What are the impacts of mercury on wildlife?

6

USF&WS

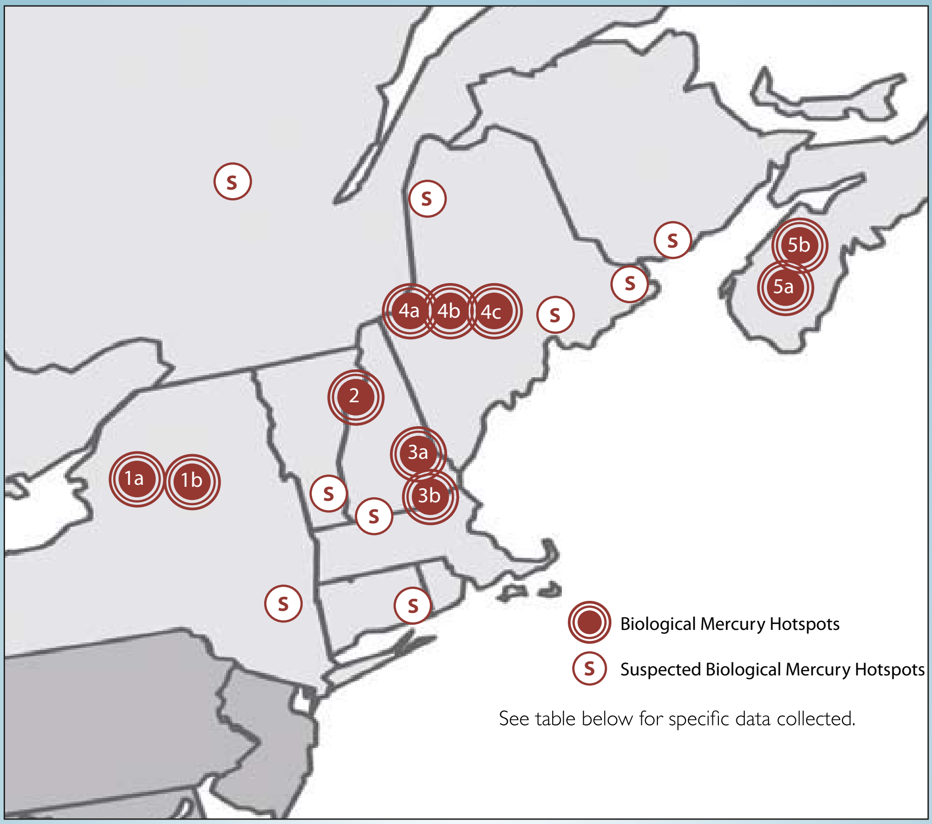
Background

Maine DEP has noted that mercury levels in the state's fish, loons and eagles are among the highest in North America (Maine DEP 2005a). Much of the research supporting this statement resulted from a call for studies on the regional bioavailability of mercury in freshwater and marine ecosystems, a need identified at the 1998 conference of the New England Governors and Eastern Canadian Premiers (NESCAUM 1998). This chapter briefly summarizes recent studies on the impacts of mercury on wildlife in Maine and, in particular, in Casco Bay and its watershed. Chapter 8 addresses the human health implications of consuming fish and shellfish with elevated mercury.

The heavy metal mercury can enter the environment through industrial processes, such as chlorine manufacturing (Evers 2005), and through combustion of coal, oil, wood, natural gas and mercury-containing trash. Over the past century, anthropogenic inputs of mercury into the environment have significantly increased (Evers *et al.* 2004). Once in the environment, elemental mercury can be transformed by bacteria into a highly toxic organic compound (methyl mercury) which is readily absorbed into living tissues. Mercury is poorly excreted, leading to bioaccumulation and biomagnification up the food chain (see Chapter 1). Exposure to methyl mercury can result in serious damage to the nervous system and kidneys of fish, birds, and mammals. Mercury can also affect the reproductive system, including reduced fertility and reduced survival of young. It has been shown that it can induce genetic mutations and interfere with embryonic development (Chan *et al.* 2003).

Figure 6-1. *Evers et al. (2007) used a new method to identify biological mercury hotspots, based on the mercury concentrations in yellow perch and Common Loons. A mercury hotspot of human health concern occurs where there are 10 or more independent sites with yellow perch concentrations above 0.3 ppm within grids that average 890 square miles in size. A biological mercury hotspot of ecological concern occurs where 25 percent or more of the Common Loons sampled in a grid containing at least 14 samples have mercury blood levels above 3.0 ppm.*

Biological Mercury Hotspots



Mercury Levels in Biological Hotspots

Biological Hotspot	State/Province	Yellow Perch		Common Loon		
		Average (ppm)	Range (ppm)	Average (ppm)	Range (ppm)	% of loons > adverse effect level
1a. Adirondack Mountains—west	NY	0.73	0.57-0.96	1.5	1.1-2.1	0%
1b. Adirondack Mountains—central	NY	0.54	0.39-0.80	2.0	0.3-4.1	25%
2. Upper Connecticut River	NH, VT	0.35	0.14-0.58	1.1	0.1-2.9	0%
3a. Merrimack River—middle	NH	0.78	0.05-5.03	2.6	0.7-7.1	28%
3b. Merrimack River—lower	NH, MA	0.65	0.23-3.81	no data		
4a. Upper Androscoggin River	NH, ME	0.44	0.21-1.25	1.9	0.15-5.5	14%
4b. Upper Kennebec River—west	ME	0.40	0.24-0.52	3.1	0.6-14.2	43%
4c. Upper Kennebec River—east	ME	0.38	0.14-0.72	2.2	0.6-4.1	26%
5a. Kejimkujik National Park	NS	0.50	0.14-0.85	5.5	2.9-7.8	93%
5b. Central, Nova Scotia	NS	0.58	0.14-3.79	no data		

Source: Driscoll *et al.* 2007. Courtesy of the Hubbard Brook Research Foundation.

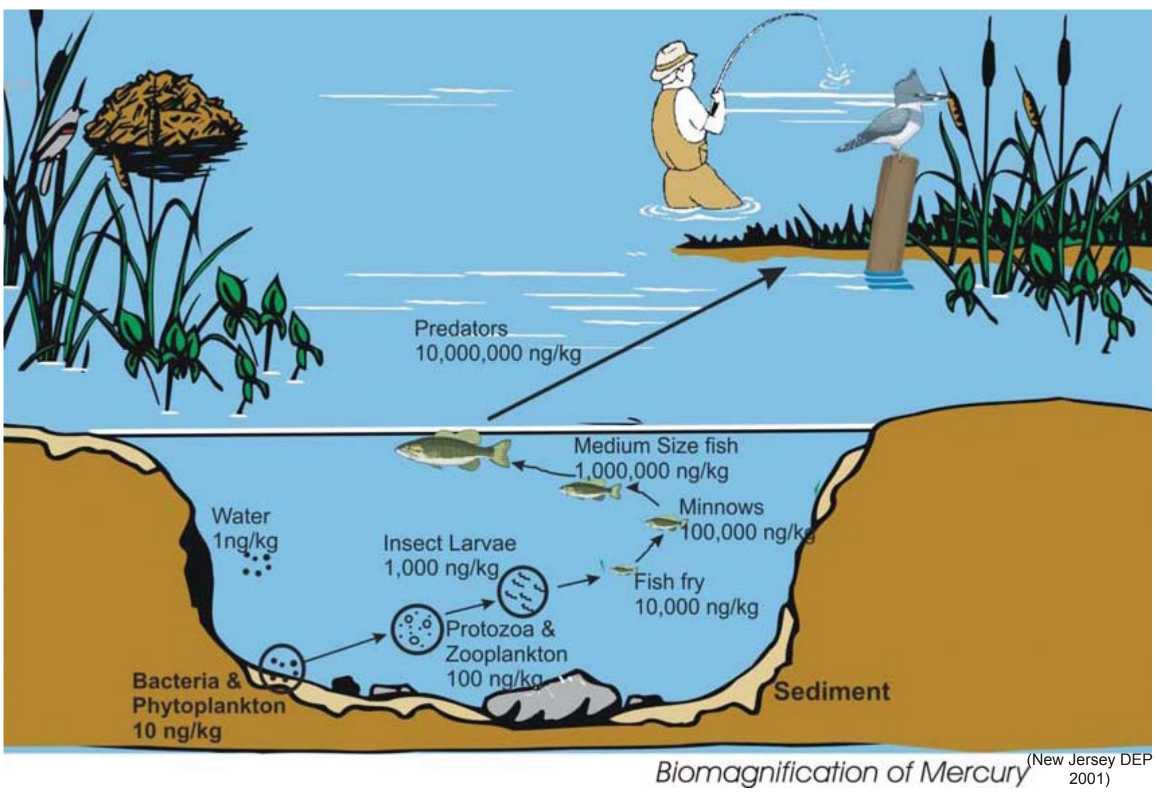
Mercury in the Northeast

During the period from 2001 through 2005, the BioDiversity Research Institute in Gorham, Maine worked together with a group of researchers in the northeast, including the New England states and Canadian provinces, US Fish and Wildlife Service, the Canadian Wildlife Service, and Environment Canada, to compile a comprehensive database on mercury sources and impacts. The database focused primarily on northeastern freshwater environments. The results of the analysis demonstrated that "mercury levels are high and pervasive in northeastern North America." The mercury comes from both atmospheric deposition (with highest levels of mercury in precipitation associated with regional transport from the west and southwest) and from local point sources (Evers and Clair 2005).

An examination of large-scale spatial distribution patterns of mercury in surface waters from Massachusetts to Newfoundland indicated that there were areas of elevated total mercury near the urban regions of Boston and Portland. However, the highest total mercury and methyl mercury were found in flat, wet areas (wetlands) located far from point sources (Dennis *et al*. 2005), likely delivered via atmospheric deposition. Research undertaken by CBEP indicated that atmospheric deposition is the dominant source of mercury to Casco Bay and its watershed (Ryan *et al.* 2003) (see Chapter 2).

Mercury has been found in the northeast in the tissues of aquatic wildlife from crayfish and salamanders to fish, birds, mink, river otters (Evers 2005) and seals (Shaw 2002) (see Chapter 7). Recent studies suggest that even terrestrial insect-eating birds, such as Bicknell's Thrush, a mountain-dwelling woodland songbird, show elevated body burdens of mercury, indicating that methyl mercury can be produced in terrestrial ecosystems in Maine as well (Rimmer *et al*. 2005).

The term "hotspots" is used to describe areas where mercury deposition is unusually high or where the levels of mercury in wildlife are especially elevated in two or more species (biological hotspots). They occur where conditions are especially conducive to methyl mercury production or where there are local emissions sources. Evers *et al*. (2007) identified at least three biological mercury hotspots in Maine, none of which is in the Casco Bay watershed (see Figure 6-1). Additional data are being collected to confirm the number and location of hotspots in Maine.



(New Jersey DEP 2001)

Figure 6-2, Biomagnification of Mercury: *The concentration of a pollutant can increase from one link in a food chain to the next highest trophic level through the process of biomagnification. This diagram illustrates a typical pathway for biomagnification of mercury.*


Maine DEP

This image of a gutted striped bass filled with juvenile alewives from a recent meal illustrates one reason why biomagnification occurs—higher level predators consume large numbers of prey in order to meet their energy requirements.


Maine DEP

Barry Mower from Maine DEP collects a fish blood sample for the Maine SWAT monitoring program.

Mercury in Fish

Through the process of biomagnification, the tissues of predatory freshwater fish near the top of the food chain may contain levels of methyl mercury that are 100,000 to 1,000,000 times higher than the concentration in the water (Maine DEP 2002; Mower 2006) (see Figure 6-2). In 1993, Maine DEP began studying the levels of toxic contaminants, including mercury, in the tissues of fish in lakes and ponds. Of 1800 potential candidate water bodies in Maine, 150 lakes from all over Maine, including some in the Casco Bay watershed, were chosen for study using a statistical design program based on probability sampling. Top predators and omnivorous fish species were collected from each lake. The results of the study indicated that mercury levels in composite tissue samples exceeded the Maine Department of Health and Human Services Level of Concern for human consumption (0.43 ppm or higher) in fish from 65% of the lakes sampled (Maine DEP 2005b). In the Casco Bay watershed, for example, chain pickerel from Forest Lake in Windham had mercury levels of 0.80 to 1.22 ppm in composite tissue samples (DiFranco *et al.* 1995).

These results led the State to issue a mercury health advisory for consumption of fish from Maine lakes and ponds in May 1994. Subsequent freshwater fish sampling through the Maine DEP's Surface Water Ambient Toxic Monitoring Program (SWAT) supports continuation of the health advisory. For example, Maine DEP SWAT sampling conducted in Pleasant Lake in 1998-99 showed mercury levels in fish ranging from a mean of 0.89 ppm in tissues of smallmouth bass and 0.83 ppm in tissues of white perch (Maine DEP 1999). Mercury concentrations in fish from Maine rivers also are elevated and warrant consumption advisories (Maine CDC 2006). The new fish tissue Action Level of 0.2 ppm (wet weight) is also Maine's ambient water quality criterion for human health for mercury. Fish consumption advisories in Maine are discussed further in Chapter 8.

Regional monitoring studies show that there is considerable variation in methyl mercury body burdens among species and types of fresh water bodies across the northeast. For example, bass species, pike, lake trout, white perch and walleye had the highest mercury concentrations of the fish species sampled in the northeast. Surface water characteristics that lead to elevated body burdens in fish include high acidity, presence of wetlands along the shore, low nutrient levels, and a complex food web (Kamman *et al.* 2005, Evers 2005).

Throughout the Gulf of Maine, elevated body burdens of mercury have also been found in saltwater fish, including swordfish, shark and tuna. Consumption advisories have been issued for these species by the Maine Center for Disease Control and Prevention. While humans may be protected from the health impacts of mercury-laden fresh and saltwater fish by public advisories, top-level predators dependent on fish as their main source of food are potentially at risk. The following sections examine the impact of trophic level transfer of mercury from fish to fish-eating birds. Chapter 7 addresses the impacts of mercury and other toxic chemicals on seals in Maine and Casco Bay.

Mercury in Fish-Eating Birds

Predatory birds whose diet is high in fish are at risk of both sub-lethal and lethal effects of mercury poisoning. Over their lifetime, predatory birds can accumulate a substantial body burden of mercury through biomagnification. The impacts of mercury on birds can be manifested in individuals as well as in entire populations through changes in behavior, reproduction and body chemistry (Evers 2005). It is difficult to assess these impacts and risks to fish-eating wildlife because the bioavailability of mercury to fish varies geographically, is influenced by the age and species of fish consumed, and because bird species often feed from multiple aquatic habitats. With such broad ecological variation, it is necessary to sample multiple target species in a variety of habitats that can represent the broader biological community. These selected species serve as indicator organisms or "biosentinels" (Lane *et al*. 2004). Belted Kingfishers, Bald Eagles, and Common Loons are examples of fish-eating indicator species.

Mercury in Belted Kingfishers

Belted Kingfishers (*Ceryle alcyon*) are found throughout Maine in areas where fish are available as food, including small streams, large rivers, ponds, lakes and estuaries. They feed on a variety of fish species ranging from 4 to 14 centimeters in length (as well as crayfish, insects and small amphibians) (Davis 1982). Because the bird is common and widely distributed, it was assessed as a potential methyl mercury biosentinel species in a study sponsored by the Maine DEP's SWAT monitoring program. The 68 nest sampling sites included the Androscoggin and Kennebec River watersheds as well as Flagstaff Lake/Dead River Reservoir, Merrymeeting Bay (estuarine habitat), and Casco Bay (Lane *et al.* 2004). The 4 Kingfisher nests sampled in Casco Bay were located at Winslow Park, Freeport.

During the four-year study, blood and feathers were collected for analysis from adults and young. Prey fish were also sampled. The results indicated that, compared to birds from Michigan, Vermont and Massachusetts, Maine's Belted Kingfishers had higher blood levels of methyl mercury. This is likely due to distribution patterns of mercury as it is transported by the atmosphere from the west to the east. The lowest levels of blood mercury were found in the marine birds (Casco Bay). Samples from Casco Bay, Merrymeeting Bay and the rivers fell below 1 ppm, a value considered to be below a No Observed Adverse Effect Level (NOAEL) critical concentration (US EPA 1997). Birds from the lake/reservoir habitat had much higher levels, with several exceeding the 1 ppm, a level at which there can be reproductive impairments (Lane *et al*. 2004). The study suggests that Kingfishers eating a diet of marine fish have lower exposure to methyl mercury than estuarine, river and especially lake/reservoir birds.

Belted Kingfisher

Mercury in Bald Eagles

In 2001-2006, researchers studied fresh-water based populations of Maine bald eagles (*Haliaeetus leucocephalus*) to determine if exposure to dietary mercury may be slowing the recovery of Maine's eagle population. Researchers visited nests to collect nestling blood samples, which reflect recent dietary uptake, and shed adult feathers, which reflect mercury bioaccumulated over time. Sampling sites were distributed throughout Maine in lake and river habitats, including a site on Little Sebago Lake in the Casco Bay watershed. Preliminary results from sampling over 300 nestlings from over 200 nests during 2001-2006 suggested a statistically significant negative correlation between nestling blood mercury exposure and productivity, and no relationship between adult feather mercury and productivity. Researchers found that eagle mercury exposure patterns on Maine's landscape were often consistent

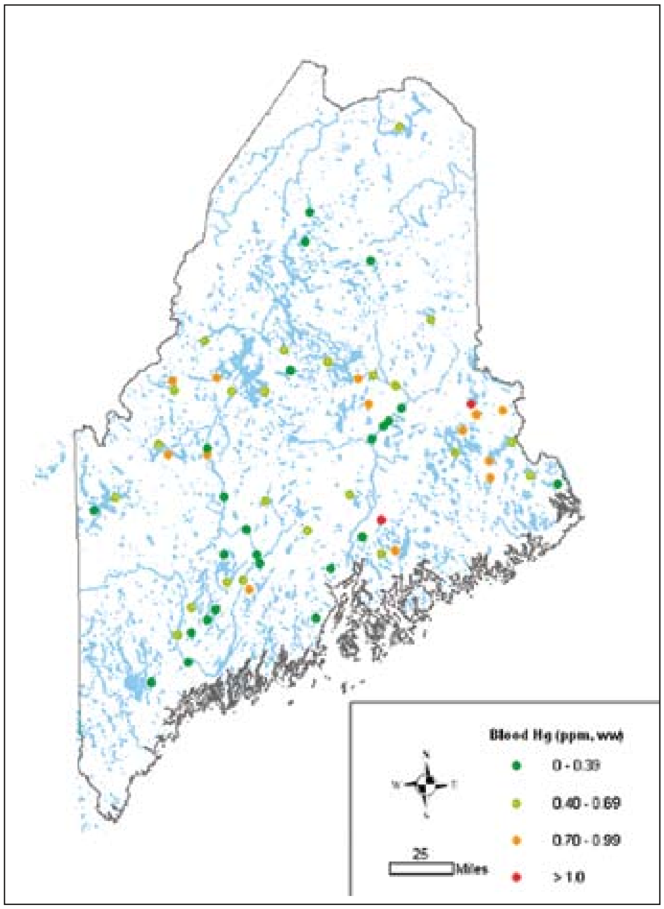


***Figure 6-3**: Mercury exposure indicated by eagle nestling blood samples 2001-2006, (DeSorbo* et al. *2006)*

Christian Niven

Researcher Chris DeSorbo climbs to an eagle nest to collect nestling blood and adult feather samples.

Chris DeSorbo

Young eagles are exposed to elevated levels of methyl mercury through their fish diet in lake and river ecosystems in Maine. Results from studies of 4.5 to 8 week old nestlings indicates that there is a statistically significant negative correlation between nestling blood mercury exposure and productivity (DeSorbo and Evers 2005)

with those observed in other wildlife and fish, and this information is being used to identify regions of specific mercury concern (DeSorbo *et al.* 2006, DeSorbo and Evers 2005) (see Figure 6-1). Comparisons to eagle mercury levels documented in 1991-1992 (Welch 1994) indicated that dietary mercury exposure may be similar on lakes, and potentially higher in rivers, in comparison to 14 years ago. Researchers will also analyze PCBs and DDE (a metabolite of DDT) in nestling eagle blood samples in order to determine how these chemicals relate to productivity (DeSorbo *et al*. 2006).

In all the eagle tissues analyzed, samples from Maine lakes displayed significantly higher mercury levels than samples from Maine rivers. Mercury exposure in Maine eagle tissues are elevated in comparison to most populations in the U.S., and most comparable to populations associated with significant point source pollution problems (*i.e.,* dredging, mercury mines). While nestling eagle blood mercury levels from the Casco Bay watershed indicated low mercury exposure in the local foodweb (see figure 6-3), feather samples from territorial adult eagles indicated significantly elevated exposure and bioaccumulation to levels of concern (DeSorbo *et al*. 2006, DeSorbo and Evers 2005).

Mercury in Common Loons

The Common Loon *(Gavia immer)* is a long-lived bird that is found throughout New England. It has emerged as a suitable biosentinel species, serving as an indicator of aquatic methyl mercury pollution. Studies of the New England breeding loon populations conducted from 1994-2003 show that the birds are at a high level of risk to mercury contamination. In Maine, 22% of the breeding population is considered to be at risk (Evers *et al.* 2004). During the study period, 324 abandoned eggs and blood and feathers from 408 adults and 142 juvenile Common Loons were collected from Maine lakes. In addition, a focused study was conducted in the Rangely Lakes area. Loon blood mercury levels from Forest Lake in Windham were quite high, perhaps because of the lake's proximity to the Portland municipal incinerator (Evers 2006). The results of the loon studies were used to relate mercury to behavioral and reproductive impacts. The studies confirmed that mated pairs whose blood levels exceeded the Low Observed Adverse Effect Level (LOAEL) produced 40% fewer fledged young than birds with mercury blood levels below the NOAEL (Evers *et al*. 2004).

The physiological impacts of increasing levels of mercury in the blood of loons were observed using two indicators: increasing corticosterone hormone stress levels (which can lead to suppression of the immune system) and asymmetry of flight feathers (which may be related to disruption of embryonic development and overall decline in reproductive fitness). Behavioral changes were also observed with increasing methyl mercury exposure. High risk adults left eggs abandoned and showed reduced hunting and foraging. All of these impacts challenge the birds' ability to maintain their population successfully.

Mercury in Insect-Eating Birds: The Saltmarsh Sharp-tailed Sparrow

A study conducted in 2004-2005 suggests that a small estuarine bird, the Saltmarsh Sharp-Tailed Sparrow, may be a good indicator of methyl mercury availability to insect-eating birds in Maine and New England. Sparrow blood was collected at Scarborough Marsh State Wildlife Management area, Libby River and Nonesuch River estuaries in Scarborough, and five estuaries in the Rachel Carson National Wildlife Refuge. In addition, samples were collected at sites in Massachusetts, Rhode Island, and Connecticut. The sparrows had elevated blood mercury levels at all the sampling sites. While the blood mercury concentrations were highest in the Parker River National Wildlife Refuge in Massachusetts) and Ninigret Marsh National Wildlife Refuge in Rhode Island, the 62 birds sampled in Maine had blood concentrations ranging between 0.23 and 0.84 parts per million. For several sites in Maine, the mercury concentration exceeded levels considered to impact the health of insect-eating songbirds (Lane and Evers 2005, 2006). This study suggests that invertebrates (such as insects) in the food chain in freshwater and estuarine wetlands are an important part of the mercury bioaccumulation problem that is just now being discovered (Evers 2006).

Oksana Lane

Researcher collects a blood sample from a Saltmarsh Sharp-tailed Sparrow using a capillary tube.

Management Tools to Protect Freshwater Wildlife from Mercury

In an effort to provide a wildlife management tool applicable throughout Maine, researchers have been using a modeling approach to develop a Maine-based wildlife criterion value (WCV). Current models of loon populations in Maine suggest that breeding population sinks exist (*i.e.* areas where loons attempt to nest but are unsuccessful because of mercury concentrations in the environment). A WCV is under development that would indicate the maximum allowable total mercury concentration in fresh water that is protective of loons at the population level. WCV levels are also in development for mink and river otters, animals that are also highly susceptible to elevated levels of methyl mercury due to their fish-heavy diet and rapid metabolism (Evers *et al.* 2004, US EPA 1997, Yates *et al*. 2004).

Summary/Conclusions

Mercury levels are elevated in many Maine species, including freshwater fish species, some marine fish species, fish-eating birds and mammals, and even in insect-eating birds. Elevated blood levels and health impacts from exposure to methyl mercury have been observed in populations of bald eagles and loons from Casco Bay. The widespread bioaccumulation of mercury in fish tissues has led to fish consumption advisories for human consumers throughout Maine (see Chapter 8). Protection of Maine's animal species from the impacts of mercury will require an ongoing commitment to dramatically reduce inputs of mercury into the environment. See Chapter 9 for a discussion of state and federal efforts to reduce the loading of mercury to our Bay ecosystem.

Ron Singer

A wildlife criterion value (the maxiumum total allowable total mercury concentration in fresh water protective at the population level) is under development for river otters, such as the animal shown above, as well as mink and loons.

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