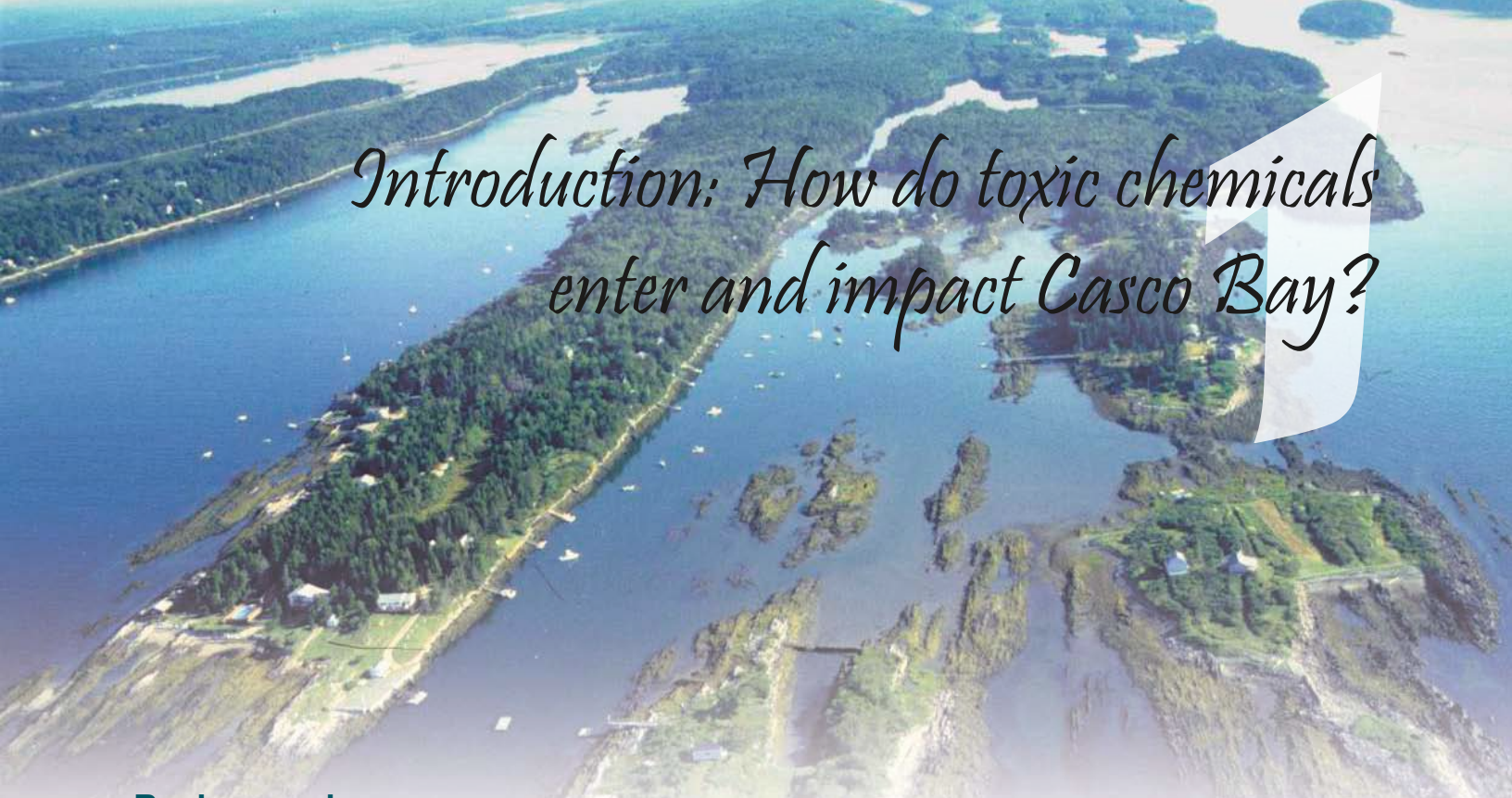


Introduction: How do toxic chemicals enter and impact Casco Bay?

Background

According to the Maine Department of Environmental Protection, the greatest stressors on estuarine and marine waters in Maine are bacteria and toxic chemicals (Maine DEP 2004). The toxic chemicals addressed in this report include two primary types of pollutants: organic chemicals and heavy metals. Organics are bonded forms of carbon, hydrogen and other atoms that occur either naturally or through human introduction. These organic chemicals slowly break down into hydrogen, oxygen, chlorine and other basic components but in the interim they and their interim metabolites (breakdown products) can be toxic to living organisms. Major pathways by which toxic chemicals enter the environment are illustrated in Figure 1-1.

Toxic organic chemicals found in Casco Bay and their primary sources include the following:

- **Polycyclic aromatic hydrocarbons (PAHs)** are the most common toxic contaminants in the Bay. They come primarily from combustion of fossil fuels and wood but also from fuel spills (Chapter 3).
- **Polychlorinated biphenyls (PCBs)** are potent carcinogens formerly used in electric transformers and other industrial applications. They were banned in the 1970s but 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. The source of these dioxin-like compounds is commercial PCB mixtures (Tanabe *et al.* 1987).
- **Pesticides** are largely carried from lawns and fields to water bodies via stormwater runoff. Although it has been 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 (US EPA 2005). Although the pulp mill discharging into the Casco Bay stopped discharging pulp waste in 2000, dioxins and furans still reach the Bay via atmospheric deposition.
- **Butyltins** are toxic organometallic compounds, molecules in which metal is bonded to a carbon atom in an organic molecule. Butyltins get into 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 with 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).

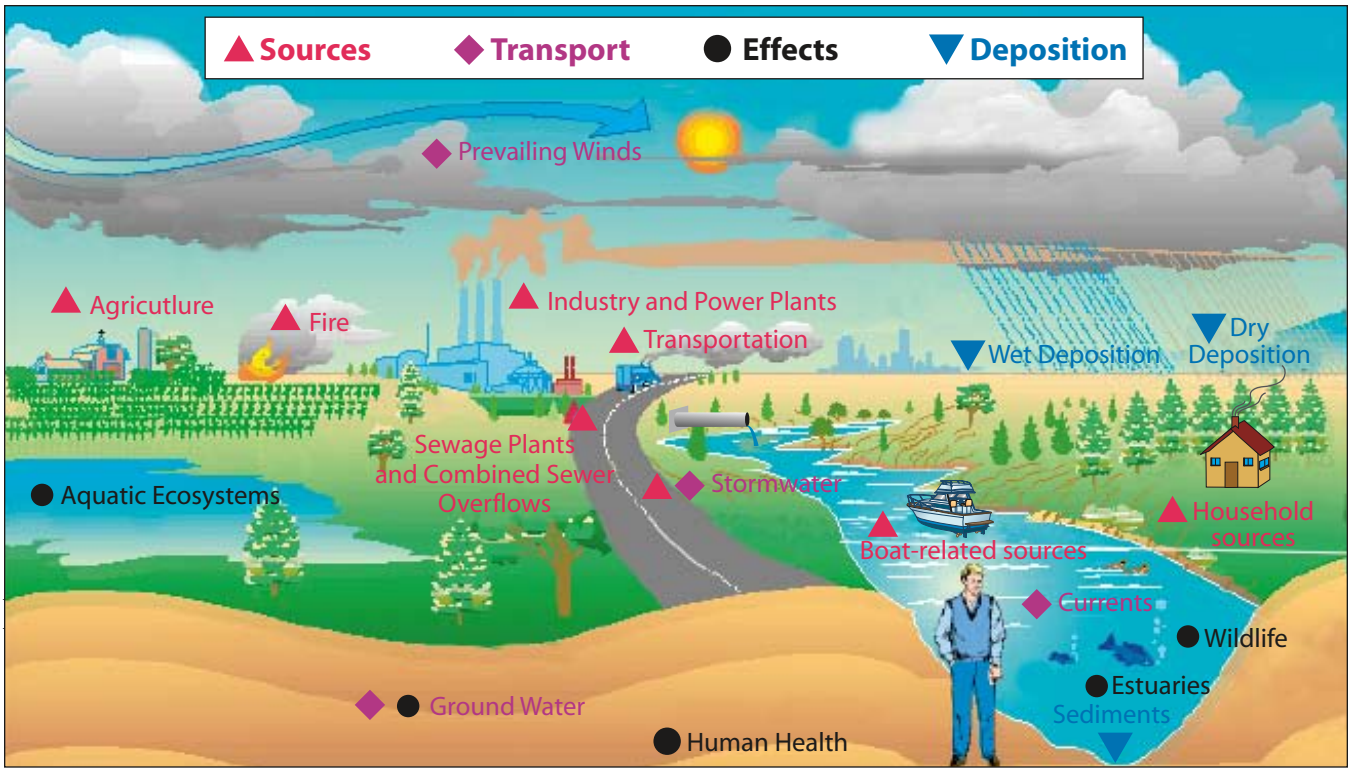


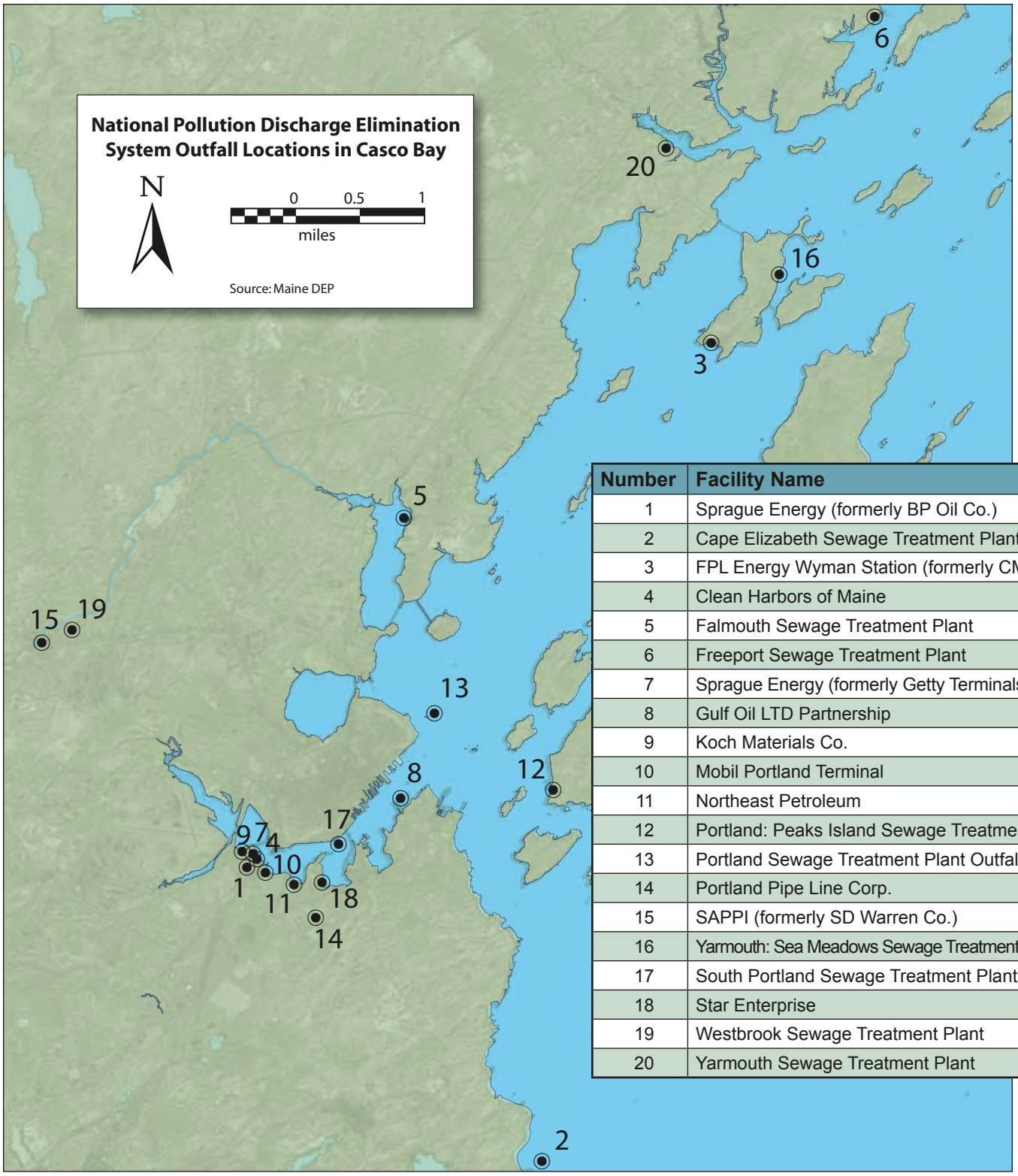
Figure 1-1. *Toxic Chemical Pathways. Major toxic chemical pathways including sources, transport mechanisms, deposition, and effects are illustrated. Sources of toxic chemicals include industrial and power plant discharges, transportation, agriculture, fires and incinerators, boats, and households. Whether the toxics are carried into the watershed by point sources such as pipes, smokestacks, and internal combustion engines, or are transported by wind, rain, and stormwater runoff, ultimately 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.*

Point Sources of Toxics to the Bay and the Watershed

Discharges to Casco Bay Waters

Prior to the passage of the federal Clean Water Act in 1970, water pollution from industrial sources had a major impact on the quality of water and sediments in Casco Bay and its watershed. Historic Sources of Pollution in Casco Bay (Hawes 1993) reviewed the "dirty" industrial past when pollutant discharges from railroad complexes, shipyards, tanneries, metal foundries, canneries, paint, textile and glass factories, along with human waste flowed into the watershed and its receiving waters. The electronics, petroleum, plastics and paper industries helped to contribute PCBs, PAHs, heavy metals and organic pollutants. By 1965, for example, the lower Presumpscot River was declared "dead" and living conditions for nearby residents "intolerable" (CBEP 1998).

As these major point source discharges were regulated and cleaned up in the decades following the Clean Water Act, it became clear that a legacy of toxic chemicals remained in the sediments of the watershed and the Bay itself (see Chapter 4). Today, a total of 49 point source discharges in Cumberland County are licensed by the State, through the National Pollutant Discharge Elimination System (NPDES) (US EPA 2006a). Among the major dischargers are: the sewage treatment plants in Portland, South Portland, Westbrook, Freeport, Falmouth and Yarmouth; the Central Maine Power Station on Cousins Island in Yarmouth; First Technology Control Devices in Standish; SAPPI Fine Paper (formerly SD Warren) in Westbrook and multiple oil-water stormwater separator discharges at oil terminals in South Portland. Smaller dischargers include industrial facilities, power plants and small sewage treatment plants. See Figure 1-2 for the locations of NPDES outfalls along the coast of Casco Bay.



Number	Facility Name
1	Sprague Energy (formerly BP Oil Co.)
2	Cape Elizabeth Sewage Treatment Plant
3	FPL Energy Wyman Station (formerly CMP)
4	Clean Harbors of Maine
5	Falmouth Sewage Treatment Plant
6	Freeport Sewage Treatment Plant
7	Sprague Energy (formerly Getty Terminals Corp.)
8	Gulf Oil LTD Partnership
9	Koch Materials Co.
10	Mobil Portland Terminal
11	Northeast Petroleum
12	Portland: Peaks Island Sewage Treatment Plant
13	Portland Sewage Treatment Plant Outfall
14	Portland Pipe Line Corp.
15	SAPPI (formerly SD Warren Co.)
16	Yarmouth: Sea Meadows Sewage Treatment Plant
17	South Portland Sewage Treatment Plant Outfall
18	Star Enterprise
19	Westbrook Sewage Treatment Plant
20	Yarmouth Sewage Treatment Plant

Figure 1-2: National Pollution Discharge Elimination System outfall locations along the coast of Casco Bay. *While licensed and monitored, point sources can still contribute toxic chemicals to the Bay. For example, sewage treatment plants are designed to treat total suspended solids (TSS) and biochemical oxygen demand (BOD). While there is some removal of metals as a side benefit, treatment plants can still contribute heavy metals (e.g., lead, cadmium, arsenic, zinc, silver, and mercury), as well as other toxic chemicals (CBEP 1996). While the levels of pollutants in effluent may meet water quality standards, over time, persistent pollutants can accumulate in the sediments. In addition to the discharges shown on the map, multiple urban combined sewer overflows (CSOs) continue to deliver toxic pollutants (PAHs from petroleum products and tires, for example) to local rivers and streams and ultimately to the Bay.*

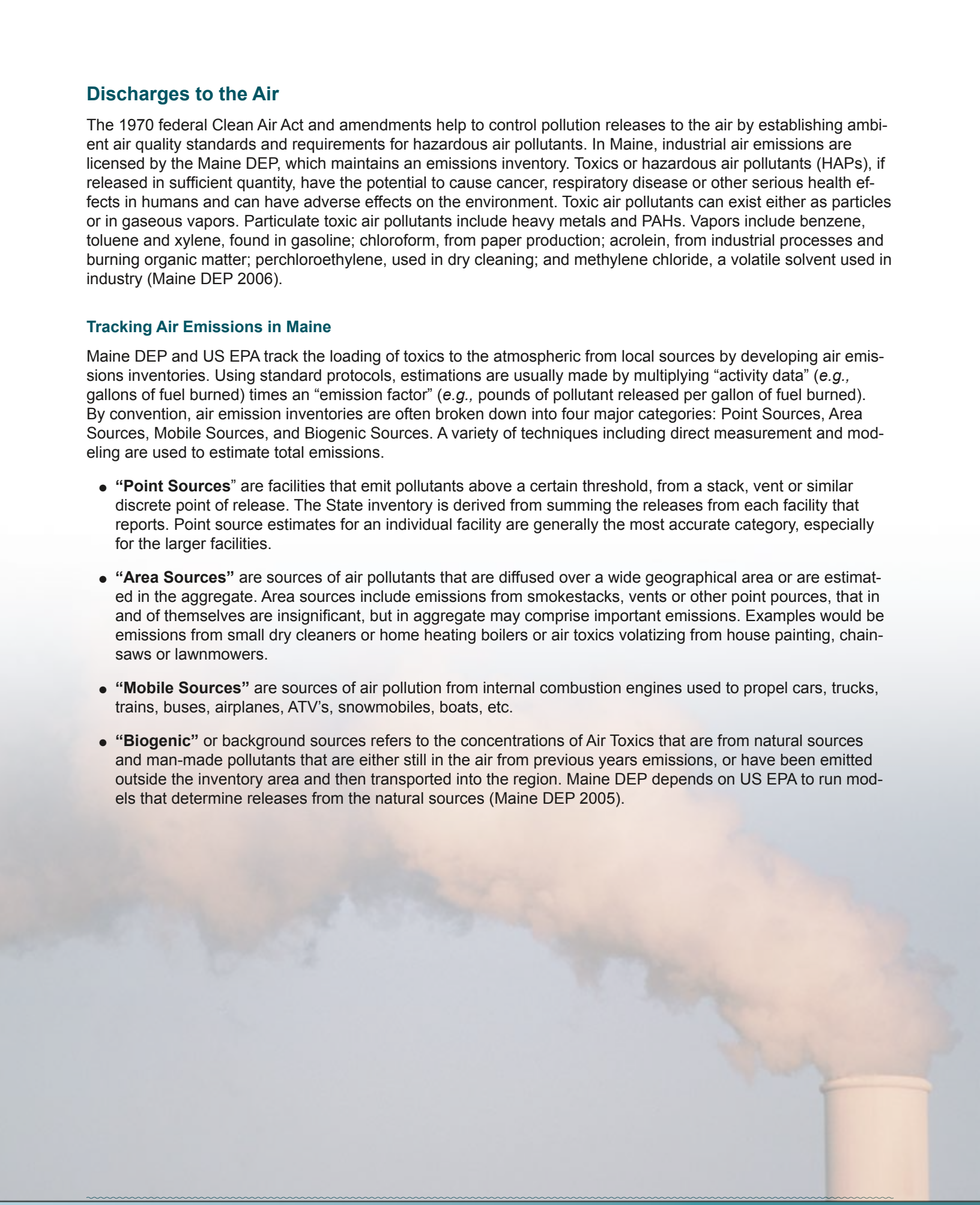
Discharges to the Air

The 1970 federal Clean Air Act and amendments help to control pollution releases to the air by establishing ambient air quality standards and requirements for hazardous air pollutants. In Maine, industrial air emissions are licensed by the Maine DEP, which maintains an emissions inventory. Toxics or hazardous air pollutants (HAPs), if released in sufficient quantity, have the potential to cause cancer, respiratory disease or other serious health effects in humans and can have adverse effects on the environment. Toxic air pollutants can exist either as particles or in gaseous vapors. Particulate toxic air pollutants include heavy metals and PAHs. Vapors include benzene, toluene and xylene, found in gasoline; chloroform, from paper production; acrolein, from industrial processes and burning organic matter; perchloroethylene, used in dry cleaning; and methylene chloride, a volatile solvent used in industry (Maine DEP 2006).

Tracking Air Emissions in Maine

Maine DEP and US EPA track the loading of toxics to the atmospheric from local sources by developing air emissions inventories. Using standard protocols, estimations are usually made by multiplying "activity data" (*e.g.,* gallons of fuel burned) times an "emission factor" (*e.g.,* pounds of pollutant released per gallon of fuel burned). By convention, air emission inventories are often broken down into four major categories: Point Sources, Area Sources, Mobile Sources, and Biogenic Sources. A variety of techniques including direct measurement and modeling are used to estimate total emissions.

- **"Point Sources**" are facilities that emit pollutants above a certain threshold, from a stack, vent or similar discrete point of release. The State inventory is derived from summing the releases from each facility that reports. Point source estimates for an individual facility are generally the most accurate category, especially for the larger facilities.
- **"Area Sources"** are sources of air pollutants that are diffused over a wide geographical area or are estimated in the aggregate. Area sources include emissions from smokestacks, vents or other point pources, that in and of themselves are insignificant, but in aggregate may comprise important emissions. Examples would be emissions from small dry cleaners or home heating boilers or air toxics volatizing from house painting, chainsaws or lawnmowers.
- **"Mobile Sources"** are sources of air pollution from internal combustion engines used to propel cars, trucks, trains, buses, airplanes, ATV's, snowmobiles, boats, etc.
- **"Biogenic"** or background sources refers to the concentrations of Air Toxics that are from natural sources and man-made pollutants that are either still in the air from previous years emissions, or have been emitted outside the inventory area and then transported into the region. Maine DEP depends on US EPA to run models that determine releases from the natural sources (Maine DEP 2005).



Maine Air Toxics Initiative 2005 Inventory

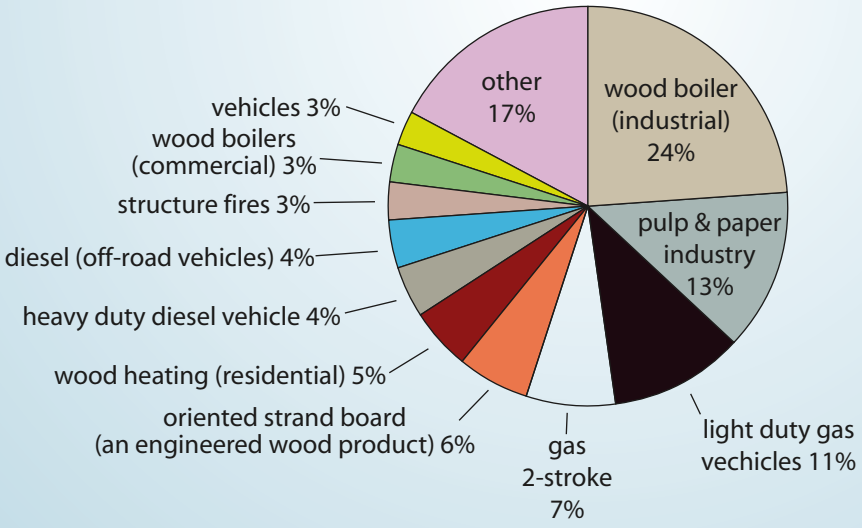
The most accurate, current emissions inventory of Hazardous Air Pollutants (HAPs) or Air Toxics for Maine, is the 2005 estimated emissions inventory that was compiled by the Maine Air Toxics Advisory Committee, a stakeholder group convened by the Maine DEP as part of the Maine Air Toxics Initiative (MATI). The Air Toxics Advisory Committee (ATAC) initially developed a complete HAP inventory for Maine. It was derived by assessing all of the available inventory data and "ground-truthed" based on field investigations, air toxics modeling results, ambient air monitoring programs, and input from the Maine Bureau of Health on the toxicity of various HAPs.

Information used to compile the HAP inventory included the US EPA National Emissions Inventory, data collected from under Maine's Chapter 137 Emissions Inventory of individual facilities that emit any of 217 pollutants above certain thresholds, and the Toxics Release Inventory (TRI). The federal Emergency Planning and Community Right-to-Know Act of 1986 as expanded by the Pollution Prevention Act of 1990 requires certain classes of companies that also employ more than 10 people, and that discharge one of 650 pollutants to the air, water, or land above certain thresholds, to report this information annually to the state and federal governments. US EPA then enters this information into the TRI database, which includes data from 1988 to the present. ATAC also compared emission results to the National Air Toxics Assessment and available ambient air monitoring data. From this information, emission sources that did not appear to be accurate were selected and revised as necessary. For the final MATI inventory, activity levels (amount of fuel burned, acres burned, etc.) are based on Maine specific data whenever possible (Maine DEP 2005). The MATI inventory has been used to assess the sources of emissions. (See Figure 1-3).

Maine Air Emissions Sources

Figure 1-3. The source of current air emissions in Maine can be assessed using the Maine Air Toxics Initiative inventory. It is important to note that the way that categories are lumped together greatly influences the relative ranking of source categories. The ranking is also greatly influenced by uncertainties in the inventory, particularly uncertainty with the emission factor for acrolein, a toxic organic chemical that is used in some industrial processes and can also enter the environment when organic matter such as wood, gasoline, and oil are burned. Total acrolein emissions could be 400% greater or 90% lower, if different emission factors were used for large wood combustion sources. Given these uncertainties, one possible ranking of sources is shown in the pie chart below. "Toxicity weighting" is an approach that accounts for the differing toxicity of air pollutants based on relative impact to human health (Maine DEP 2006). Note that many of the HAPs in the inventory (like acrolein) are primarily a concern due to human inhalation risks and that the toxicity weighting is not based on impacts to the ecosystem.

Sources of Maine Air Emissions
(Based on 2005 Estimated Toxicity-Weighted Emissions)

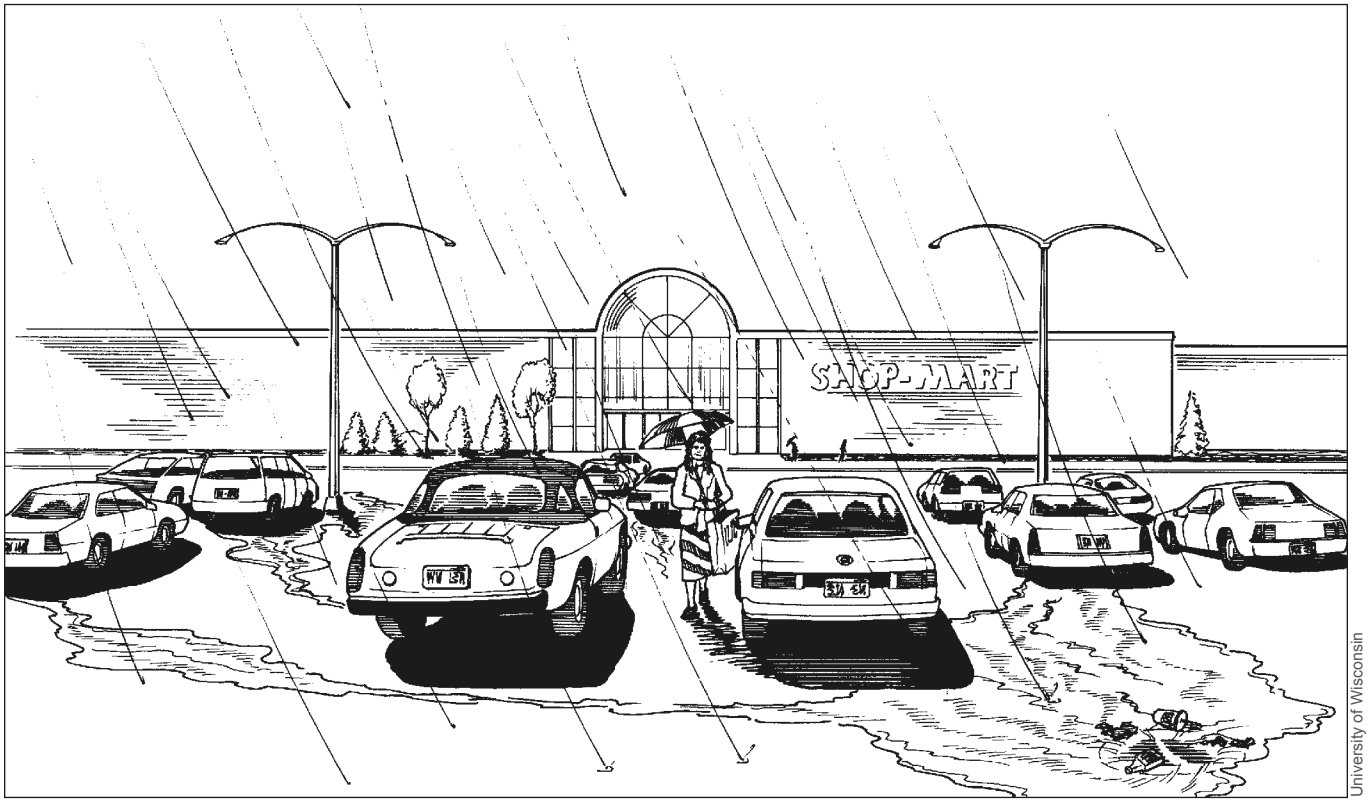


Nonpoint Sources of Toxics to the Bay and the Watershed

Today, nonpoint source pollution is a major contributor of toxic chemicals to the Bay and its watershed. A study undertaken by CBEP revealed that atmospheric deposition is likely the major source of the toxic heavy metal mercury and an important source of PAHs to the watershed and the Bay. Wet atmospheric deposition via precipitation and dry deposition via gases and particles also contribute other heavy metals such as cadmium, zinc, chromium and lead, which can serve as tracers of the sources of pollution (see Chapter 2).

Stormwater is also a major nonpoint source of toxic pollution to the Bay. As rainfall or snowmelt runs over paved or disturbed land surfaces, it picks up pollutants deposited to the ground surface from the atmosphere or local land-based sources and washes them into streams, rivers and eventually to the Bay. Metals and organic contaminants from construction sites, paved urban areas and roads, lawns and farms, underground storage tanks, and landfills adhere to the soil particles and organic matter carried in runoff water. Marinas and boating activities can also contribute toxic solvents and paints via stormwater runoff. And, when oil is spilled on roadways or directly into waterways, PAHs and other organic chemicals can impact wildlife and accumulate in the sediments (see Chapter 3).

Atmospheric deposition of pollutants carried by wind, rain, and snow is an important source of toxics to Casco Bay and its watershed. Above is a satellite image of a major snowstorm blanketing the east coast of the US (NASA Visible Earth 2006, http://veimages.gsfc.nasa.gov/4331/Sea_2002340.jpg).



University of Wisconsin

Figure 1-5. *Runoff from paved surfaces is a major nonpoint pollution source.*

Toxics in the Food Chain

Both toxic organic chemicals and some metals have the potential to increase in concentration as they move up the food chain from the algae and seagrasses that convert sunlight and carbon into food, to fish, birds and mammals, including humans (see Figure 1-6).

Since toxic chemicals tend to collect in sediments, the organisms that inhabit bottom sediments are exposed to the highest levels of contamination. These bottom-dwelling (benthic) organisms play a key role in the food chain, from the bacteria that recycle organic matter and release nutrients to the small crustaceans, worms and mollusks that are consumed by, for example, groundfish, lobsters and crabs. The benthic community in areas that are impacted by toxics lacks the expected diversity and abundance of animals found in clean, healthy bottom communities.

Moving up the food chain, fish that are exposed to toxics chemicals in the environment can experience altered biochemical, respiratory and immune function, developmental and structural abnormalities, cataracts, skin and gill diseases as well as both benign and malignant tumors (O'Connor and Huggett 1988). For example, PAHs have been shown to alter the egg maturation processes in fish (Nicolas 1999). Dietary exposure to mercury has been shown to cause neurological damage in Atlantic salmon (Berntssen *et al*. 2003). Consumption of worms contaminated by PAHs can cause flounder to develop tumors (McElroy *et al.* 1989). While a direct link with pollution has not been demonstrated, fishermen have observed liver tumors in fish caught off Casco Bay (CBEP 1996).

Mammals and birds that feed on benthic organisms or fish from contaminated fresh or salt water environments may absorb toxic pollutants, concentrating them in liver, fat, and muscle tissue (Chapters 6 and 7). Toxic organic chemicals have the potential to disrupt the normal activity of hormones (endocrine-disruption), causing cancer, adverse reproductive effects, birth and developmental effects, and effects on the immune systems (Shaw and DeGuise 2000, DeGuise *et al*. 2001). For example, susceptibility to massive viral epidemics has been observed in European harbor seals exposed to organic pollutants in their environment (Van Loveren *et al*. 2000).

In humans, the causal linkages between endocrine-disrupting organic chemicals and disease have been directly demonstrated in a few cases. PCB exposure to human fetuses *in utero* has been linked with neurological problems, and increased breast cancer risk has been linked with exposure to PCBs and the pesticides DDT and dieldrin (DeGuise *et al*. 2001). Dioxin, considered to be one of the most toxic substances ever identified, has the potential to cause severe reproductive and developmental problems and has been categorized most recently as "likely to be carcinogenic to humans" (NRC 2006) (see Chapter 8).

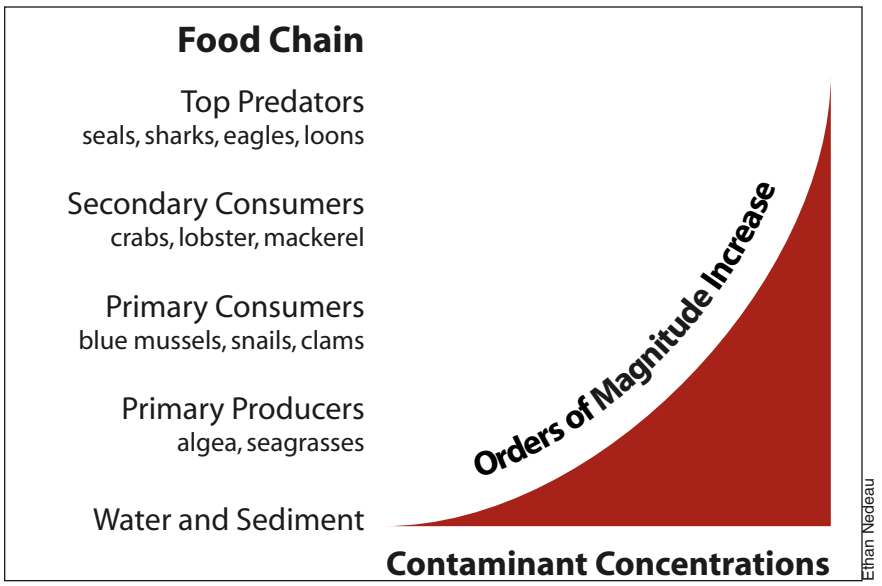


Figure 1-6: *This diagram illustrates the marine food chain, but the same processes occur in fresh water. When organisms are exposed to certain toxic chemicals through, for example, contact with contaminated water or sediment or by consuming prey, the chemicals can become sequestered in their tissues at a higher concentration than in the source (bioaccumulation). The concentration of toxics in organisms may become higher with each step up the food chain from the lowest to the highest links (biomagnification).*


Lee Doggett

In the contaminant-impacted inner Fore River, samples taken in 1989 included some hardy worm species. More sensitive organisms such as mollusks, crustaceans and other typical benthic invertebrates were absent. Even the few pollution-tolerant worms such as this Nephtys *had oil stuck to their "feet" (parapodia) (Doggett 2005).*

Casco Bay Water Bodies That Are Currently Impacted by Toxic Contaminants

According to the Maine DEP's 2004 Integrated Water Quality Monitoring and Assessment Report, elevated levels of toxic contaminants are most often found in harbor and port areas, near the mouths of rivers, in areas with high population density or where there is a legacy of pollutants in the sediments from past activities. Based on sediment analysis and mussel tissue testing, Maine DEP has identified three "Marine and Estuarine Areas of Concern for Toxic Contamination" in Casco Bay. They are the Fore River (1,230 acres), Back Cove (460 acres) and the Presumpscot River Estuary (620 acres) (Maine DEP 2004) (see Figure 1-7).

In addition, all fresh waters in Maine, including those in the Casco Bay watershed, are considered impaired by atmospheric deposition of mercury, resulting in elevated levels of mercury in fish (Maine DEP 2004). As a result of mercury accumulation in fish tissue, the State has issued fish consumption advisories with safe eating guidelines for all freshwater and some marine species. Elevated levels of PCBs, dioxins and DDT have also been identified in the tissues of some freshwater fish, resulting in additional limits to fish consumption for certain ponds and rivers. Fortunately, none of these fresh water bodies impacted by organic pollutants is in the Casco Bay watershed. PCBs and dioxins have been found in some saltwater fish in Maine, resulting in state-wide consumption advisories and safe eating guidelines for striped bass and bluefish. Due to elevated concentrations of dioxin, the State advises that consumers avoid any consumption of lobster tomalley, an organ that serves as the lobster's pancreas and liver, where contaminants can bioaccumulate (Maine CDC 2006).

Maine DEP

Because of the presence of certain toxic contaminants in fish tissues, state-wide consumption advisories and safe eating guidelines have been issued for all freshwater fish as well as for some marine fish, including the striped bass shown above (see Chapter 8).

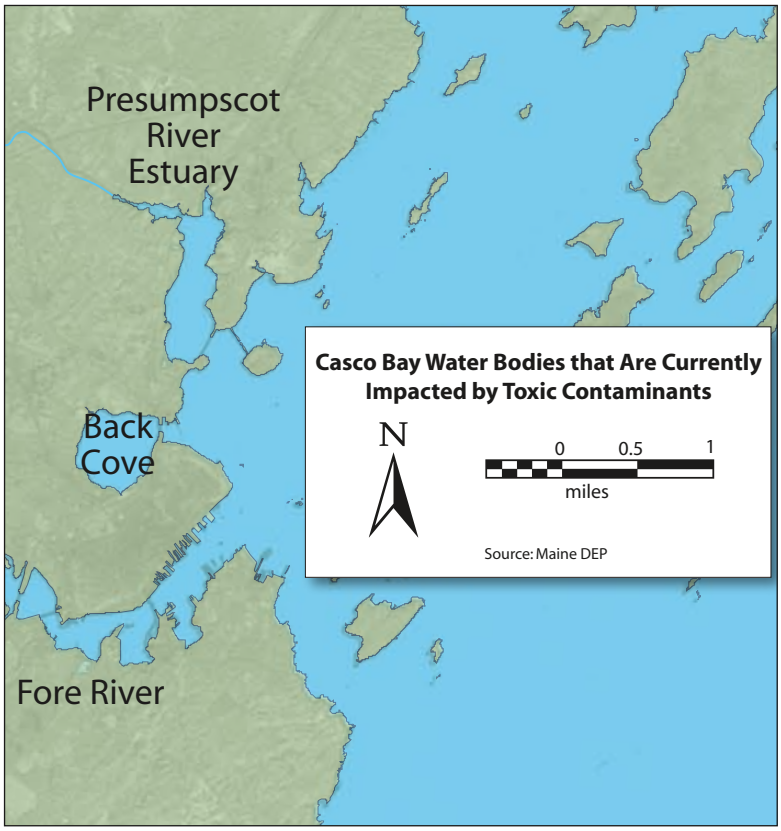


***Figure 1-7**. The Fore River, Back Cove and the Presumpscot River Estuary have been identified by Maine DEP as "Marine and Estuarine Areas of Concern for Toxic Contamination" in Casco Bay (Maine DEP 2004).*

Mike Bradley

Chris Taylor collects sediment samples from Casco Bay as part of the NCA and CBEP Monitoring Programs.

Monitoring Toxics in the Bay

CBEP and our partner organizations have been monitoring toxic contaminants along Maine's coast in recent years. These programs include: the National Coastal Assessment (NCA) (funded by the United States Environmental Protection Agency and administered in Maine by CBEP); the Maine Department of Environmental Protection Surface Water Ambient Toxics Monitoring program (SWAT); the Maine DEP Air Toxics Monitoring Program, including the Breathing Easier through Monitoring (BEAM) program in Portland and the two Mercury Deposition Network sites in the watershed, located in Freeport and Bridgton; the Gulf of Maine Council on the Marine Environment Gulfwatch mussel monitoring program, and CBEP Monitoring Program. CBEP and our partners are tracking the levels of organic chemicals and metals in the Bay's sediments (see Chapter 4), in lobsters, fish, clams and blue mussels (see Chapter 5), and in the precipitation that reaches the Bay (see Chapter 2). Other ongoing monitoring and research programs (such as studies by the Biodiversity Research Institute in Gorham, the Marine Environmental Research Institute in Blue Hill, and the Wise Laboratory of Environmental and Genetic Toxicology at the University of Southern Maine) are assessing the impacts of mercury and other toxic contaminants on Maine's birds and mammals (see Chapters 6 and 7).

A Report Overview

In the chapters that follow, *Toxic Pollution in Casco Bay: Sources and Impacts* describes studies undertaken by CBEP, our partners, state agencies, and research scientists on the sources of toxic chemicals that are entering the Bay and its watershed, on the impacts of toxic chemicals on Casco Bay area wildlife, and on potential risks to human consumers of fish and shellfish. The report also explores the ways that CBEP and our partner organizations are working to reduce the loading of toxics to the Bay and its watershed and to promote stewardship among all the citizens of Casco Bay. A glossary is provided which defines acronyms, abbreviations, and technical terms.

Steve Karpiak

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