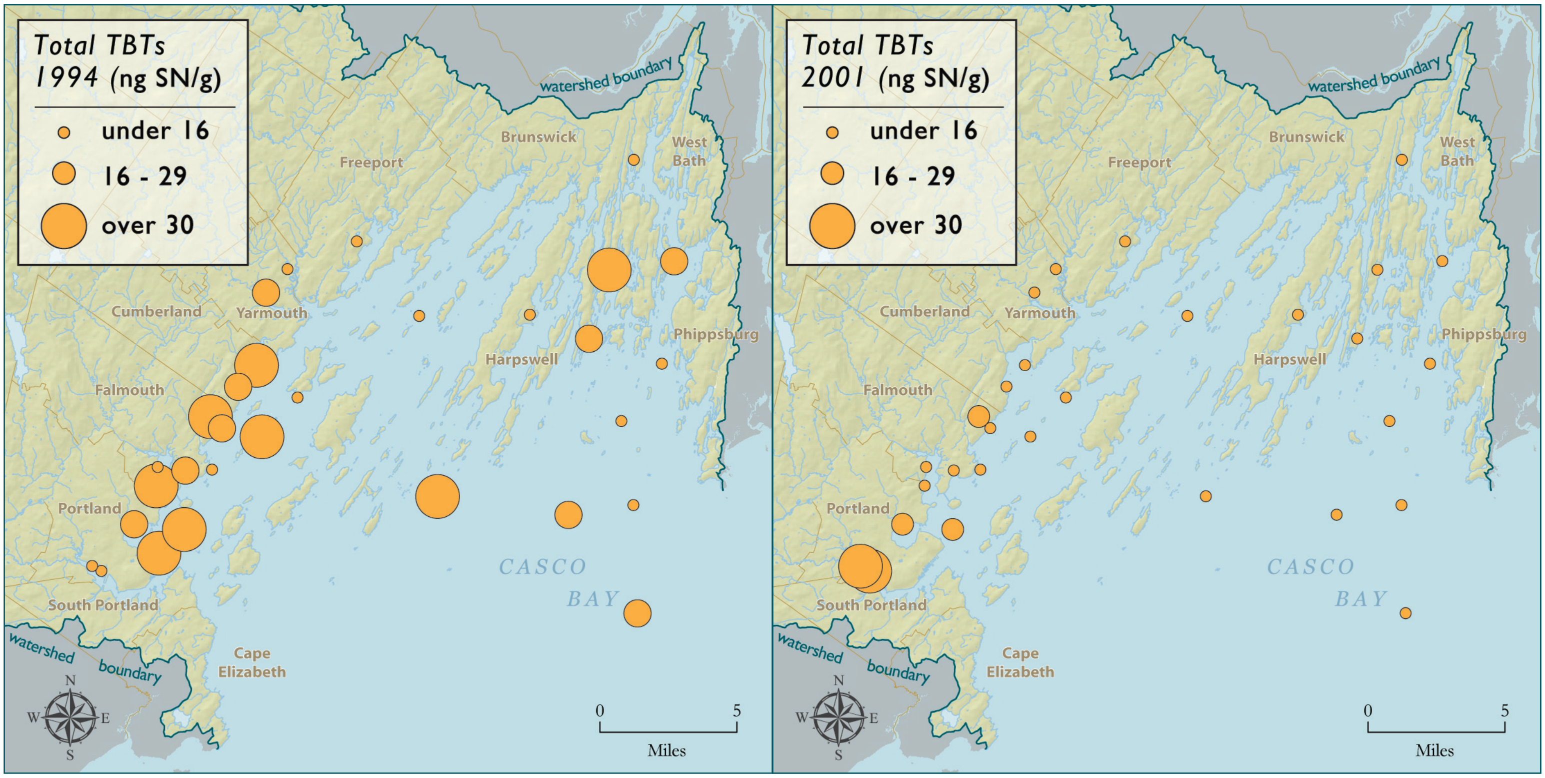
Pesticide Runoff from Urban Areas

Maine Bureau of Pesticides Control (BPC) has been concerned about pesticides running off the land surface of urban watersheds into coastal sediments. In 2008 BPC analyzed sediment samples from Mussel Cove in Falmouth and Back Cove in Portland for pyrethroid pesticides, including bifenthrin. Pyrethroids are used in common household insecticides and are toxic to aquatic fish and invertebrates. (Commercially available products that include bifenthrin include Talstar, Capture, Brigade, Bifenthrine, Ortho Home Defense Max, and Scotts LawnPro Step 3.) Mussel Cove's intertidal mud flats are commercially harvested for soft-shell clams. Land use in the 5.4 square mile drainage area of Mill Creek, which empties into Mussel Cove, is both residential .and commercial, especially along Route 1, where there are large areas of impervious surface. Land use in areas adjacent to Back Cove is heavily residential and stormwater continues to discharge to the Cove. Back Cove, an important migratory waterfowl wintering and stopover area, also serves an important marine worm habitat (DEP 2005).

The results indicated that bifenthrin was present at detectable levels in samples from both sites, with the highest levels found at Payson Park (Back Cove) (BPC 2008). More extensive sampling will be needed to confirm the concentrations present and their potential for impacts to organisms. Pyrethroids were not found at detectable levels in mussels sampled by Maine DEP in the Mill Creek/Mussel Cove area in 2009 (see Indicator 9).



Bifenthrin molecule



Tributyl tin (TBT) is an ingredient in marine anti-fouling paints. Federal and state laws now ban the use of paints with TBT for all uses except for vessels longer than 25 meters, or those having aluminum hulls (Maine DEP 1999). The overall decline of TBT concentrations in the Bay's sediments reflects the effectiveness of those laws at reducing toxic chemicals in the marine environment. The continued use of TBT paints on large commercial vessels may explain the continued presence of elevated TBT in the sediments of inner Casco Bay sites (Wade and Sweet 2005).

The results of the 1991/1994 and the 2001/2002 sampling were reported in more detail in both the 2005 *State of the Bay* report and the 2007 report *Toxic Pollution in Casco Bay*. The figure above illustrates an interesting pollutant management success story.

Conclusions and Future Directions

Management strategies for reduction of pollution inputs in the Bay are having a positive impact. In addition to the observed declines in metals, PCBs and pesticides, the overall decline in low molecular weight PAHs in the Bay suggests that management strategies to reduce PAH inputs from spills and stormwater are working. The increase in high molecular weight PAHs, which are primarily a byproduct of combustion, is likely due to increased use of fossil fuels throughout the region.

CBEP will report on the long-term spatial and temporal trends in the concentration of toxic contaminants in the Bay's sediments based on sampling in 1991/1994, 2001/2002 and 2010, as soon as that analysis is ready. The results will be included in the 2015 *State of the Bay* report. In addition, data from the 2001/2002 and 2010 NCA samples of benthic community structure will be analyzed to determine how pollutants are impacting the Bay's benthic organisms.

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How prevalent are selected contaminants of emerging concern in the Casco Bay ecosystem?

CBEP Goal: Reduce toxic pollution in Casco Bay; minimize adverse environmental impacts to ecological communities from the use and development of land and marine resources.

Why Is It Important to Monitor Contaminants of Emerging Concern?

Many common synthetic chemicals, which were not recognized as pollutants in the past, are now being detected in aquatic ecosystems throughout the world, where they are accumulating in the tissues of wildlife and humans. Those "contaminants of emerging concern" persist in the environment along with the more traditionally monitored persistent pollutants like polychlorinated biphenyls (PCBs), organochlorine pesticides (OCs) and heavy metals. They are typically introduced into the air and water through municipal, agricultural, and industrial wastewater sources, and are transported by wind and water currents.

Among that new class of contaminants are polybrominated diphenyl ethers (PBDEs), used as flame retardants in commercial and residential textiles, furniture foam, and electronics since the 1970s. The primary forms are penta, octa- and deca-PBDE. Those lipophilic (fat-loving) molecules can accumulate in the fatty tissues of organisms, leading to negative health effects. Another important class of emerging contaminants is perflorinated chemicals (PFCs), industrial chemicals whose common uses include stain repellents, Teflon coatings, cleaning agents, and fire-fighting foam. They are highly resistant to degradation, and persist in the environment. Two forms, perfluorooctanesulfonate (PFOS) and perfluorooctanoate (PFOA) are most common in the environment and in organisms (Goodale 2008).

Despite some recent restrictions on their use, those chemicals have been used in a variety of consumer and household products for over four decades. They cause cancers, endocrine disruption, reproductive and neurodevelopmental effects in animals, and are associated with reproductive and endocrine-disrupting effects in people (Birnbaum and Staskal 2004, Jensen and Leffers 2008).

The recent monitoring studies described below indicate that those contaminants are found in seal and bird populations in Maine.


MERI

The *Seals as Sentinels* project indicated that seal pups had higher levels of PBDEs and PFCs than adults, reflecting their high exposure to the compounds from their mothers' milk.

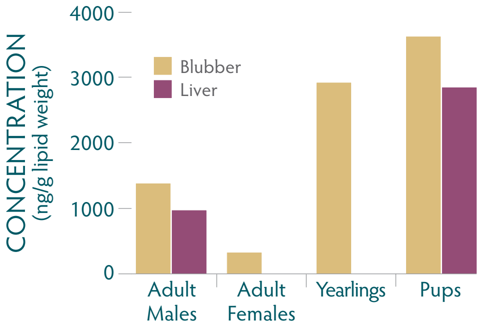
Status and Trends

Contaminants of Emerging Concern in Seals from Casco Bay and the Gulf of Maine

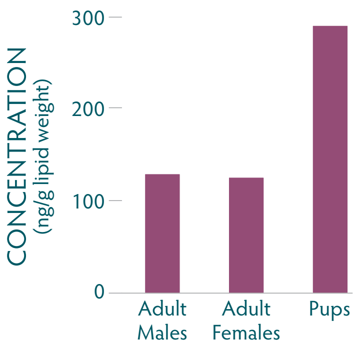
Since 2001, Dr. Susan Shaw and her co-workers at the Marine Environmental Research Institute (MERI) in Blue Hill, Maine, have been conducting a long-term investigation, *Seals as Sentinels*, that analyzes the levels and effects of environmental pollutants in harbor seals (*Phoca vitulina concolor*) along the northwest Atlantic coast. To date, the study has measured 395 compounds in 487 tissue samples from 181 stranded and live seals from Canada to Long Island, New York, including Casco Bay.

As top predators, seals accumulate persistent organic pollutants (POPs) from the fish they consume, and pass them on to their pups in their milk. High concentrations of chemicals such as PCBs can weaken the immune system of seals and increase their susceptibility to disease (Shaw 2007). In recent years, Gulf of Maine seals have been plagued by disease outbreaks, including a die-off in 2006 that claimed the lives of 800 animals (Shaw *et al.* 2005, 2007). Similar mass mortalities and reoccurring epidemics linked with contaminant stress are common among harbor seals worldwide. Recently, the *Seals as Sentinels* study found

Mean Sum of PBDE Concentration in Harbor Seals



Mean Sum of PFC Concentration in Harbor Seal Livers



high levels of contaminants of emerging concern, including PBDEs and PFCs, in harbor seal tissues. (Shaw *et al.* 2008, 2009a,b; see graphs). It was the first study to reveal that PBDEs and PFCs have permeated the northwest Atlantic Ocean environment.

- PBDEs were detected in 42 harbor seal blubber samples and 56 liver samples at levels among the highest reported worldwide for the species, reflecting the heavy usage of these compounds in North America.
- PBDEs are rapidly working their way up the food web. Biomagnification rates calculated for persistent PBDEs show they are readily transferred from fish to seal tissues, and become highly concentrated in top predators. People eat many of these fish: flounder, hake, and herring, for example.
- PFCs are also widespread in the Gulf of Maine; they were detected at substantial levels in liver tissues of 68 harbor seals.
- Unlike the pattern for PCBs, which are higher in seals near densely populated urban centers, there was no clear urban to rural trend in the distribution of PBDEs and PFCs. (Those compounds originate from multiple urban and rural sources, *e.g.*, wastewater treatment plants, farmland sludge, landfills, and airports.)
- Seal pups had higher levels of PBDEs and PFCs than adults, reflecting their high exposure to the compounds in their mothers' milk. The highest level of PBDEs was found in a female pup from mid-coast Maine (25700 ng/g lw). A male pup from Massachusetts Bay had the highest level of PFCs (1430 ng/g ww).

Contaminants of Emerging Concern in Birds of Casco Bay

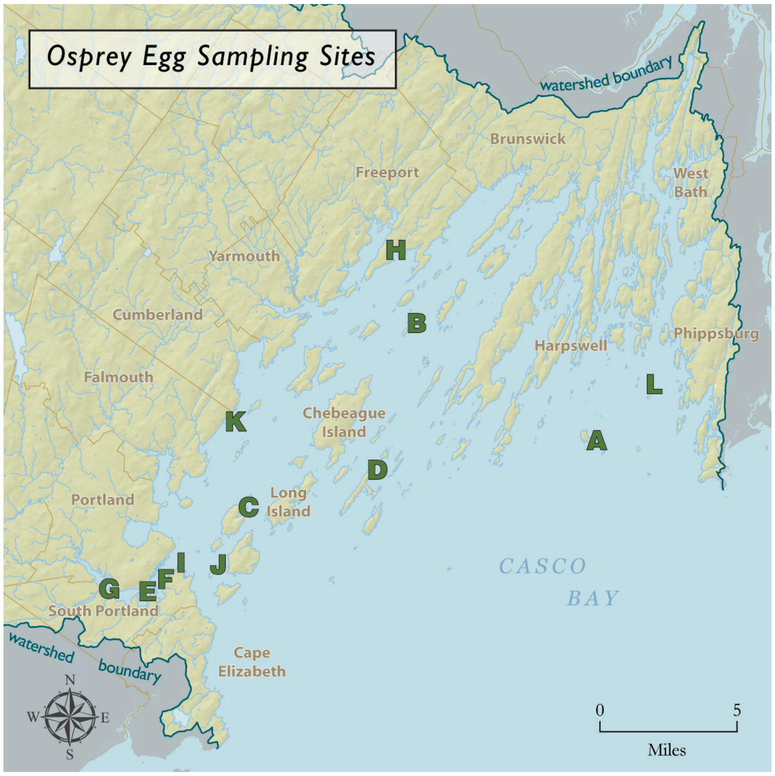
With support from CBEP and other partners, in 2007, BioDiversity Research Institute (BRI) began the first study to measure PBDEs, PFCs, PCBs, OCs and mercury in eggs from 23 species of birds in Maine from marine, estuary, river, lake and terrestrial habitats. The suite of chemicals studied was found in all the species sampled across all types of ecosystems, with the highest contaminant loadings in southern coastal Maine. That pattern suggests that while atmospheric deposition is an important transport pathway, local point sources near the urban and industrial areas of the southern coast are also important. For PCBs, PBDEs, PFCs, and OCs, birds with a high level of one chemical tended to also have elevated levels of the others.

Chris DeSorbo, BRI

Collecting osprey eggs in Casco Bay for analysis of contaminants, including PBDEs and PFCs.

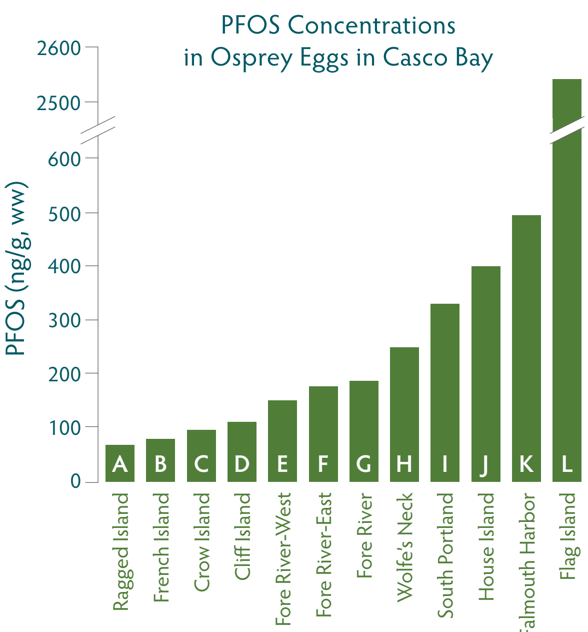
The study indicated that osprey (*Pandion haliaetus*) in the greater Portland area had some of the highest levels of PCBs, PBDEs, and PFOs seen in 14 species sampled there. As foraging predators, osprey accumulate contaminants and pass them to their offspring. Of six osprey samples collected along the Maine coast, the sample from the Portland Breakwater Light (Bug Light) had the highest total contaminant load, and levels of PFOs three times greater than the threshold for adverse effects (Goodale 2008). A follow-up study of osprey from Casco Bay was funded by CBEP to determine if the high PFOS levels observed in the Bug Light sample were found elsewhere in Casco Bay (Goodale 2010).

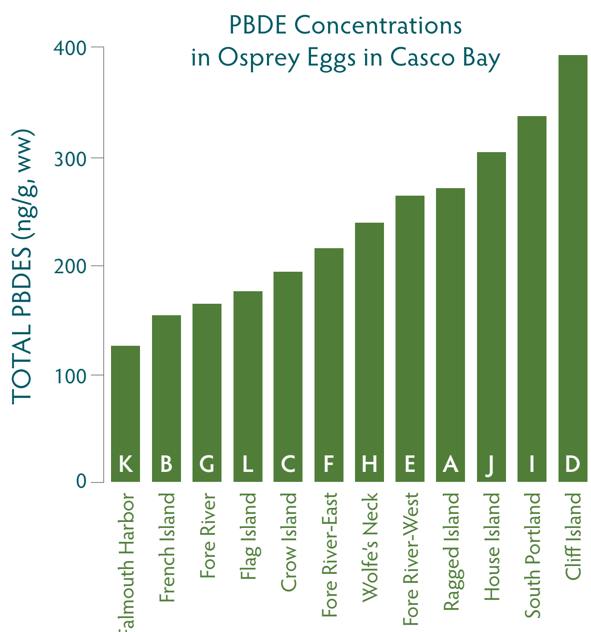
Starting in May of 2009, ten additional eggs were collected at Casco Bay sites and analyzed for PCBs, PBDEs, PFCs (including PFOs), and OCs. The combined results of osprey egg studies in 2007 and 2009 are summarized in the figures on the opposite page.



Kevin Cole

Wayne Boardman





Results of 2007 and 2009 osprey egg sampling in Casco Bay. PCBs, PBDEs, PFCs and OCs were found in all of the eggs sampled. Deca-PBDE was detected in 10 of 12 eggs collected in Casco Bay during the two sampling seasons. PFOS in an egg collected from Flag Island were the highest ever seen in Maine wildlife, and among the highest ever observed in a bird egg. Fully 75 percent of osprey eggs had PFOS concentrations exceeding the threshold for negative health effects established for chickens (100 ng/g, wet weight). No spatial trend was detectable among the samples, suggesting that point sources, watershed characteristics and food web dynamics may all play a role in exposure to contaminants (Goodale 2010). While osprey are highly mobile and there is no certainty about where birds are exposed to contaminants, research indicates that the toxic contaminants in eggs come from food consumed in the bird's local breeding territory (Hobson *et al.* 1997, Elliott *et al.* 2007).

Solution and Actions

The studies raise concerns about the long-term health of marine mammals and birds in the region and, more critically, the overall health of the food web and the ecosystem. Data from *Seals as Sentinels* have influenced policy decisions, including two recent Maine laws: LD 1658 (2007) which bans the neurotoxic flame retardant deca-PBDE from furniture, foam mattresses and electronics, and LD 2048 (2008) which requires manufacturers to disclose the toxic chemicals they add to baby products and children's toys, and authorizes the state to require safer alternatives whenever available. Data from the BRI bird egg study were provided as testimony during the development of LD 2048.

Penta- and octa-PBDE mixtures have been banned in Maine since 2006 and are no longer in production in the United States (DEP 2007a). PFOS, formerly an ingredient in Scotchguard brand stain repellent, was phased out by its primary US manufacturer in 2000. Nevertheless, large reservoirs of BFRs and PFCs, like PFOS, still exist in consumer products, ensuring ongoing inputs to the environment for decades to come (Shaw and Kannan 2009).

PPCPs (pharmaceuticals and personal care products) are also important contaminants of emerging concern. A cocktail of painkillers, hormones, antibiotics, beta-blockers and other drugs, along with household products like soaps, hairspray and sunscreens, enters the waste stream when washed off, excreted or discarded. Research suggests that some PPCPs can result in impacts to biota, although their cumulative and synergistic effects in aquatic systems are still unknown. The complexity of the possible mixtures and their limited biological degradability make removal from municipal wastewater a major challenge (Ternes *et al*. 2004). Addressing PPCPs at the source is an important control strategy. In 2007, Maine became the first state to pass legislation authorizing a mail-in program for unused and unwanted medicines. Maine DEP is also working with communities on one-day collection events. (To learn more about the Safe Medicine Disposal for ME program visit http://www.safemeddisposal.com.)

Given the vulnerability of Gulf of Maine and Casco Bay wildlife, as well as concerns for human health, monitoring for the presence of emerging contaminants and their effects in Casco Bay and the larger Gulf of Maine ecosystem will continue to be an important challenge.

ME DEP

Researchers from the Maine Department of Environmental Protection (DEP) collect white suckers for Cumulative Effects Assessment.

Endocrine Disruptors: Maine DEP Cumulative Effects Assessment

Endocrine disruptors are contaminants of emerging concern that disrupt the normal functioning of hormonal systems. They include man-made chemicals such as pesticides and plasticizers, pharmaceuticals, or hormones that are excreted in animal or human waste (EPA 2009). Since 2000, Maine DEP has been conducting Cumulative Effects Assessments (CEA) of fish populations in Maine rivers, measuring the effects of exposure to endocrine disruptors on survival, growth and reproduction. Studies have examined fish collected upstream and downstream of major discharges. Between 2007 and 2009, DEP conducted CEA studies in the Presumspcot River. Male and female white suckers (*Catostomus commersoni*) were caught in overnight gill net sets at stations in Windham and Gorham above the Westbrook wastewater treatment plant and the SAPPI mill – sites of the major discharges into the Presumpscot River – and at a station below the discharges.

Although there were individual metabolic or physiological responses for one or both sexes, indicating endocrine disruption below Westbrook compared to stations upstream, there is no consistent evidence of endocrine disruption in white suckers at the population level in the river below Westbrook. Growth rates and abundance appear to be lower below Westbrook. Those data are consistent with a 2006-2007 study of fish communities in the Presumpscot River that found reduced species richness, abundance, and biomass downstream of Westbrook (Yoder and Hersha 2009). The causes may be natural differences in habitat exacerbated by past or present discharges of sediments or other pollutants from municipal and industrial activities and urban runoff from Westbrook (DEP 2008, 2010).

Cynthia Stroud

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