DETERMINING MERCURY EXPOSURE IN MAINE'S FISH-EATING BIRDS

1997 Final Report

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by

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Abstract:

This study provides mercury (Hg) exposure information for a high-risk wildlife group in an area of the continental U.S. that has been predicted by the U.S. EPA to receive high amounts of wet and dry atmospheric Hg deposition. Local-scale deposition (e.g., Maine chlor-alkali plant and municipal waste incinerators), long-range transport deposition (e.g., from the Midwest), and increasing global atmospheric reservoirs all contribute to Hg availability on Maine's landscape. Recent geographic studies indicate that Maine's Common Loon and Bald Eagle breeding population are exposed to some of the highest levels of methylmercury (MeHg) in North America. We quantified the extent of Hg availability for five piscivorous birds on 92 lakes across Maine. All species exhibited elevated levels of Hg in their blood, feathers, and eggs. The Common Loon was the species most widely represented and adults showed the highest levels of Hg exposure. Our non-random sampling of Maine lakes prevented a statewide assessment of risk. However, Hg levels in Common Loons indicate that 31% of the adult males, 30% of the juveniles, 24% of the eggs, and 10% of the adult females exceeded impact thresholds determined by laboratory and *in situ* studies. Based upon data from previous studies, 48% of juvenile Bald Eagles were at risk. Interior nesting pairs of eagles had Hg concentrations over 6 times higher than coastal or riverine pairs. Osprey Hg concentrations were also higher on interior lakes but were significantly lower than eagle Hg levels. The calculated uptake of dietary MeHg is considered to be 3-4 times higher in the Belted Kingfisher than the other target piscivorous birds and was apparent on Flagstaff Lake when compared to young loons and mergansers. Common Mergansers sampled also exhibited high exposure to Hg. There were few indications of statewide geographic patterns in MeHg availability except that marine habitats tended to have significantly lower levels than interior Maine. There was also an apparent effect from atmospheric Hg being deposited downwind of the Orrington area as indicated by loon blood and egg samples. Lake morphometric and water chemistry Hg patterns were not readily apparent dictating the need for a lake to lake sampling scheme. We developed an index that included each species and matrix sampled. It indicated that a majority of Maine lakes sampled generate enough MeHg to cause moderate to high risk to loons (50%) and the piscivorous bird community (70%).

Background:

U.S. EPA models have predicted mercury (Hg) deposition in the northeastern United States to be at the highest levels in the country (U.S. EPA 1996). Preliminary studies of northern Maine lakes by BioDiversity Research Institute agree with these predictions through recent findings of elevated Hg concentrations in Common Loon (*Gavia immer*) adults and juveniles. Northeastern blood levels are significantly higher than the upper Great Lakes, Pacific Northwest, northern Rocky Mountains, central Canada, and Alaska (Evers et al. 1998). Evidence from the Bald Eagle (*Haliaeetus leucocephalus*) (Welch 1994) indicate an exposure to Hg that affects the freshwater fish-eating bird community, not just loons. Results from the Regional Environmental Monitoring and Assessment Program (REMAP) study also show fish Hg concentrations at or above levels considered safe for human and wildlife consumption across Maine (Stafford and Haines 1996). Older piscivorous fish have the highest Hg concentrations, although biogeochemical processes play a significant role in methylmercury (MeHg) bioavailability and need to be considered during lake evaluation.

In response to elevated fish Hg body burdens the Maine Department of Human Services has issued the most stringent fish consumption advisory in the U.S. It recommends no warmwater fish to be consumed by pregnant women and young children. Recently, representatives of New England and eastern Canada air, water, waste, and public health divisions compiled a technical and policy information document (NESCAUM 1998). This broad based workgroup recommended that "Additional research is needed to assess the ecosystem impacts of mercury in the Northeast, particularly with respect to fish-eating wildlife." Similarly, Maine's Land and Water Resources Council (1997) recommends "additional research should be undertaken" in "determining whether adverse health effects are occurring in Maine fish and wildlife".

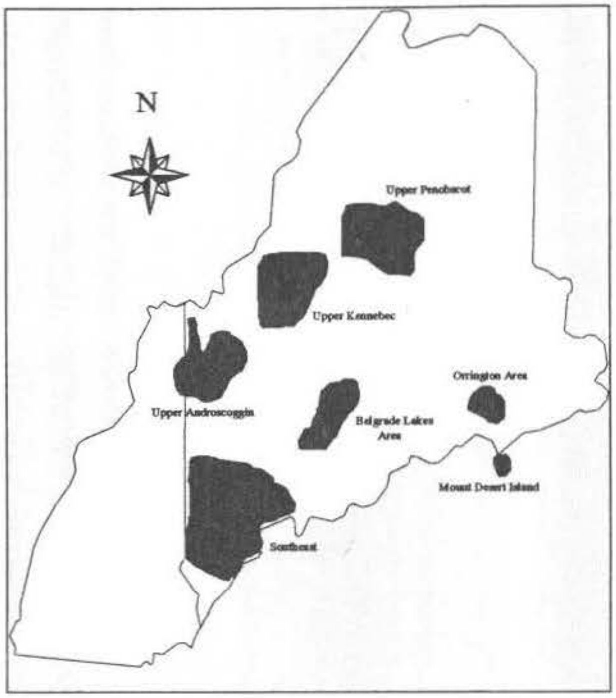
Although the REMAP fish results indicate widespread and elevated environmental Hg exposure, they are limiting toward an understanding of the availability of Hg, particularly MeHg. In general, lower trophic level, short-lived biota are less sensitive to MeHg than birds that are higher on the food chain and longer lived. The subtle neurological effects of MeHg may not impact an individual until concentrations attain levels that are reached through bioaccumulation and biomagnification. For example, the U.S. EPA (1996) predicts a five-fold increase in MeHg exposure between forage fish (trophic level 3) and predatory fish (trophic level 4). Therefore, we recommend evaluating MeHg exposure and potential impacts on Maine's environment in piscivorous birds.

Aquatic ecosystems are primary repositories for atmospheric Hg deposition and the patterns of biomagnification and bioaccumulation are best evaluated through obligate piscivorous species. Although our sampling efforts emphasized the Common Loon, a multi-species approach accounted for differences in ecological and physiological responses and distribution or availability limitations. We evaluated spatial and physiogeochemical patterns of Hg exposure in 5 piscivorous birds and determined interspecies relationships with prey MeHg uptake models. A national context developed by BioDiversity Research Institute also provided the means to assess regional population exposure of selected piscivorous birds relative to Hg toxicity. The selected species have a range of life-history characteristics, such as micro-habitat associations, seasonal movements and in-state breeding distribution, nesting requirements, and sensitivity to toxic substances. Target birds included the Common Loon, Bald Eagle, Osprey (*Pandion haliaetus*), Common Merganser (*Mergus merganser*), and Belted Kingfisher (*Ceryle alcyon*).

Study Areas:

The collection of field samples concentrated on seven areas of Maine (Figure 1). Two of these areas, the Upper Androscoggin River Watershed (Rangeley Lakes Region) and the headwaters of the Kennebec River Watershed (e.g., Indian and Flagstaff Lakes), were linked with a study (funded by Central Maine Power Company and the U.S. Fish and Wildlife Service) investigating the potential effects of reservoir water level fluctuations on MeHg availability. Loon and merganser blood, feather, and egg samples collected from 1994-97 are included in the following analyses, unless otherwise noted.

Figure 1. 1997 MOHF Mercury Study Areas, 1997.



Lakes from the other five areas were based on hydrological, physiogeochemical, and geographical parameters that have been identified to influence MeHg availability as well as logistical feasibility and historical information on water quality and productivity of the target species. Southeastern Maine (Piscataqua, Saco, and Presumpscot River Watersheds) that is subject to higher levels of regional atmospheric deposition (i.e., sources in southern New England) than the rest of the state. Another area of concern was within a 25 km radius of the HoltraChem Manufacturing Corporation in Orrington. Mount Desert Island was selected because of elevated levels of Hg being measured in a newly installed atmospheric deposition station on the island and a study by the University of Maine at Orono that indicated above average Hg levels in fish tissue. Both of these areas are within the coastal river watershed. The Belgrade Lakes area (Kennebec River Watershed) rated highly because of the long-term information on loon productivity (provided by the Maine Audubon Society) and its proximity to major municipalities (Augusta and Lewiston-Auburn). Lastly, because some reservoirs and low pH/alkalinity lakes are now known to accentuate MeHg production and therefore availability we chose several northern Maine lakes outside of known emission plumes (i.e., the Millinocket area of the Upper Penobscot River watershed).

Methods:

1a. Experimental Design

The Maine Department of Environmental Protection (MDEP) initiated the "Regional Environmental Monitoring and Assessment Program" (REMAP) in 1993 to measure levels of contamination in fish populations and assess wildlife and human risk (DiFranco et al. 1995). A total of

150 Maine lakes were randomly selected statewide using the U.S. EPA's Environmental Monitoring and Assessment Program (EMAP) sampling design. Fish, water, and sediment samples were collected from 125 of the target lakes for chemical analyses. Morphometric information was also collected and included surface area, drainage area, maximum depth, mean depth, flushing rate, and shoreline length.

We concentrated part of our sampling efforts on these target lakes and collected matrices from 7 lakes. Since the bioaccumulation of Hg is enhanced in fish inhabiting water bodies with low acid-neutralizing capacity and low pH (Cope et al. 1990, Spry and Wiener 1991, Wiener and Spry 1996), high dissolved organic carbon (Nilsson and Hakanson 1992), high water temperatures (Bodaly et al. 1993), large watersheds (Joslin 1994), and reservoirs, especially those that are less than 30 years old (Hecky et al. 1991, Verdon et al. 1991) and/or have widely fluctuating water levels (Evers and Reaman 1997) we have compared several of these parameters with the Hg levels of the various matrices.

1b. Field sampling, archiving, and analysis

We measured pH, alkalinity, and apparent color in a subset of the study lakes in 1997. Water chemistry data from the MDEP and Maine Department of Inland Fisheries and Wildlife were used for lakes that were not tested in 1997. The pH was measured with a pH meter model Orion SA 250™ and Orion Sure Flow™ electrode. Alkalinity was determined by Gran Plot titration with 0.02 N H_2SO_4. Apparent color was measured with a Hack™ color kit. Water samples were collected during bird capture and analyzed within 24 hours.

Capture of breeding adult and juvenile loons and mergansers relied on nightlighting methods developed by Evers (1993) for loons and Derr (1995) for mergansers. Adult kingfishers were captured at their nest burrows with a mist net strung at the entrance. We used a modified noose carpet to capture the adult osprey while 4-6 week old osprey were taken from their nest and lowered to the ground. Young eagles were also briefly taken from their nests in 1991-92 by Welch (1994) and in 1993-96 by Matz (pers. com.).

Collection of blood and feather samples used standardized methods outlined in Evers et al. (1996). One secondary feather was symmetrically taken from loons, mergansers, and kingfishers. Breast feathers were collected from eagles and osprey. Blood was drawn from the medialtarsal vein from all adult and juvenile birds with a combination of 21-25 gauge needles and 1-10 cc syringes, with g a Leur adapter. Blood drawing never approached the upper limits of safe levels (i.e., 1% of the body weight). All birds were banded with USFWS bands (federal and state permit #22636) and colored plastic leg bands were wrapped around loon legs for later field identification of individuals. The plastic bands are time proven for color retention and leg wear (Evers et al. 1996). Morphological measurements were taken to determine loon gender.

Blood was preserved by 10% formalin (Wiemeyer et al. 1984) for later analysis of mercury levels. Feathers were clipped at the calamus and stored in polyethylene bags. Eggs from abandoned nests were opportunistically collected for loons, osprey, and eagles. Eggs were frozen until contents could be placed in sterile I-Chem jars. Length, width, volume, and weight of each egg was recorded.

Analysis of Hg concentrations for each matrix was through Cold Vapor Atomic Absorption techniques (detection limit was 0.025 ug/g). Samples from 1993-95 were analyzed at Michigan State University under the direction of Dr. Emmett Braselton, and from 1996-97 at the University of Pennsylvania under the direction of Dr. Robert Poppenga. Because studies have shown blood (Scheuhammer et al. 1998), feather (Burger 1993) and egg (Barr 1986) tissues are primarily laden with MeHg (> 95%), we only tested total Hg concentrations. Therefore, all mercury concentrations in this study represent total Hg.

Results and Discussion:

The bioaccumulation and biomagnification of MeHg causes concern for high trophic level, obligate piscivorous species. We identified five species of birds that have a relatively ubiquitous state distribution and are some of the most at-risk wildlife to MeHg because of their dependence on fish during the breeding season. Understanding the exposure levels of Hg in the various species of wildlife is paramount to understanding patterns of MeHg availability and interspecies relationships. Because target species were not uniformly sampled and species-specific pharmacokinetics differ we initially discuss exposure to MeHg availability by species and then make inferences into geographic and physiogeochemical patterns, interspecies relationships, and finally risk thresholds. Although the effects of Hg are most likely based on a continuum, we have identified certain step thresholds that will provide a reference for low, moderate, and high risk categories.

In 1997, survey efforts totaled over 500 person-hours and covered 92 lakes (Appendix I). We located over 450 adult and 144 juvenile target birds of which 66 adults and 70 juveniles were captured resulting in 120 blood and 110 feather samples collected in 1997 (Table 1). A total of 43 loon eggs were also collected from 15 lakes (Table 1). A total of 63 Maine lakes were thereby represented with eggs collected from 1994-97 and blood and feather samples collected in 1997. These lakes have associated water quality (Appendix II) and morphometric information (Appendix III). We have also included 206 loon samples (115 blood and 91 feathers) gathered from lakes in 1994-96 and 103 eagle samples (50 blood and 53 feathers) gathered from lakes in 1991-92 (Welch 1994) and 1995-96 (Matz pers. com.). Therefore, the grand total number of Maine lakes represented with piscivorous bird Hg levels is 92. The percentage of lakes with Hg samples by target area were: Southeast (16%), Upper Androscoggin (12%), Upper Kennebec (15%), Belgrade Lakes (15%), Upper Penobscot (11%), Orrington area (10%) and Mount Desert Island (8%). A total of 13% of the samples were opportunistically collected outside of the target areas (primarily for the Bald Eagle).

Species-specific Exposure of MeHg and the relationship with their breeding ecology

Common Loon:

Loons typically arrive on southern Maine lakes in mid to late April and northern Maine lakes by early May. Males may precede females by several days. Over 80% of the adults return to their previous year's territory and 10-15% switch territories to nearby lakes within 7 miles (Evers et al. 1996, Piper et al. 1997). Adult loons frequently maintain multiple lake territories, usually if the nest lake is 16 ha (40 acres) or less (Piper et al. 1997) or prey availability is limited (Barr 1996). However, the majority of breeding loons in this study were on lakes large enough to provide sufficient prey resources (i.e., 99% of lakes > 40 acres and 90% of lakes > 60 acres). The average statewide first nesting attempt is in early June. Second nesting attempts occur 1-3 weeks after the first nest failure and 21% of the renesting attempts are with a new mate (the tendency is for intruding males to initiate switching) (Evers et al. 1996). Two eggs are laid and are typically incubated for 26-28 days. Juveniles experience three different full body molts that change at 2 and 6 weeks of age. Juveniles are capable of flight at 10-11 weeks. Blood supply to developing flight feathers therefore ends around that time.

Loons are obligate fish-eaters. They are opportunistic predators, however they favor fish that have an erratic swimming behavior or fusiform shape (Barr 1996). Yellow perch (*Perca flavescens)* and white sucker (*Catastomus commersoni*) are favored for these reasons. Adult loons in Ontario have a daily fish uptake of approximately 960g (Barr 1996). Loons are sexually dimorphic. In New England,

Table 1. Summary of regions surveyed, birds captured and eggs collected in Maine Loons, Common Mergansers, Kingfishers and Osprey, 1997

Location	Survey Results			# of piscivorous birds captured			Loon Egg samples	
	# lakes	Adults	Juveniles	# lakes	Adults	Juveniles	# lakes	eggs
Belgrade Lakes Region	**12**	**35**	**5**	**10**	**6**	**5**	**0**	**2**
Mount Desert Island	**10**	**23**	**1**	**6**	**4**	**1**	**0**	**0**
Orrington Area	**12**	**12**	**0**	**7**	**6**	**2**	**1**	**3**
Southeast	**12**	**17**	**2**	**9**	**5**	**6**	**6**	**8**
Upper Androscoggin	**11**	**120**	**21**	**8**	**22**	**29**	**3**	**21**
Upper Kennebec	**17**	**104**	**2**	**9**	**19**	**21**	**3**	**6**
Upper Penobscot	**17**	**44**	**1**	**3**	**3**	**1**	**0**	**0**
Other Sites	**1**	**2**	**1**	**2**	**1**	**5**	**2**	**3**
ALL SITES	**92**	**466**	**144**	**54**	**66**	**70**	**15**	**43**

Table 2. Summary of Common Loons, Common Mergansers, Belted Kingfishers and Osprey captured in 1997

Location	Common Loon		Mergansers*		Belted Kingfisher		Osprey	
	Adults	Juveniles	Adults	Juveniles	Adults	Juveniles	Adults	Juveniles
Belgrade Lakes Area	**5**	**0**	**0**	**0**	**1**	**0**	**0**	**5**
Mount Desert Island	**3**	**1**	**0**	**0**	**1**	**0**	**0**	**0**
Orrington Area	**6**	**2**	**0**	**0**	**0**	**0**	**0**	**0**
Southeast	**5**	**5**	**0**	**1**	**0**	**0**	**0**	**0**
Upper Androscoggin	**21**	**21**	**0**	**8**	**1**	**0**	**0**	**0**
Upper Kennebec	**13**	**11**	**2**	**10**	**4**	**0**	**0**	**0**
Upper Penobscot	**2**	**1**	**0**	**0**	**1**	**0**	**0**	**0**
Other Sites	**0**	**0**	**0**	**1**	**0**	**0**	**1**	**4**
ALL SITES	**55**	**41**	**2**	**20**	**8**	**0**	**1**	**9**

*includes one Hooded Merganser from Moosehead Lake, the rest of the birds sampled were Common Mergansers.

mean male weights (6,050g, n=78) average nearly 30% greater than females (4,700g, n=81), therefore adult males tend to eat more and larger fish. The exposure of MeHg to adult male and female Common Loons partly reflects this difference: 69 and 63 ug MeHg/kg of body weight per day, respectively (see section - *Interspecies Relationships*).

During this study, we attained the largest sampling of blood, feathers, and eggs from the loon (Table 2). Matrices that best represent MeHg availability on a target lake are, in priority: juvenile blood and full-grown flight feathers, adult blood, eggs from a late nest or renest, eggs from the first nest, and adult feathers. All but the adult flight feathers are acceptable for correlating with MeHg availability on a breeding lake.

The half life of blood MeHg is approximately 2 months (Scheuhammer et al. 1998). Therefore, eggs laid during the first nesting attempt represent blood Hg concentrations deposited from prey on the breeding lake and wintering and migration areas. The longer the loon is on its breeding lake and the higher the MeHg availability on this lake, the more likely blood and egg MeHg concentrations represent breeding lake MeHg availability. Maine's mean egg Hg level was 0.93 +/- 0.55 ppm (Table 3) and was 3 times higher than background levels found in Saskatchewan (Younge 1981) and was significantly higher ($p<0.001$) than the mean egg level in Vermont (0.48 ppm) and New Hampshire (0.70 ppm). Mean egg Hg level of the 15 Maine lakes sampled was 0.75 ppm and was similar to the mean level in 45 New Hampshire lakes (0.71 ppm).

Table 3. Total mercury concentrations measured in Common Loon egg contents from Maine, 1994-97

Lake	Mean Egg Hg (µg/g)			
	Hg	SD	n	range
Wyman	2.49	-	1	-
Brewer	1.75	0.11	3	0.62 - 1.83
Aziscohos	1.27	0.48	11	0.56 - 2.42
Lake Umbagog	0.90	0.60	8	0.39 - 2.49
Seven Tree Pond	0.85	-	1	-
Mooselookmeguntic	0.85	0.03	2	0.83 - 0.87
Hancock Pond	0.77	0.24	2	0.61 - 0.94
Pierce Pond	0.63	0.41	4	0.38 - 1.25
Long Pond (Belgrades)	0.59	0.09	2	0.83 -0.87
North Pond	0.53	-	1	-
Howard Pond	0.47	0.07	2	0.42 - 0.52
Cold Stream Pond	0.46	0.11	2	0.38 - 0.53
Kennebunk	0.45	-	1	-
Moose Pond	0.37	0.22	2	0.22 - 0.52
Flagstaff	0.27	-	1	-
ALL SITES	**0.93**	**0.55**	**43**	**0.22 - 2.49**

The mean blood Hg level in adults was 2.1 +/- 1.1 ppm (Table 4) and was 3 times higher than background levels found in Alaska (Evers et al. 1998) (Figure 2). Blood was generally taken from adults with established breeding territories (> 95%). Adult blood Hg levels determined in this study reflect the greatest MeHg availability from the nesting lake and are therefore important indicators for maximum potential risk on a lake. All Maine lakes have elevated levels of MeHg, however several lakes are inhabited by adult loons with Hg body burdens approaching effect levels (e.g., Aziscohos and Flagstaff Reservoirs).

Table 4. Total mercury concentrations in adult blood of piscivorous birds in Maine, 1994-97

	Mean Blood Hg (µg/g)										
	Female				Male				Combined		
Location	Hg	SD	n	range	Hg	SD	n	range	Hg	SD	n
Common Loon	**2.12**	**1.47**	**64**	**0.42 - 4.42**	**2.50**	**1.12**	**67**	**0.60 -6.02**	**2.13**	**1.13**	**131**
Osprey	**1.54**	-	**1**	-	-	-	-	-	**1.54**	-	-
Belted Kingfisher	**1.50**	**1.65**	**2**	**0.33 - 2.66**	**1.72**	**1.00**	**4**	**0.705 - 2.73**	**1.48**	**1.07**	**6**
Common Merganser	**1.33**	**0.85**	**2**	**0.74 - 1.94**	-	-	-	-	**1.33**	**0.85**	**2**

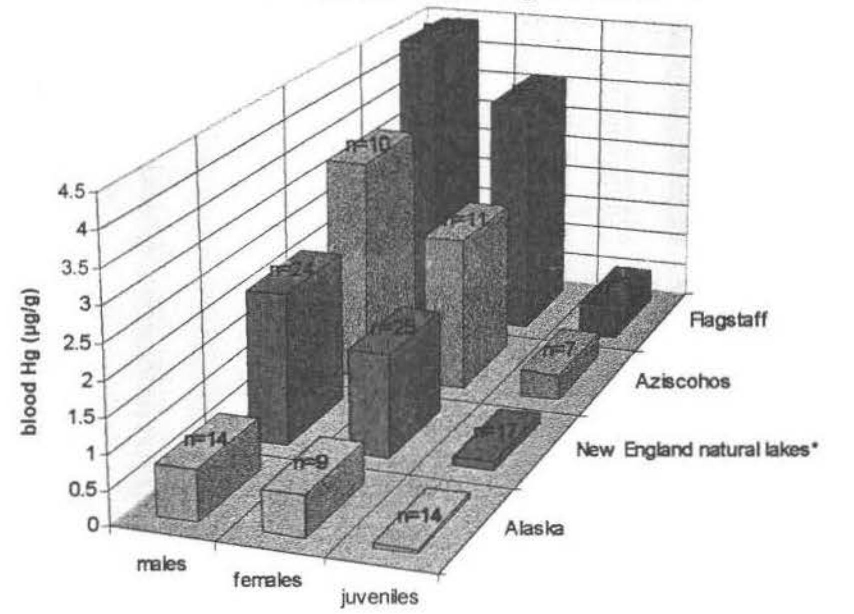
Table 5. Total mercury concentrations in feathers of adult piscivorous birds in Maine, 1994-97

	Mean Feather Hg (µg/g)*										
	Female				Male				Combined		
Location	Hg	SD	n	range	Hg	SD	n	range	Hg	SD	n
Common Merganser	**17.4**	**0.42**	**2**	**17.1 - 17.7**	-	-	-	-	**17.4**	**0.42**	**2**
Common Loon	**12.7**	**5.4**	**64**	**3.85 - 29.4**	**17.1**	**7.3**	**66**	**5.51 - 41.6**	**15.0**	**6.8**	**130**
Belted Kingfisher	**11.7**	**6.1**	**3**	**1.8 - 27.1**	**6.2**	**8.4**	**5**	**0.6 - 20.8**	**8.3**	**10.0**	**8**
Osprey†	**0.05**	-	**1**	-	-	-	-	-	**0.05**	-	-

*** Measured in a composite of 2 second secondaries from each individual except for osprey where 3 breast feathers were sampled**

† Limited sample quantity may have affected detection limits

Figure 2. Mercury concentrations measured in Common Loon blood from selected sites in New England and Alaska



* includes lakes with small check dams that flucutate minimally

The mean feather Hg level for adult Common Loons was 15.0 +/- 6.8 ppm (Table 5). The flight feathers we sampled develop between January and March. They therefore reflect the blood Hg concentrations during feather growth. However, synchronous flight feather molt is a stressful physiological event for loons and individuals with elevated Hg body burdens are likely to remobilize MeHg bound in muscle protein, especially in the highly vascularized dark muscle that is characteristic of this species. Evers et al. (1998) found no correlation in blood-feather Hg concentrations for loons in areas with relatively low environmental Hg levels ($p>0.05$) while in breeding loons with elevated Hg body burdens their blood-feather Hg concentrations were significantly correlated ($r^2=0.24$, $p<0.001$). This indicates a contribution of the MeHg from the breeding season during feather formation. Recaptured adult loons also exhibit up to a 10% annual increase of Hg in their feathers. Therefore, feathers are good indicators of chronic exposure of Maine's breeding loon population.

Mercury levels in loon blood and feathers were significantly different between sexes in a national study (Evers et al. 1998) and this study ($p<0.001$) (Table 5). Mean blood and feather Hg levels in males were, respectively, 43% and 36% higher than females. Males are more exposed because they tend to eat larger fish (Barr 1986 and 1996, Evers and Reaman 1997) and females are able to depurate Hg through eggs.

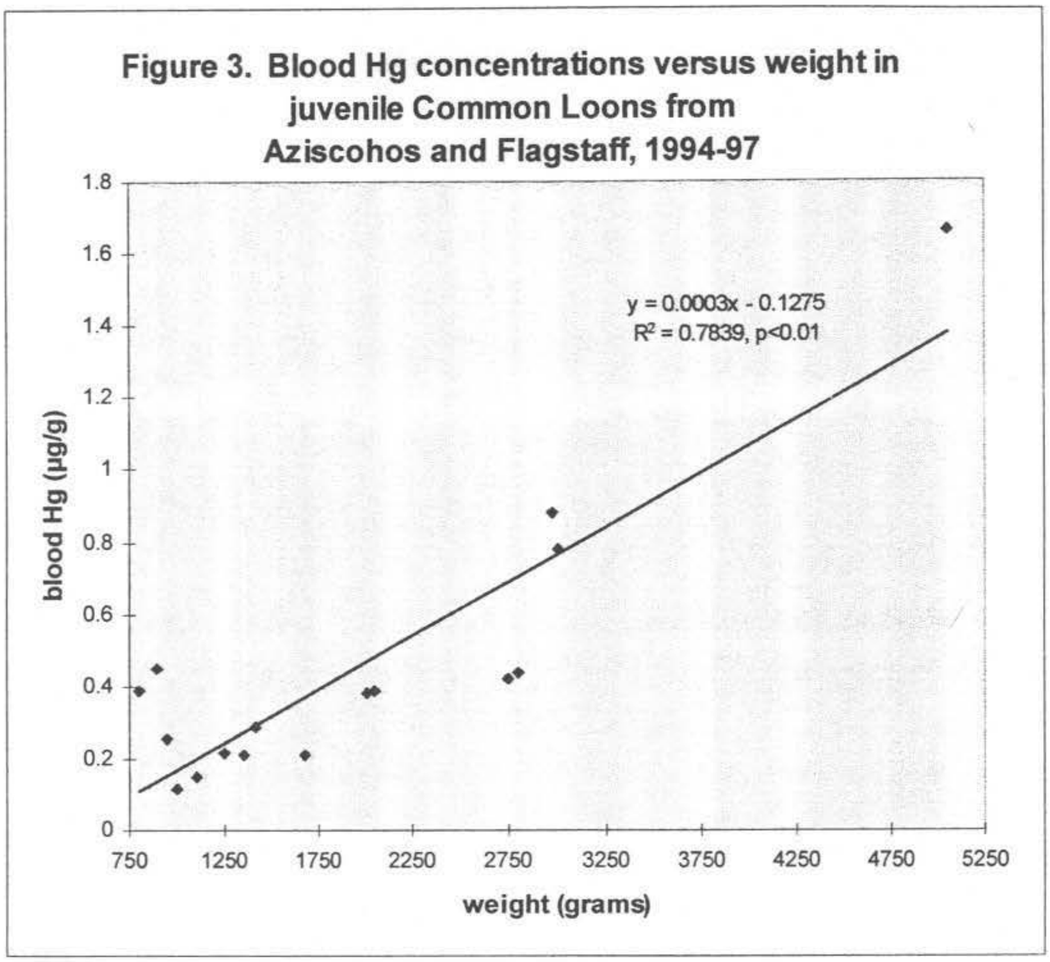
Juvenile blood and feather Hg concentrations represent MeHg availability on the natal lake. We sampled juveniles of 3 to 11.5 weeks of age and found a mean blood Hg level of 0.22 +/- 0.29 ppm and a mean feather Hg level of 6.4 +/- 5.8 ppm (Table 6). Juvenile Hg concentrations increased with age due to increasing prey size and Hg levels (Evers and Reaman 1997).

Table 6. Total mercury concentrations in juvenile piscivorous birds from selected sites in Maine, 1994-97

Location	Mean Blood Hg Concentration (ug/g, ww)				Mean Feather Hg Concentration (ug/g, fw)‡			
	Hg	SD	n	Range	Hg	SD	n	Range
Common Merganser	**0.50**	**0.49**	**16**	**0.06 - 1.65**	**9.5**	**7.8**	**13**	**3.53 - 31.4**
Common Loon	**0.22**	**0.29**	**52**	**0.01 - 1.66**	**6.4**	**5.8**	**9**	**0.3 - 19.0**
Osprey	**0.16**	**0.10**	**8**	**0.01 - 0.31**	**0.5**	**0.8**	**7**	**0.05 - 1.9**
Interior Lakes	*0.21*	*0.06*	*6*	*0.02 - 0.31*	*0.6*	*0.9*	*5*	*0.05 - 1.9*
Marine	*0.03*	*0.03*	*2*	*0.01 - 0.05*	*0.1*	*0*	*2*	-
Bald Eagle†								
Interior Lakes	*0.580*	*0.325*	*25*	*0.094 - 1.530*	*20.7*	*7.8*	*29*	*8.0 - 36.7*
Marine	*0.094*		*25*	*0.027 - 0.459*	*4.1*		*24*	*1.8 - 12.3*

† Data provided by L. Welch and A. Matz; Marine and interior lake feather concentrations are from 1992, interior lake blood is from 1991-96.
‡ Feathers sampled: Common Loon - 2 second secondaries, Common Merganser - 3 tail feathers; Osprey - 3 breast feathers; Bald Eagle - 2-3 breast feathers

However, a significant increase in blood and feather Hg levels during the loon's first 12 weeks was most apparent on lakes with small fish (5-25 g) that have Hg levels greater than 0.40 ppm (r^2=0.78, $p<0.05$) (Figure 3). Therefore, juvenile loons from highly contaminated lakes are more likely to accumulate Hg and need to have their blood Hg levels adjusted by their weight (which correlates with age) to provide a standard index of Hg exposure. Young loons depurate their Hg body burdens in three distinct feather molts and can depurate Hg through their initial 12 weeks of life as long as Hg input is less than feather output. Juvenile loons from lakes with lower prey Hg levels (e.g., <0.30 ppm) had a significant accumulation of Hg over time ($p<0.001$), but it was less related to weight (r^2=0.37) and also exhibited a slower accumulation rate (Figure 4). Three of the 15 lakes sampled for juvenile loons had elevated MeHg levels that cause a significant accumulation over a 12 week period (i.e., Aziscohos, Flagstaff, and Little Lobster lakes) (Figure 5).

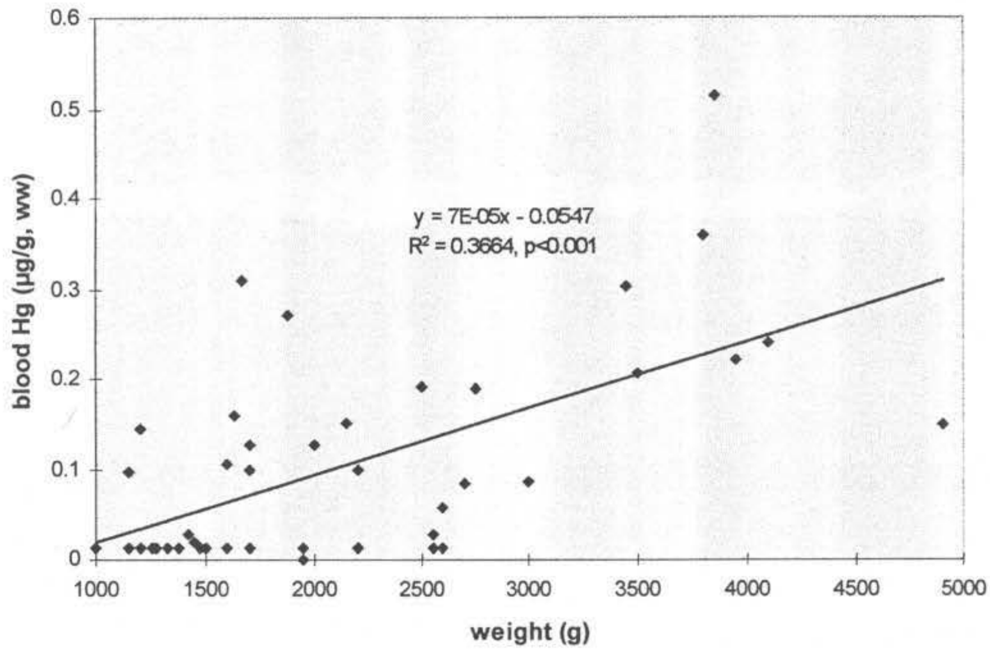


Common Merganser:

This species overwinters in rivers, estuaries, and the ocean. Adults return to their breeding areas soon after ice-off on major rivers and are present on their breeding lakes during partial ice-off. Male adult mergansers only occupy the breeding lake during mating. No brood care is provided by the males and they are not present on breeding lakes with merganser broods. Nests are initiated between late April and late May. Usually 9-12 eggs are in a clutch and sometimes two or more females will lay eggs in the same tree hollow (Bellrose 1976). Nest trees are usually close to water but may be as distant as 70 meters (White 1957). Merganser broods may be brought to a lake via streams and rivers. Young may form cresches, where one female cares for several broods. We found this evident on Lake Umbagog in 1994 (around 60 unfledged young) and in 1997 (around 40 unfledged young each on Lake Umbagog and Indian Lake). Merganser young are full grown (over 1,000 grams) and are able to fly at 9-10 weeks of age.

Adult mergansers target 6-12 cm fish and consume around 250g per day (Bellrose 1976). Their calculated daily ingestion of MeHg ranged from 57 ug per kg of body weight on Indian Lake (small fish Hg was 0.25 ppm) to 102 ug per kg of body weight on Flagstaff Lake (small perch Hg was 0.45 ppm). Mean Common Merganser exposure to MeHg in Maine is estimated at 68 ug MeHg per kg of body

Figure 4. Blood Hg concentration versus weight in juvenile Common Loons from natural lakes and reservoirs in New England, 1994-97

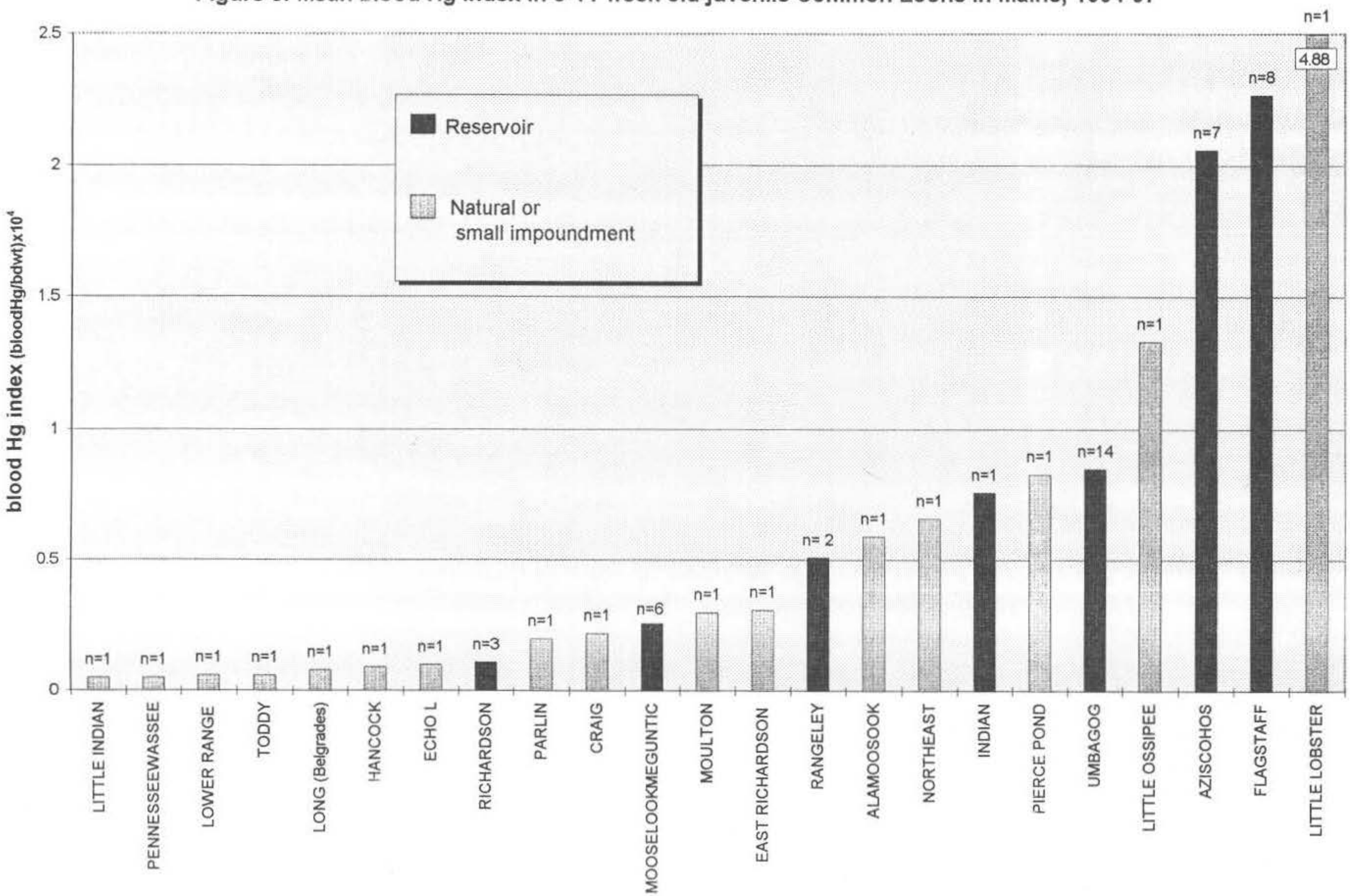


weight per day (Table 7).

Adult female blood, juvenile blood, and juvenile feathers are the best measures for MeHg availability in a lake. Adult female blood Hg concentrations were higher than those of young mergansers (Table 4 and 6). For example, the Indian Lake female had a blood Hg level of 0.74 ppm and young from her brood and nearby broods of similar age had a mean blood Hg level of 0.12 +/- 0.03 (n=7). The adult female and her offspring from Flagstaff Lake were respectively 2 and 6.5 times higher than their counterparts on Indian Lake. Relatively full grown young (>1,000 grams) had Hg levels ranging from 0.254 to 1.08 ppm: the highest concentrations were from Flagstaff and Parmachenee Lakes.

Juvenile blood and feather (tail and flight) Hg concentrations were marginally significantly correlated (r^2=0.26, $p<0.08$). Like loons, juvenile mergansers regularly depurated a large portion of their MeHg body burden into their flight feathers. Juvenile mergansers had feather Hg concentrations between 3.5 to 31.4 ppm (Table 6). Parmachenee and Flagstaff full-grown juveniles had similar blood Hg levels, but their flight feather Hg levels were 18.4 ppm and 31.4 ppm, respectively. This indicates that the young merganser on Flagstaff heavily depended on its feather molt to depurate high levels of MeHg input. The two adult females had 17 ppm in their flight feathers. These feathers are grown in during late summer and could either represent the breeding lake or a communal feeding lake depending on the merganser's reproductive status during the previous summer.

Figure 5. Mean blood Hg index in 3-11 week old juvenile Common Loons in Maine, 1994-97



Belted Kingfisher:

Male kingfishers remain on their territory year-round when open water is present. On most interior Maine lakes, adult kingfishers return soon after ice-off. Kingfisher breeding territories are typically around 1 km in radius (D. Albano, pers. com.) although the juxtaposition of high quality feeding areas determines ultimate territory size (Davis 1982). Even though prey items are generally 14 cm or less and average 6-12 cm in an adult diet (Davis 1982), ingestion of MeHg is extremely high. U.S. EPA (1996) estimated this species had a MeHg ingestion rate 2-3 times higher than other target piscivores (i.e., eagles, osprey, otter, and mink). The known amount of MeHg exposure from fish ingested in Maine lakes varied from 19 ug (or 125 ug per kg of body weight) in Parlin Pond (small fish Hg was 0.25 ppm) to 34 ug (or 225 ug per kg of body weight) in Flagstaff Lake (small fish Hg was 0.45 ppm). Belted Kingfisher mean daily exposure to MeHg in Maine is estimated at 160 ug MeHg per kg of body weight (Table 7).

Adult and juvenile kingfisher blood and feather Hg levels indicate potential MeHg availability from more than one waterbody unless samples are collected from individuals occupying large lakes (e.g., Flagstaff). We captured kingfishers from burrows in gravel pits or other areas excavated by humans (n=4) and along eroded shorelines of Flagstaff (n=3) and Chesuncook (n=1) lakes. We designated foraging lakes for each kingfisher captured at a gravel pit burrow. The kingfisher from Mt. Desert Island is an indication of collective MeHg availability on Jordan and Bubble Pond, while the one captured in the Upper Androscoggin represented prey Hg levels from East Richardson, West Richardson and Pepperpot Ponds. Blood Hg levels were equal or less than 1.0 ppm in all kingfishers (n=4) except those captured on Flagstaff Lake. The blood Hg levels in 3 Flagstaff kingfishers ranged from 2.41 to 2.73 ppm (mean=2.6 ppm) and was significantly higher than kingfisher blood Hg concentrations representing 9 lakes (mean=0.65 ppm) ($p<0.05$).

Flight feathers are molted asynchronously in spring but may represent MeHg availability in the breeding lakes ($r^2=0.69$, $p=0.02$). Flagstaff Lake individuals had higher feather Hg levels than kingfishers from other lakes. Two of the Flagstaff Lake kingfishers had feather Hg concentrations over 20 ppm (our risk threshold level) and were 6.5 times higher than a breeding male from the Connecticut River, Massachusetts and were higher than adult kingfishers from Tennessee (Baron et al. 1997).

Osprey:

This species overwinters in warm marine environs from Florida south into South America and returns in early April on the Maine coast and by late April to northern interior territories. Adults are site-faithful to their breeding areas and while there maintain habitual foraging areas (Poole 1989). Usually 3-5 eggs are laid 1-2 days apart. Late eggs are smaller than first laid eggs. Incubation is by both sexes although the female generally incubates longer. Males frequently feed the female during the incubation and brood rearing period. MeHg input for the larger female may be less than expected during the breeding season since the smaller male is catching her prey. In Massachusetts a mean of 2.35 young hatched and 1.92 young fledged per nest (Poole 1984). Young fledge at 7-8 weeks and continue to be fed by their parents for another 1-3 weeks (Poole 1989).

The osprey diet is primarily fish. Fish weighing 150-300 grams with a length of 25-35 cm are preferred (Poole 1989). During the breeding season, male osprey spend one-third of their day hunting for the 6-8 fish needed to meet the energy requirements of his mate and young. A breeding male requires approximately 400g of fish per day. Most hunting forays are in shallow habitats and tend to focus on slow moving benthic feeding fish such as longnose sucker (*Catostomus catostomus*) versus quicker, piscivorous species such as northern pike (*Esox lucius*) and salmonid species (Swenson 1979). Although U.S. EPA models indicate osprey MeHg uptake is around 16 ug MeHg per kg of body weight per day, Maine osprey appear to have a greater uptake.

One adult osprey was captured in 1997. Her blood Hg level was a relatively low 1.54 ppm (Table 4) and may reflect a potentially low Hg diet due to a tendency to concentrate on suckers and other slow-moving nonpiscivorous fish. Evers and Reaman (1997) found large sized suckers (75-200g) with Hg levels significantly lower than associated piscivorous species. Mean juvenile blood Hg levels were 7 times higher on inland lakes (mean=0.21, n=6) versus a marine nest on Casco Bay (mean=0.03, n=3) (Table 6). Sibling blood Hg levels varied but correlated with size. Flight feathers were not gathered from adults. Flight feathers molt gradually in winter (asynchronous) indicating a required flight efficiency during migration and the breeding season. Breast feathers were sampled from the adult and juvenile osprey and their Hg levels were generally less than the back feathers (similar feather mass) of same-age, juvenile loons. The two eggs, one from Bog Brook Flowage (0.14 ppm) and one from Casco Bay (<0.02) were well below the 0.5 ppm risk threshold and again indicate that interior osprey are exposed to higher Hg levels than osprey foraging in marine habitats.

Bald Eagle:

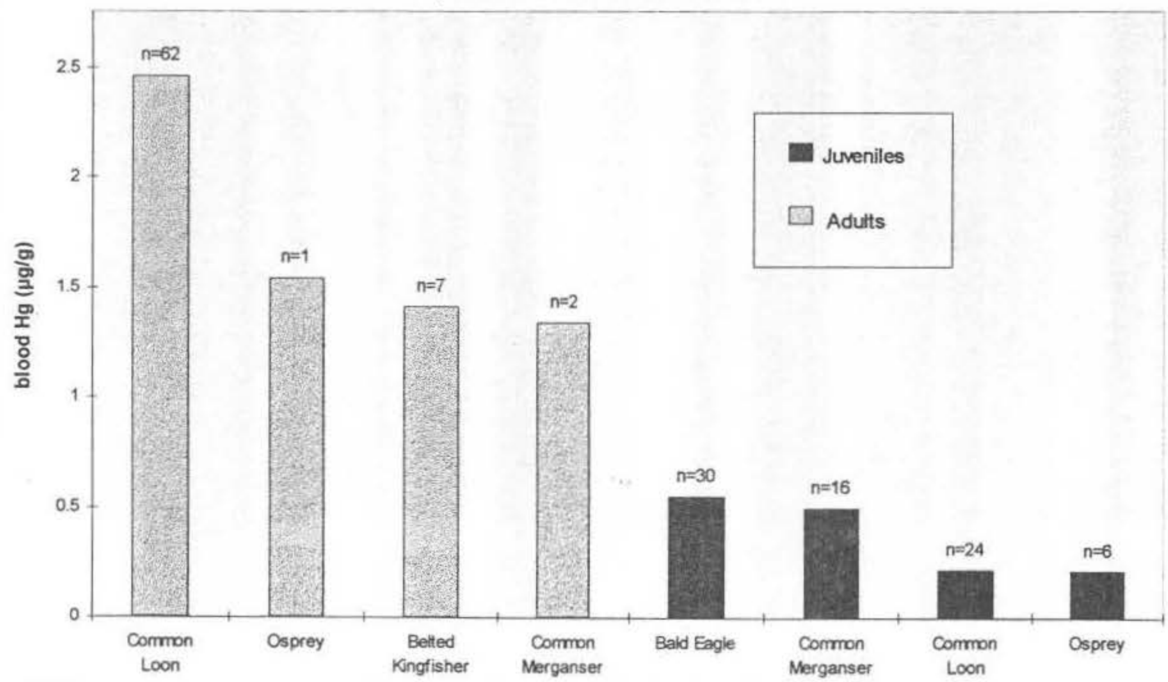
Eagles exhibit high fidelity to their nesting area. Territories generally encompasses several waterbodies except for some of Maine's largest lakes and reservoirs. Therefore, eagle egg, adult blood, and juvenile blood and feathers do not necessarily represent a specific waterbody. Eagle diets are the least piscivorous of the five target species. In Maine, fish comprised only 66% of the diet for eagles foraging on rivers and lakes, 18% in marine, and 28% in estuary environs (Welch 1994). Birds and mammals comprised the remainder of prey items. Eagles prefer to feed on bottom-dwelling fish such as suckers and bullhead (*Ictalurus* spp.). Although, eagles were more likely to catch higher trophic level species such as birds, particularly gulls, in marine areas, their Hg levels were lower than eagles foraging on interior lake and river territories that depended on fish prey items.

Maine's bald eagle breeding population dynamics and their body burden of contaminants are well documented. Welch (1994) collected egg, feather, and blood samples in 1991 and 1992 while Matz (pers. comm.) collected samples from 1993-96. Mercury levels in Maine's bald eagles are the highest recorded in North America (Land and Water Resources Council 1998). Mean juvenile blood Hg levels for the period 1991-96 were 0.58 +/- 0.33 ppm in lake habitats and 0.09 +/- 0.03 ppm in marine habitats (Table 6). Juvenile blood Hg levels are over 6 times higher from nests where adults foraged on lakes than those on marine environs. Juvenile breast feather Hg levels are significantly correlated with blood Hg levels (r^2=0.67, $p<0.001$) (Welch 1994) and are therefore good indicators for assessing breeding lake risk. Mean breast feather Hg concentrations for eagle nests on Maine's interior lakes is 20.7 +/- 7.8 ppm and is 5 times higher than coastal nests (Table 6). Nearly half (48%) of the eagle feathers exceeded our designated threshold level of 20 ppm indicating a large component of Maine's interior eagle breeding population is at risk.

Interspecies Relationships

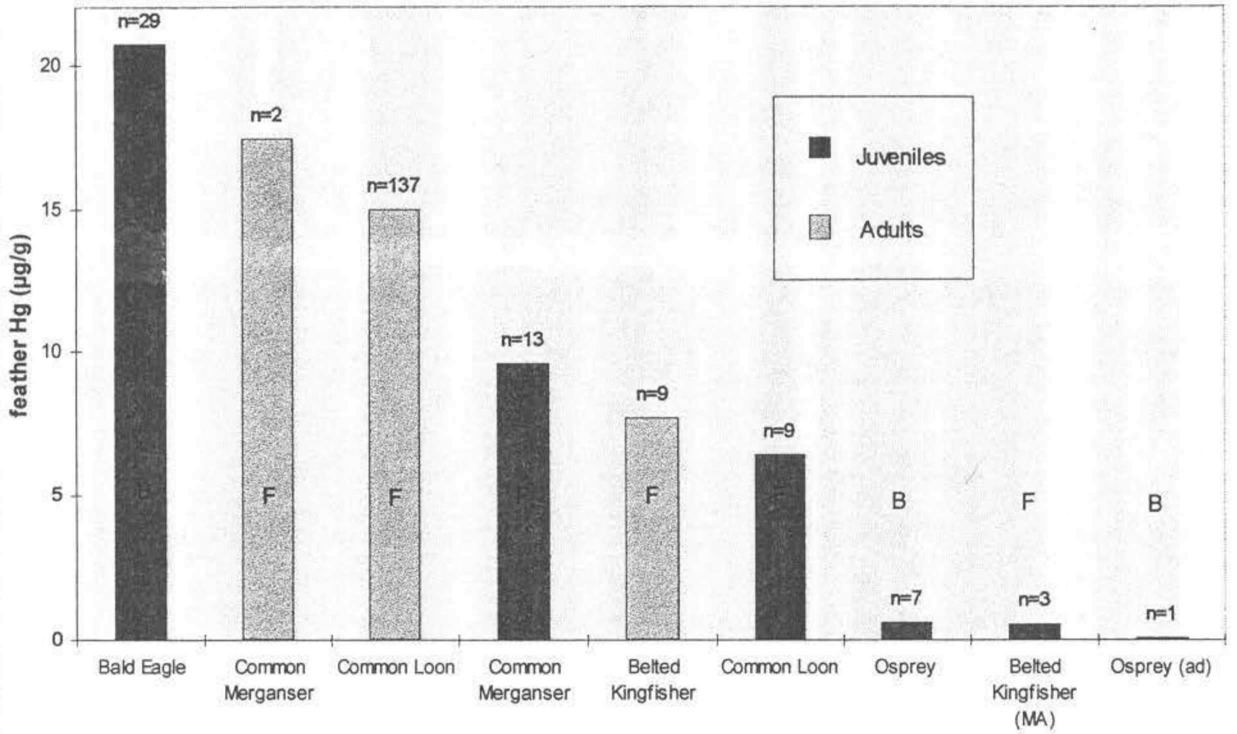
The Hg concentrations and sample size of blood, feathers, and eggs greatly varied by species. Adult blood Hg levels were higher than juvenile levels (Table 4 & 6, Figure 6). The mean blood Hg levels in adults were highest in loons and were significantly higher than osprey, kingfishers ($p=0.03$), and mergansers ($p=0.02$) (Table 4, Figure 6). The mean blood Hg levels for juvenile eagles and mergansers was similar ($p>0.05$) but significantly higher than loons and osprey ($p=0.02$) (Table 6). Feathers were collected from the wing and body depending on species, although the relationship of MeHg deposition between the two feather tracts was unknown. Juvenile eagle breast feathers were significantly higher than osprey ($p<0.05$) (Table 6, Figure 7) and were higher than adult loon and merganser flight feathers. Flight feather mean Hg concentra:.ons did not differ between adult loons and mergansers but loons were significantly higher than adult kingfishers and juvenile loons and mergansers with full-grown flight feathers ($p<0.01$) (Table 5, Figure 7).

Figure 6. Mean blood Hg concentrations measured in selected piscivores from Maine in 1997#



Eagle samples were collected by L. Welch and A. Matz from 1991-96. Note: all birds sampled inhabited freshwater ecosystems

Figure 7. Mean feather Hg concentrations measured in selected piscivores from Maine*, 1994-97 (F=Flight feather - second secondary, B=Breast Feathers)



The U.S. EPA determined exposure of 5 piscivores to MeHg by using certain documented national standards and average energy needs (USEPA 1996). Ingestion rates were calculated by multiplying consumption rates (grams/day) of prey and their mean MeHg levels by trophic level and then dividing the average weight of the species. Mean small fish Hg concentrations for lakes in Maine typically exceed the 0.08 ppm fish Hg levels used by the U.S. EPA model by 5-15 fold (Evers and Reaman 1997). For example, in Maine the kingfisher consumes 75 g of fish per day. By multiplying this rate with trophic level 3 fish that have mean Hg concentrations of 0.30 ppm (determined for several Maine lakes by Evers and Reaman 1997) and then dividing the average weight of an adult kingfisher yields an average daily exposure of approximately 150 ug MeHg per kg of body weight per day. According to these calculations, kingfishers tend to be the most exposed piscivorous bird in Maine and nationally. We found this model to indeed reflect MeHg exposure for kingfishers on Flagstaff Lake. Adult kingfishers, 4-6 week old common loon juveniles, and 4-8 week old common merganser juveniles all feed on similar sized fish (6-12 cm or 5-25g), however mean blood Hg levels in adult kingfishers were significantly higher in loons and mergansers ($p<0.001$) feeding from the same areas of the lake.

Table 7. Calculated rate of MeHg exposure for five piscivorous birds.

Species	*Body Weight(g)*	*Ingestion Rate (g/day)*	*Trophic Level*	*% fish diet by trophic Level*	*ME MeHg Exposure[a,b]*	*U.S. MeHg Exposure[c]*
Loon	5,400	1100	3,4	78,22%	65[d]	31
Merganser	1,100	250	3	100%	68	18
Kingfisher	150	75	3	100%	150	40
Osprey	1,500	300	3	100%	60	16
Eagle	4,600	500	3,4	74,18%	32	14

[a] Units are ug MeHg per kg of body weight per day.

[b] Based on fish Hg levels in Maine lakes (Evers and Reaman 1997). See text for specific differences between national and Maine calculations.

[c] Based on national fish Hg levels (USEPA 1996). Trophic level 3 fish are 0.08 ppm and level 4 fish are 0.40 ppm.

[d] Based on national mean body weights with adjusted ingestion rates. For the common loon, males are 4,700g and females are 3,800g.

Our most comprehensive database is for the Common Loon. This provides us with a more detailed analysis of MeHg uptake. Loons require a food consumption rate of 20% of their body weight per day (Barr 1973). The mean weight of Maine males is 6,050g (n=78) and of females is 4,700g. Since males average 30% larger than females, we separated exposure rates by sex. This dimorphism also created differences in prey choice. Evers and Reaman (1997) showed the strongest correlations are between loons and yellow perch which agreed with Barr's (1996) findings during hand-feeding experiments. We found the strongest correlation between loon blood Hg levels and medium-sized (20-35g) yellow perch (r^2=0.84 for males and r^2=0.79 for females). There was also a tendency for females to select smaller perch than males. The average adult-sized loon from Barr's study ate 45 fish or 960g which were divided into the following size categories: 432g (45%) of small, 365g (38%) of medium, and 163g (17%) of large. As adults, these loons would weigh an average of 4,800g. Because Maine male loons average a larger body mass, the size class distribution was adjusted to reflect this difference. Therefore the calculated distribution of prey size classes for males is: 33% small, 40% medium, and 27% large. Evers and Reaman (1997) reported mean Hg concentrations for yellow perch representing 5 northern Maine lakes as 0.30 ppm for small- and medium-sized perch and 0.39 ppm for large perch.

Our calculated daily exposure rate for the Common Loon in Maine is 69 and 63 ug MeHg per kg of body weight for males and females, respectively (Table 8). Maine loons are 4.3 (male) and 3.5 (female) times more exposed than the national average and are generally more exposed than other species. This agrees with Evers et al. (1998) study that shows significantly higher adult and juvenile blood Hg levels in the Northeast compared to the Upper Great Lakes, Pacific Northwest, and Alaska.

Table 8. Calculated MeHg exposure rate for the Common Loon (µg/kg).

Sex	Body Weight(g)	Ingestion Rate (g/day)	Size Class[a]	% fish diet by size class	Maine MeHg Exposure[b]	National MeHg Exposure[b,c]
Male	6,050	1300	1,2,3	33, 40, 27%	69	16
Female	4,700	950	1,2,3	45, 38, 17%	63	18

[a] Size classes for yellow perch are: 1 is small (5-20g), 2 is medium (20-35g), and 3 is large (35-60g)

[b] Units are µg MeHg per kg of body weight per day.

[c] Based on national fish Hg levels (USEPA 1996). Trophic level 3 fish are 0.08 µg/g and level 4 fish are 0.40 µg/g .

Geographic Comparisons

Because there was a limited number of lakes sampled we were only able to perform species-specific geographic comparisons of MeHg exposure in loons (Table 2). Regional differences in mean Hg concentrations are best interpreted from blood and egg Hg concentrations. Feather and blood Hg levels indicated similar distributions among regions (Figure 8 & 9).

Figure 8. Mean blood Hg concentrations in adult Common Loons from selected regions in Maine

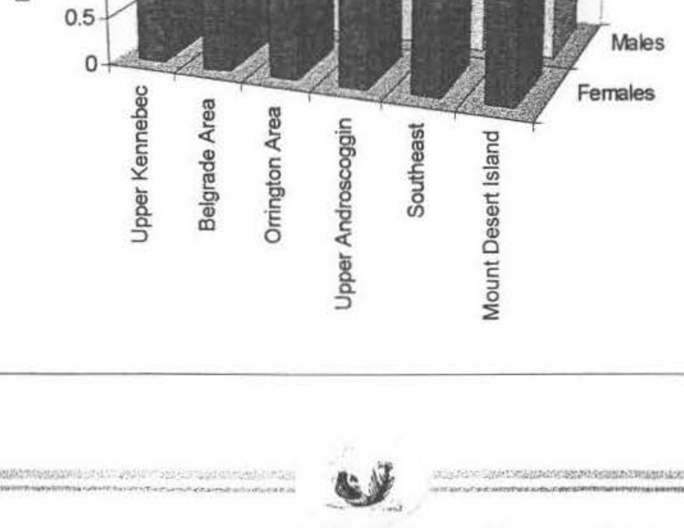
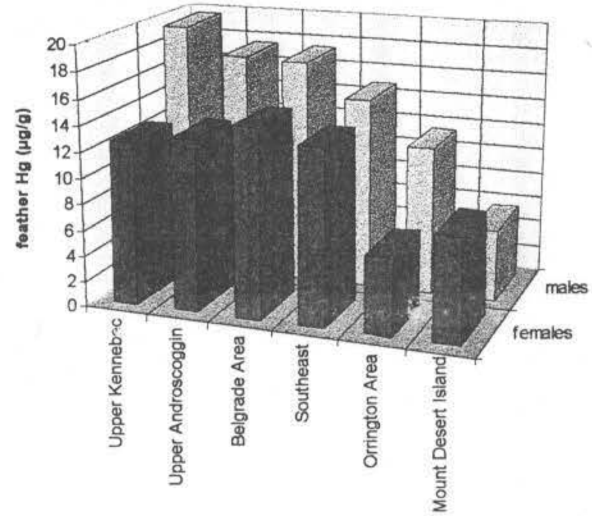


Figure 9. Mean feather Hg concentrations in adult Common Loons from selected regions in Maine



Adult blood Hg levels in loons attained moderate (i.e., 2.00-3.00 ppm) and high levels (i.e., >3.00 ppm) in 5 of the 7 study areas (Figure 10 & 11). Blood Hg levels remained below 2.00 ppm in all 6 lakes from Southeast Maine and Mt. Desert Island. Juvenile blood Hg levels in loons and mergansers slightly confound adult Hg distribution. Their levels were moderate (i.e., > 0.30) to high (i.e., > 0.50) in 4 of the 7 study areas and were < 0.30 in the Belgrade Lakes, Orrington, and Mt. Desert Island areas (Figure 12). Mercury levels in loon eggs were elevated (> 0.50 ppm) in the 6 study areas sampled but did not exhibit geographic patterns (Figure 13). Young, 6-8 week old eagles indicated high environmental Hg levels across much of northern Maine (Figure 14 & 15). Coastal areas generally had lower levels, however some eagles with high Hg levels were found in these areas and conversely some low blood and breast feather Hg levels were found in eagles at interior sites.

We placed adult blood, juvenile blood and feather, and egg Hg levels for loons in three categories. These categories represent low, medium, and high Hg levels for each matrix. The highest score measured in any one of the matrices is used as the index of the lake's maximum capacity for MeHg availability. Medium to high levels were recorded in all study areas. The proportion of lakes in each region that are medium or high risk is: Upper Androscoggin (50%), Upper Kennebec (55%), upper Penobscot (100%), Orrington area (50%), Mt. Desert Island (0%), Belgrade Lakes Region (75%), and Southeast Maine (43%). Of the 50 lakes sampled for loon tissues, 50% had exposure to Hg at levels that potentially place individuals or eggs at risk (Figure 16). We also mapped blood, feather, and egg Hg levels from all target species and found 70% of the 92 lakes sampled indicated environmental Hg levels that place individuals at risk (Figure 17).

Figure 13

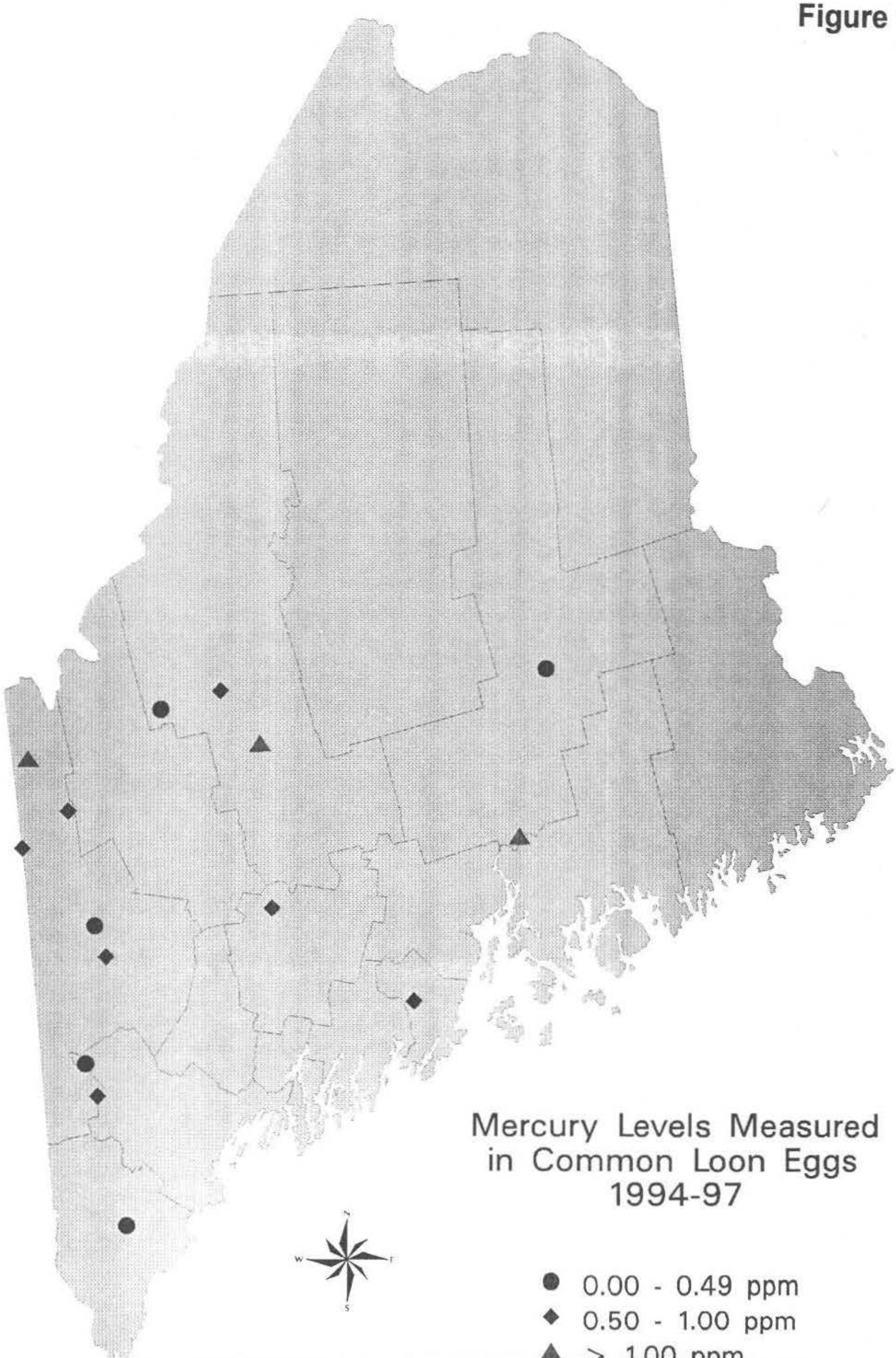
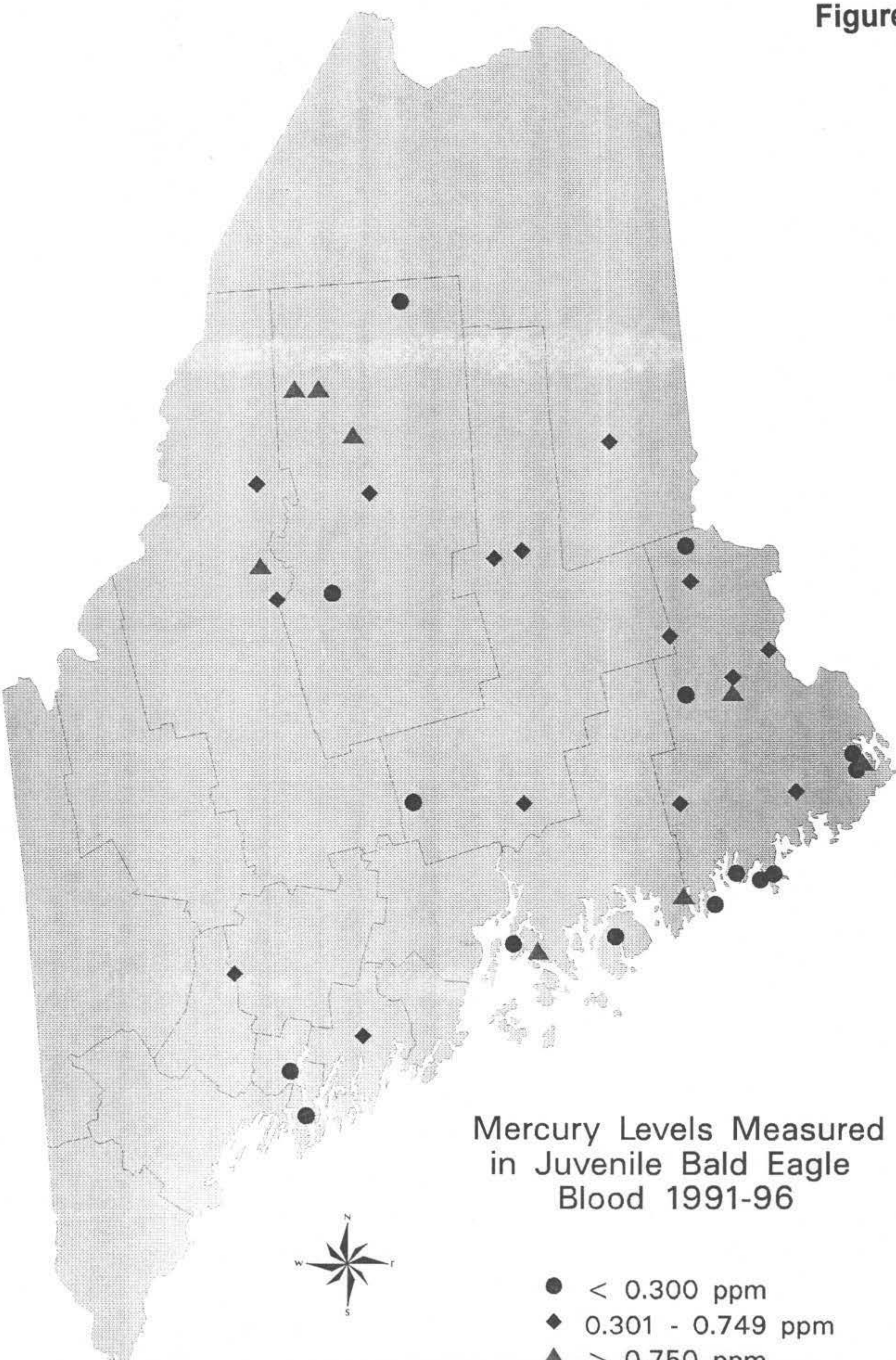
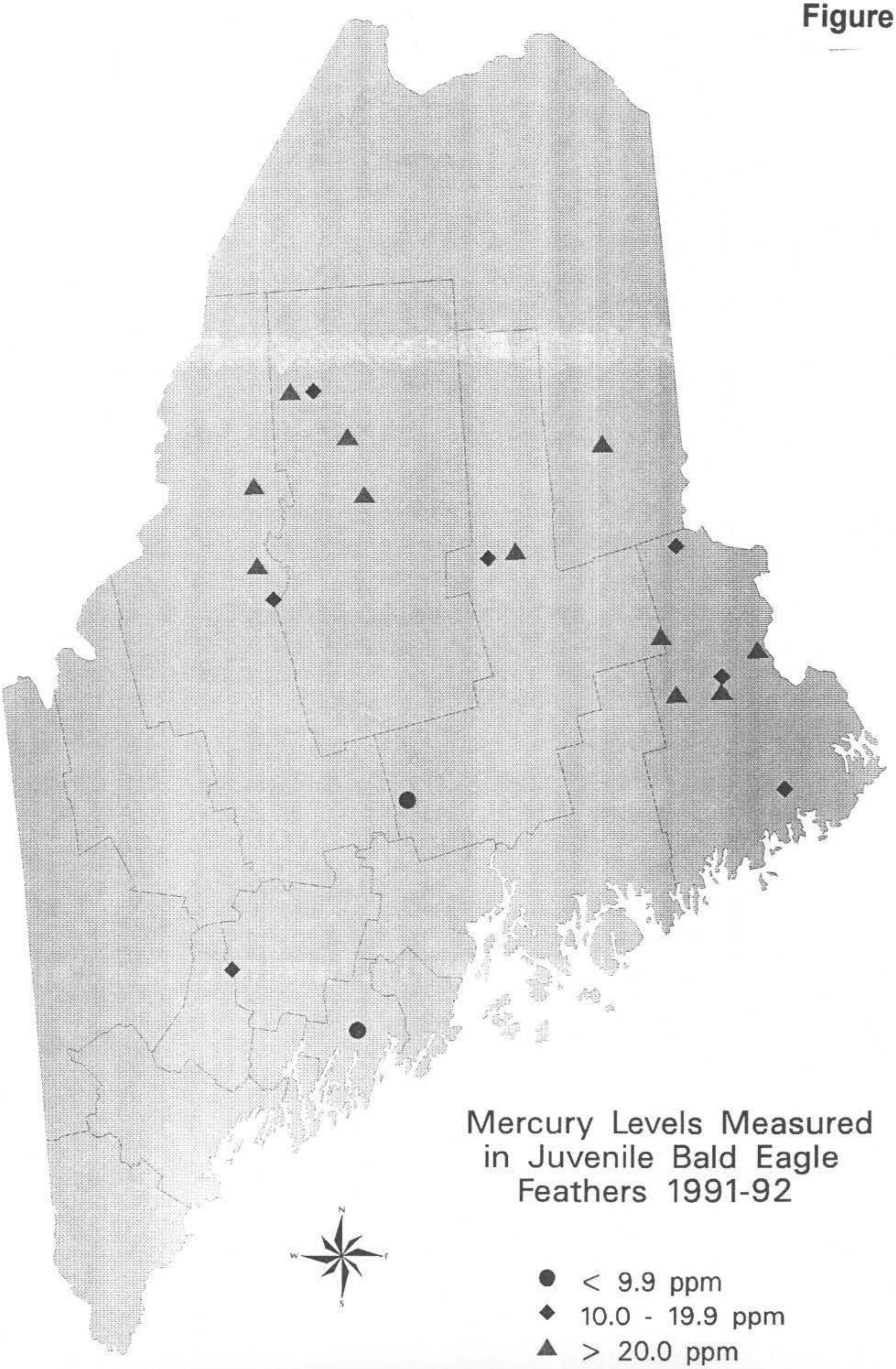

Mercury Levels Measured
in Common Loon Eggs
1994-97
N
W
E
S
0.00 - 0.49 ppm
0.50 - 1.00 ppm
> 1.00 ppm

Figure 14



Data provided by A. Matz and L. Welch.

Figure 15



Data provided by L. Welch.

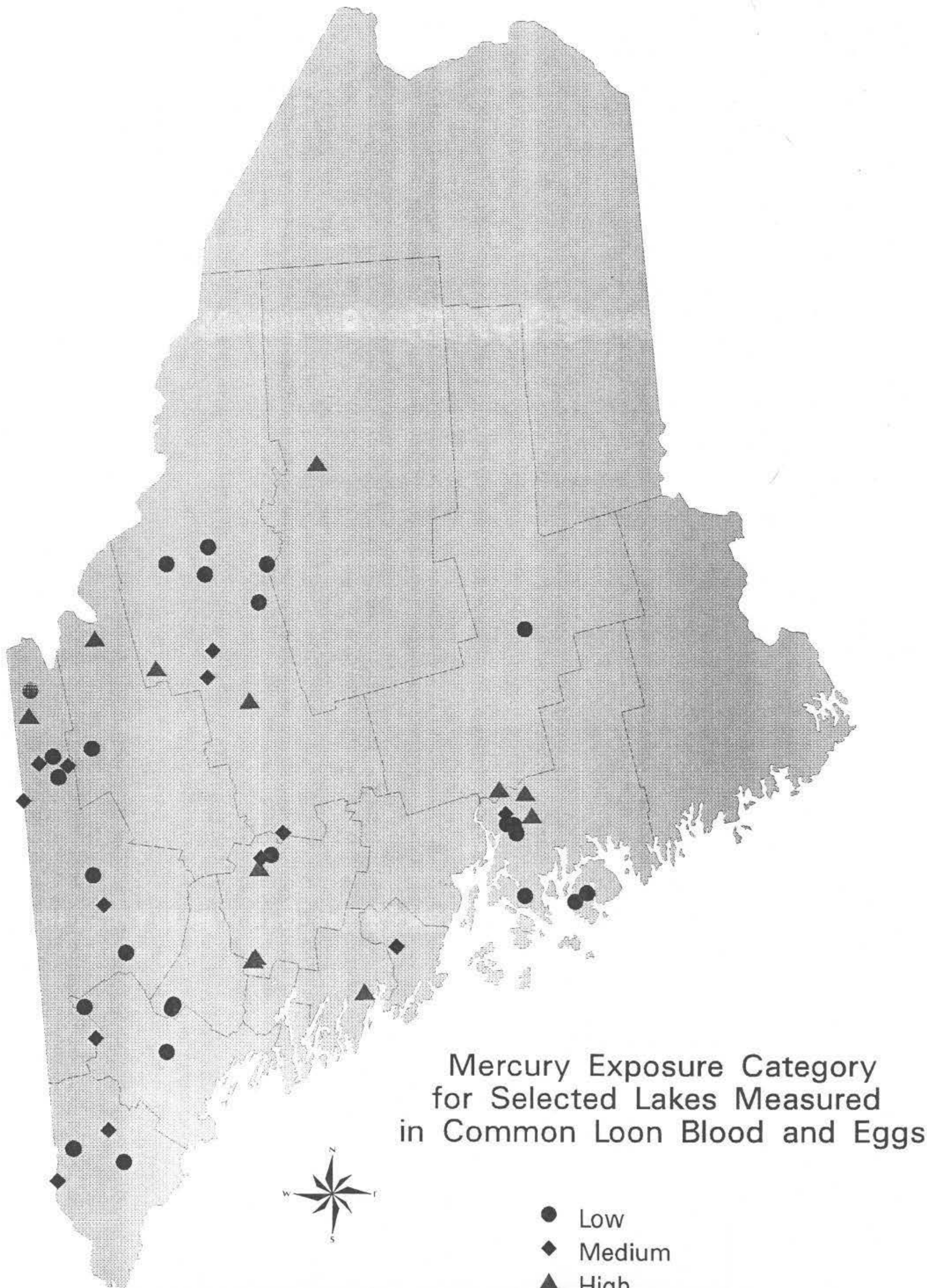
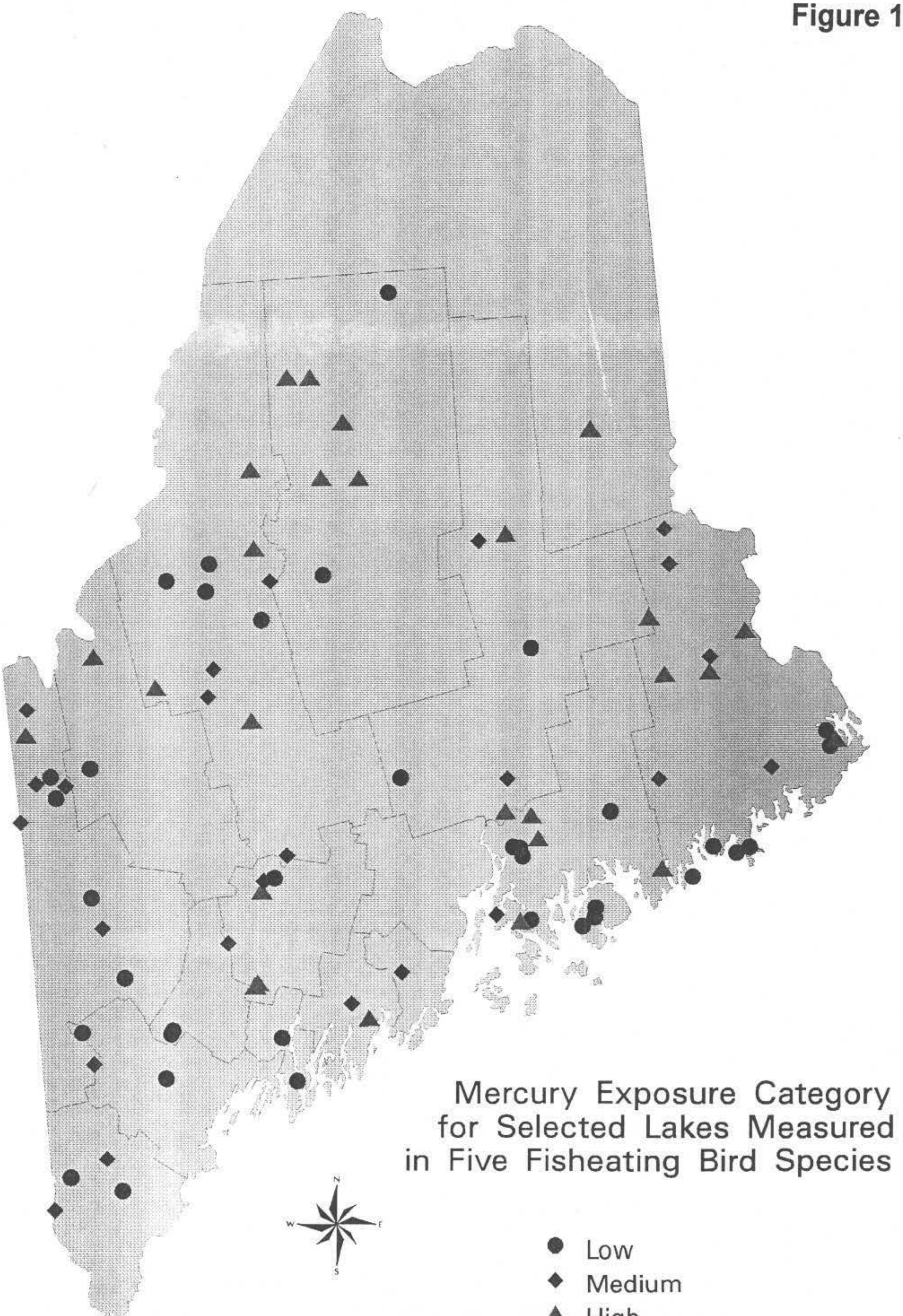

Mercury Exposure Category
for Selected Lakes Measured
in Common Loon Blood and Eggs
N
W
E
S
Low
Medium
High

Figure 17



Mercury Exposure Category
for Selected Lakes Measured
in Five Fisheating Bird Species
N
W
E
S
Low
Medium
High

Morphometric and Water Quality Patterns related to MeHg availability

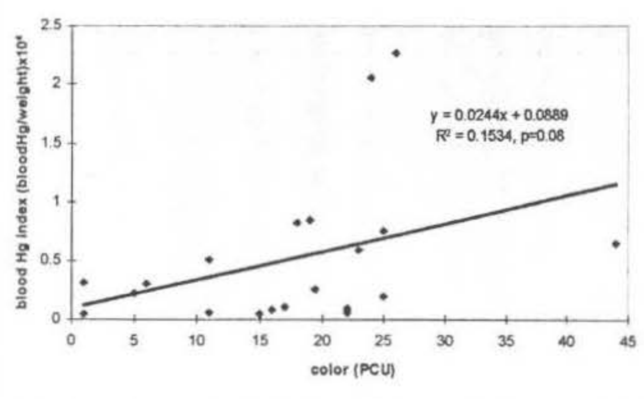
We selected pH, alkalinity, and color as predictors of Hg in the lake based on numerous studies that have demonstrated that fish from low pH, low alkalinity lakes have elevated Hg levels in their tissues (Wiener 1987, Cope, et al. 1990, Winfrey and Rudd 1990, Wiener and Spry 1996). Meyer et al. (1995) found that mean blood Hg concentrations in juvenile loons sampled from low (< 6.3) pH lakes were significantly higher than those from neutral or alkaline (pH>7.0) lakes. Haines et al. (1992) found that fish from low pH and high color lakes had higher Hg levels than fish from low pH, low color lakes. Stafford and Haines (1997) considered lakes with a pH < 6.7 acidic for fish. In this study, the pH values ranged between 5.6 in East Richardson Pond and 7.7 in Sebasticook Lake (Appendix II). From the 63 study lakes tested 14% had a pH < 6.3 and 52% had a pH < 6.7.

Lakes with alkalinity less than 10 mg/L have little or no buffering capacity and are considered to be potentially sensitive to acid precipitation (Heiskary and Wilson 1990). More than half of our study lakes have alkalinity values less than 10 mg/L and therefore make inorganic Hg more available to sulphur-reducing monobacteria that produce MeHg. Alkalinity values ranged from 2 mg/L in Third Machias lake to 45.5 mg/L in Pierce Pond. Because of the difficulty in obtaining a stable pH reading in samples from many lakes, alkalinity is a more reliable measure of acid neutralizing capacity (E. Swain, pers. com.). Our pH and alkalinity measurements were highly correlated (r^2=0.69, p<0.001).

Color gives an indication of the relative amount of dissolved organic matter in the water. In general, lakes with color values between 0-20 PCU are considered clear, 21-50 indicate moderate coloration, and 51-100 are considered highly colored (Heiskary and Wilson 1990). Of the lakes we sampled only Bog Brook Flowage and 3 lakes sampled by MDEP had a color value above 50 PCU (Appendix 2).

Color ranged between 1 PCU in several lakes and 110 PCU in Hadley lake. We found no statistically significant relationships between piscivore blood or feather Hg concentrations and water quality parameters (p>0.10). We detected a marginally significant correlation between water color and juvenile loon blood Hg index (p=0.08) (Figure 18). Adult blood Hg levels were not significantly correlated with water color, pH, or alkalinity but their offspring, showed tendencies for higher Hg levels in higher color lakes.

Figure 18. Blood Hg index versus lake water color in juvenile Common Loons from Maine, 1994-97



We did not find significant relationships between avain matrix Hg levels and water quality parameters. This is most likely because the pH, alkalinity, and color measurements are within a relatively small range and a variety of other factors also contribute to MeHg availability. Therefore, single water quality parameters are insufficient to predict MeHg risk to piscivorous birds. Similarly, single lake morphometric parameters appear to be poor predictors of MeHg availability. There were no significant relationships between lake surface area, watershed acreage, and flushing rates and juvenile loon blood Hg levels ($p>0.10$). Further investigation into the association of lake morphometeric and water quality parameters with MeHg availability require multivariate analysis that incorporates a host of factors. In the interim, Hg exposure to fish-eating wildlife needs to be assessed on a lake by lake basis.

Risk thresholds

Few studies have been conducted on the five target species to determine when Hg affects their survival, reproductive success and overall well-being. Several studies have provided some avian references for no (NOAEL) and lowest observed adverse effects (LOAEL) and LD50 levels. Laboratory or captive experiments with wild birds provide ample information on NOAEL, LOAEL, and LD50 levels (e.g., Fimreite 1971, Heinz 1974, Finley and Stendall 1978, Finley et al. 1979, Heinz 1979, Scheuhammer 1988). While care is essential when applying these effect levels to free-ranging wildlife and for making interspecies comparisons, laboratory experiments provide toxicosis benchmarks and insights for measurable endpoints. Elevated MeHg levels are related to neurological, immunological, and genetic toxicosis (Wolfe et al. 1998) and disrupt the biochemical functions with cortisol (Friedmann et al. 1996) in fish, cholinesterase in quail (Dieter 1974), and glutathione in mallards (Hoffman and Heinz 1998). In-situ wildlife studies complement many of these laboratory experiments.

Scheuhammer (1991) considered that the dietary concentrations of MeHg needed for adult birds to exhibit overt toxicity were 5 times those needed to produce significant reproductive impairments. One of the most important reference studies for piscivorous birds is a study on Hg effects for loons in a lake system highly contaminated from an upstream chlor-alkali plant in Ontario (Barr 1986). He found reproductive impairment in loons feeding on fish with 0.30 ppm (e.g., reduced egg laying and territorial fidelity) and no reproduction from loons feeding on fish with 0.40 ppm or more. Highly exposed adults (i.e., mean brain MeHg levels of 0.76 +/- 0.50 ppm) did not show overt signs of Hg toxicosis. Mercury levels without overt signs can cause a 35-50% decrease in reproductive success (Heinz 1974, Scheuhammer 1987). In Maine, Evers and Reaman (1997) found yellow perch Hg concentrations to exceed 0.30 ppm on 7 of 8 lakes studied in northern Maine. They also documented elevated Hg levels in 18 species of fish preferred by loons (for the three size classes identified by Barr 1996). Over 2/3 of the fish in the small size class (5-20g) had Hg levels that were reported to cause reproductive impairment in loons and were the size class most frequently used by the Common Merganser and Belted Kingfisher.

Maine's fish Hg levels are elevated across the state (Stafford and Haines 1996), and according to comparable studies are affecting wildlife. How these levels relate to exposure in piscivorous birds varies. Although prey Hg levels are effective indicators of MeHg availability to piscivorous birds, diet composition, species toxicokinetics, and biotransformation rates are needed to effectively model MeHg loads. We chose to nonlethally collect blood, feathers, and eggs as best indicators of MeHg availability.

Wolfe (1998) describes mercury as "an extremely potent embryo toxicant." Egg hatchability is potentially related to parental investment or high Hg loads. The LOAEL of Hg in eggs is generally accepted at 0.50 ppm (Scheuhammer 1991, Thompson 1996, Wolfe et al. 1998) and is partly based on Fimreite's (1971) pheasant study but has also been shown in the wild with Bald Eagles (Wiemeyer et al. 1993). Significant effect threshold levels vary considerably but are thought to range from 1-3.6 ppm (Fimreite 1974). Barr (1986) documented egg Hg levels on a series of lakes with differentiating exposures. The highest exposed series of lakes had a mean Hg level of 1.39 ppm. The lowest exposed series of lakes had a mean Hg level of 0.59 ppm and was similar to a control group of natural lakes independent of the contaminated system. The lowest reproductive success for this loon population was recorded for pairs that laid eggs with > 1.00 ppm.

In our study, 43 loon eggs had a mean of 0.915 ppm with a range from 0.215 to 2.49 ppm. A breakdown by threshold category showed 23% of these eggs below 0.50 ppm, 45% between 0.5 and 1.00 ppm, and 32% greater than 1.00 ppm. Two eggs (one from Aziscohos Lake and the other from Wyman Lake) were above 2.00 ppm. The collection of loon eggs in 1997 represents 15 lakes, in 56% of which the mean egg Hg level was above 0.50 ppm and 33% of which were above 1.00 ppm. Lakes with loon egg Hg concentrations greater than 1.00 ppm are some of the most at-risk lakes in the state and include Aziscohos, Brewer, Pierce, Umbagog and Wyman. Water level fluctuations greater than 2 meters are a common denominator with each lake except for Brewer, which is 4 miles southeast of the Holtra-Chem Manufacturing Plant in Orrington. Eggs were gathered from 10 eagle nests with a mean level of 0.39 +/- 0.35 ppm (Welch 1994, Matz pers. com.). There were differences in egg Hg levels between marine and lake nests. The highest Hg level was 1.29 ppm from Brandy Pond. Two Osprey eggs were collected in 1997 and were both below threshold levels. An egg from Bog Brook Flowage had 0.142 ppm and an egg collected from a nest on Casco Bay had a Hg concentration below our detection limit of 0.025 ppm.

Designated thresholds for blood Hg levels are the least known for the three matrices that were sampled during this study. Blood provides an indication of recent dietary Hg uptake. Nearly all Hg in the blood is MeHg bound to erythrocytes and because the half-life of MeHg in avian blood is 2-3 months (Scheuhammer 1987) it is one of the better matrices for determining exposure at a breeding lake. Wolfe and Norman (1998) showed a significant correlation between blood and brain Hg.

Several recent studies have used blood to document exposure to Hg. Derr (1995) collected blood from a suite of piscivorous birds in Minnesota, including the common merganser. Welch (1994) and Matz (pers. com.) collected blood from juvenile Bald Eagles in Maine. And, several studies have documented exposure levels in loons, including Meyer et al. (1995) and Meyer et al. (1998) in Wisconsin, Scheuhammer et al. (1998) in Ontario, Evers and Reaman (1997) in Maine and New Hampshire, and Evers et al. (1998) across North America. Of these, the only study providing information on threshold impacts is Meyer et al. (1998). Four to eight week old loons found with blood Hg levels of 0.30 ppm or more were associated with territories where fewer chicks hatched or survived to 8 weeks of age. Over 30% of the juvenile loons sampled had blood Hg levels that exceeded 0.30 ppm. This threshold level is not necessarily useful for other species. Welch (1994) considered 0.50 ppm as a relevant threshold blood level in Maine juvenile eagles.

Threshold Hg blood levels in adults are relatively unknown. We have categorized adult loon blood Hg levels based on qualitative observations of effects in the wild and associations with highly contaminated lakes (based on other matrices criteria). For example, on Flagstaff Lake, where forage fish mean Hg levels exceed 0.40 ppm (levels that are related to effects in Ontario, Barr 1986), 83% of the adult loon blood Hg levels exceed 3.0 ppm (n=12). Adult loons with blood Hg levels of 2-3 ppm are considered to have a moderate risk and those over 3 ppm have a high risk to effects from Hg contamination. Risk evaluation includes potential effects on the adult's well-being,

Feathers are chronic indicators of Hg body burdens. Evers et al. (1998) found recaptured loons showed significant Hg accumulation in their feathers over time, particularly for individuals with elevated blood Hg levels during the breeding season. Mercury ingested in prey during the loon's 6-7 months on Maine's breeding lakes is deposited in organs (e.g., liver and kidney) and muscle tissue. Although bile excretion contains some MeHg, most of the MeHg available for remobilization is found in muscle tissue. This Hg probably reenters the blood stream during stressful times such as full remigial molts. The correlation between flight feathers and breeding season blood Hg levels is strongest for individuals that are more exposed during the summer (e.g., Alaska r^2=0.03, New England r^2=0.24). Therefore, the uptake of Hg in Maine lakes by breeding adult loons is related to their feather Hg levels.

Table 9. Adult flight feather Hg levels for three target piscivorous birds in Maine, 1994-97.

Species/Sex	*≤5 ppm*	*5-9 ppm*	*9-20 ppm*	*20-30 ppm*	*>30 ppm*	*Total*
Common Loon						
Male	*0*	*7*	*39*	*16*	*5*	*67*
Female	*2*	*18*	*40*	*6*	*0*	*66*
Belted Kingfisher	4	1	0	2	0	7
Common Merganser	0	0	2	0	0	2
Total	**6**	**26**	**81**	**24**	**5**	**142**

Feather Hg threshold levels vary according to feather type and bird species. Eisler (1987) considered 5 ppm as a LOAEL while 9 ppm was suggested by Heinz (1979). Scheuhammer (1991) and Thompson (1997) consider a higher risk threshold of 20 ppm and the coauthors have observed abnormal behavior in loons above 30 ppm. Adult feather Hg levels for loons, kingfishers, and mergansers were normally distributed using these various threshold levels (Table 9). Over 20% of the birds sampled exceeded 20 ppm. Adult male loons appear to be most at risk. Over 31% of them had feather Hg levels that are potentially associated with effects.

Conclusions:

The results of this study follow a pattern established by the Maine DEP's REMAP project. The availability of MeHg to Maine's piscivorous bird community is elevated statewide but exposure to the biota varies by lake. Geographic or physiogeochemical patterns are difficult to discern although there is a tendency for lower Hg exposure in marine environs and higher levels on freshwater lakes, especially on reservoirs that are flooded river valleys with low flushing rates and exhibit wide water level fluctuations (> 2 meters during the summer). We demonstrate the ability of birds to bioaccumulate MeHg that has biomagnified through the aquatic food web. Trophic status, ingestion rates, and pharmacokinetics all contribute to varying individual and species response to MeHg availability. Shorter-lived and slightly lower trophic level avian piscivores like the Common Merganser and Belted

Kingfisher can accumulate MeHg at levels that endanger their well-being. Larger, longer-lived piscivores like the Common Loon, Bald Eagle, and Osprey are also highly exposed, but determining species greatest at risk remains difficult.

The largest databases for Hg exposure in Maine's piscivores are for the loon and eagle. Over 350 samples of loon matrices have been collected from 50 Maine lakes since 1994 and around 250 blood, feather, and egg samples from the Bald Eagle. The Hg exposure levels measured from these various matrices exceed threshold levels designated by laboratory and *in situ* studies for 10-31% of the breeding loon population and nearly half of the breeding eagle population. By overlaying our designated threshold levels across the 93 Maine lakes with samples from the five target piscivorous birds, we believe that approximately 70% of Maine's lakes have the capacity to biomagnify MeHg to levels that pose a risk.

We conclude that MeHg exposure for these piscivorous birds is a potential risk to the viability of local breeding populations. Refining the risk and determining potential effects is now needed.

Publicity:

Doug MacPherson of NH Public Radio ran a story in New Hampshire and Maine's Public Radio. Bill Maroldo of Maine Watch interviewed our staff and included us as part of a half-hour special feature on mercury in Maine's environment. Marnie McLean of TV 13 covered a night of loon capture for a story associated with Deiter Bradbury's five part series on mercury in Maine. One part of this series featured BioDiversity Research Institute and the piscivorous bird study. Deiter and other journalists covered our field collection efforts in 1997 and stories were printed in the following newspapers (Appendix IV):

"Biologists study toxins in local loons" in The Enterprise of Bucksport, ME,
"Mercury rising in NE loons" in Sunday Rutland Herald, VT and New Hampshire Sunday News of Manchester, NH,
"Northeast faulted for mercury pollution" in Boston Globe, MA,
"Experts confer on mercury, acid rain" in Portland Herald Press, ME,
"Biologists issues warning over mercury, acid rain" in Toronto Globe and Mail, Ontario,
"Belgrade Lakes' loons touched more by mercury" in Kennebec Journal, Maine,
"Protecting loons....projects monitor mercury, lead exposure in our stately bird" in Kennebec Journal,
"Tiny mercury levels pack huge wallop" in Toronto Globe and Mail, Ontario,
"Loons' future is threatened by mercury" in Toronto Globe and Mail, Ontario,
"Pollution threatens a beloved symbol of Canada" in Christian Science Monitor, Boston

The following are presentations incorporating information from this study:

"Maine's fish-eating birds and mercury: what is the risk?" Maine Audubon Society special evening program for the public, scheduled May 14, 1998.
"Methylmercury in Maine's piscivorous birds: an assessment of risk" Maine Bird Conference 1998, scheduled May 2, 1998.
"Mercury exposure in New England's fish-eating birds" Bryant College Seminar, Bryant College, RI, scheduled April 9, 1998.

"Mercury in loons from the Northeast" New England Association of Environmental Biologists (NEAEB), 22nd annual meeting, Kennebunkport, Maine. March 13, 1998.

"Mercury in Maine's Birds" Patagonia presentation series, Freeport, Maine. February 24, 1998.

"Effects of Mercury on Wildlife" The Conference of New England Governors and eastern Canadian Premiers - Public Advocate Caucus, Portland, Maine. Feb 12, 1997.

"Mercury in Maine's environment" Maine Audubon Society conference, Falmouth, Maine. December 2, 1997.

"Summary of Maine Outdoor Heritage Fund project 'Determining mercury in Maine's fish-eating birds'" Northeast Loon Study Workgroup, Falmouth, Maine. December 1, 1997.

"Mercury in Common Loons in North America" University of Maine, Department of Biological Science Seminar, Orono, Maine. October 3, 1997.

Other recent presentations by BRI about mercury in Maine:

"The importance of working together: a case study of the Northeast Loon Study Workgroup" Northeast Fish and Wildlife Conference, Framingham, MA. April 30, 1997.

"Loon Biomonitoring Program" Annual meeting of the Maine chapter of the wildlife society, Brewer, Maine. April 24, 1997.

"A comparison of mercury exposure in Common Loons and Fish between artificial impoundments and nearby natural lakes" Maine Water Conference, Augusta, Maine. April 19, 1997.

"A geographic trend in mercury measured in Common Loon feathers and blood" Society of Environmental Toxicology and Chemistry, 18th annual meeting, San Francisco, CA. November 16-20, 1997.

"Mercury in loons: geographic trends and potential impacts in Maine" University of New England, Biddeford, Maine. April 1997.

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Appendix 1. 1997 Maine Outdoor Heritage Fund Piscivore Survey summary

	Lake Name	***Gen. local***	***Date***	***COLO****		***COME***		***BEKI***		***OSPY***		***BAEA***		***Boat Access***
				ad	juv	ad	juv	ad	juv	ad	juv	ad	juv	
1	Adams Pd.	Southeast	7/7/97	1										Trailer
2	Attean Pond	Upper Kennebec	7/16/97	12		2								
	Attean Pond	Upper Kennebec	7/16/97	9										Aerial Survey
3	Aziscohos	Upper Androscoggin	6/30/97	36	5	5	15	2	0					
4	Beech Hill	Orrington Area	6/18/97											Trailer
5	Big Beaver	Upper Androscoggin	6/30/97	3										
6	Black Brook Pond	Upper Kennebec	7/16/97	2										Aerial survey
7	Bog Brook Flowage	Graham	7/7/97	2	1			2		20	2			Trailer (poor/shallow) GBHE rookery
8	Branch Lk.	Orrington Area	6/17/97	2										Portage
9	Brassua Lake	Upper Kennebec	7/16/97	3										
10	Brewer Lk.	Orrington Area	6/17/97	4										Trailer
11	Burnham	Upper Kennebec	8/3/97	2	1									
12	Burnt Meadow	Southeast	7/7/97											Trailer
	Burnt Meadow	Southeast	6/23/97											Trailer
13	Caribou	Upper Penobscot	8/4/97	1										
14	Carleton Pd. Gravel pit	Belgrade Lakes Area	8/6/97					1						No Access to pond
15	Carlton Pd.	Belgrade Lakes Area	7/6/97											No Access
16	Chain of Ponds	Upper Kennebec	7/16/97	4										Aerial Survey
17	Chesuncook	Upper Penobscot	6/28/97	10										Trailer
	Chesuncook	Upper Penobscot	6/29/97					1		3		2		Trailer -COTE colony
	Chesuncook-S	Upper Penobscot	8/4/97	5										
18	Cobbosseecontee	Belgrade Lakes Area	7/9/97	4	1	1				4	1			Trailer
19	Cochnawagon	Belgrade Lakes Area	7/6/97	1						1				Trailer
	Cochnawagon	Belgrade Lakes Area	7/6/97	1						1				Trailer
20	Deer Pond	Upper Penobscot	8/4/97											
21	Dexter Pd.	Belgrade Lakes Area	7/6/97											Canoe Portage
	Dexter Pd. area	Belgrade Lakes Area	7/8/97					2						Not Applicable
	Dexter Pond	Belgrade Lakes Area	7/6/97											Portage
22	Eagle Lake	Mount Desert Island	6/16/97	3		2	10							Trailer
23	East Pd.	Belgrade Lakes Area	7/7/97	2										Trailer
	East Pond	Belgrade Lakes Area	7/10/97	7	2					1	2			Trailer
24	Echo Lake	Mount Desert Island	6/16/97	1										Trailer
	Echo Lake	Mount Desert Island	7/18/97	1	1									
25	Fields	Orrington Area	6/17/97											Trailer
26	First Roach	Upper Penobscot	8/4/97	3										
27	Flagstaff	Upper Kennebec	6/24/97	7		1		6		2				Trailer 1 MALL, 4 chicks
	Flagstaff	Upper Kennebec	6/25/97	2				3		1				Trailer 1 MALL, 7 chicks
	Flagstaff	Upper Kennebec	6/26/97					2		1				Trailer
	Flagstaff - N Branch	Upper Kennebec	6/24/97	2	1									Canoe Portage
28	Flying Pd.	Belgrade Lakes Area	7/7/97	2	1									Trailer
	Flying Pond	Belgrade Lakes Area	7/7/97	2	1									Trailer
29	Frost Pond	Upper Penobscot	8/5/97	1										

* COLO=Common Loon, COME=Common Merganser, BEKI=Belted Kingfisher, OSPY=Osprey, BAEA=Bald Eagle

Appendix 1. 1997 Maine Outdoor Heritage Fund Piscivore Survey summary

	Lake Name	Gen. local	Date	COLO*		COME		BEKI		OSPY		BAEA		Boat Access
				ad	juv	ad	juv	ad	juv	ad	juv	ad	juv	
30	Goose Pd.	Orrington Area	6/17/97											No Public Access
31	Graham	Orrington Area	6/18/97	1						1		2		Trailer (on Rt. 180)
32	Granger Pd.	Southeast	6/23/97											No Access
33	Green Lk.	Orrington Area	6/17/97	2										Paid Boat Access
34	Hancock Pd.	Southeast	7/6/97	4		2	4							Trailer
35	Harrington Lake	Upper Penobscot	8/5/97					2	8					
36	Hoddgon	Mount Desert Island	7/18/97	1										
37	Holeb Pond	Upper Kennebec	7/16/97	4										Aerial survey
38	Indian	Upper Kennebec	8/3/97	9										
	Indian Pond	Upper Kennebec	6/16/97	10										
	Indian Pond	Upper Kennebec	6/27/97	7								2		Trailer
	Indian Pond	Upper Kennebec	7/16/97	7						1				Aerial Survey
39	Jacob Buck	Orrington Area	6/17/97	2										No Public Access
40	Jim	Upper Kennebec	6/30/97	2										
41	Jordan Pd.	Mount Desert Island	6/16/97			1	?							
	Jordan/Stancey Brook	Mount Desert Island	6/16/97					1						
42	Kennebago (Little)	Upper Androscoggin	6/30/97	2		1	3	1						
43	Knights Pond	Upper Kennebec	7/16/97	1										Aerial Survey
44	Lincoln Pond	Upper Androscoggin	6/30/97	1										
45	Little Beaver	Upper Androscoggin	6/30/97	2										
46	Little Indian	Upper Kennebec	6/16/97	2										
	Little Indian	Upper Kennebec	7/16/97	2										Aerial Survey
47	Little Lobster	Upper Penobscot	8/5/97	2	1									
48	Lobster Lake	Upper Penobscot	8/5/97	5										
49	Long	Mount Desert Island	7/18/97	5										
50	Long Pd. area (gr.pit)	Upper Kennebec	6/27/97					2						Not Applicable
51	Long Pond	Orrington Area	6/17/97											No Access
	Long Pond	Upper Kennebec	7/16/97	2										
	Long Pond	Upper Kennebec	7/16/97	4										Aerial survey
52	Loon Pd.	Belgrade Lakes Area	7/6/97											Private Access Only
	Loon Pond	Belgrade Lakes Area	7/6/97											Private access only
53	Lovewell Pd.	Southeast	6/23/97	1										Trailer
54	Lower Hadlock	Mount Desert Island	6/18/97											Trailer
55	Lower Togue	Upper Penobscot	8/6/97											
56	Maranacook	Belgrade Lakes Area	7/10/97	15						2				Trailer
57	Moosehead-S	Upper Kennebec	8/3/97	8										
58	Mountain View	Upper Kennebec	8/3/97											
59	Nequasset	Southeast	7/6/97	1						1		1		Trailer
60	North Pd.	Belgrade Lakes Area	7/7/97	2						2				Portage
	North Pond	Belgrade Lakes Area	7/7/97							1				Trailer
61	North Pond	Southeast	7/8/97											Trailer
62	North Twin	Upper Penobscot	8/6/97	1										

* COLO=Common Loon, COME=Common Merganser, BEKI=Belted Kingfisher, OSPY=Osprey, BAEA=Bald Eagle

Appendix 1. 1997 Maine Outdoor Heritage Fund Piscivore Survey summary

	Lake Name	*Gen. local*	*Date*	*COLO**		*COME*		*BEKI*		*OSPY*		*BAEA*		*Boat Access*
				ad	juv	ad	juv	ad	juv	ad	juv	ad	juv	
63	Parker Pond	Belgrade Lakes Area	7/7/97											Trailer (steep & poor)
64	Parlin Pd.	Upper Kennebec	6/27/97	1				2						Trailer
65	Parmacheenee	Upper Androscoggin	7/16/97	6	1	1	3							Aerial Survey
66	Pattee Pd.	Belgrade Lakes Area	7/7/97											Trailer
	Pattee Pond	Belgrade Lakes Area	7/7/97											Private access only
67	Penesseewassee	Southeast	7/8/97	5										Trailer (off 117)
68	Phillips	Orrington Area	6/17/97											Trailer
69	Pleasant Pd.	Southeast	6/23/97											Poor Access
70	Quakish Lake	Upper Penobscot	8/6/97	2										
71	Ragged Lake	Upper Penobscot	8/4/97	5										
72	Range Pd.	Southeast	7/4/97	2	2									Trailer
73	Rangeley	Upper Androscoggin	6/30/97	12	3	3				1				
74	Richardson (East)	Upper Androscoggin	6/30/97	1	1									
75	Richardson (West)	Upper Androscoggin	5/24/97	3		2								
76	Ripogenous	Upper Penobscot	8/4/97	6										
77	Round	Upper Androscoggin	6/30/97	2										
78	Round Pond	Upper Penobscot	8/5/97	1										
79	Seal Cove	Mount Desert Island	7/18/97	2				1						
80	Shack Pond	Upper Penobscot	8/5/97											
81	Somes	Mount Desert Island	6/16/97	2						1				Canoe portage
82	South Twin	Upper Penobscot	8/6/97	1										
83	Swetts Pd.	Orrington Area	6/17/97	1										Ramp by box 328A
84	Thomas Pd.	Southeast	7/9/97	1										Trailer
85	Tim	Upper Kennebec	6/30/97	2										
86	Umbagog	Upper Androscoggin	6/30/97	52	11	2	60	2	0	8	3	2	0	
87	Upper Hadlock	Mount Desert Island	6/18/97	2										Portage (short)
88	Upper Togue	Upper Penobscot	8/6/97	1										
89	Walden Pd.	Southeast	7/6/97	2										No public Access
90	Williams Pd.	Orrington Area	6/17/97											No Public Access
91	Witch Hole Pd.	Mount Desert Island	6/16/97					?						No Access
92	Woods Pd.	Southeast	7/7/97											
			Total	*352*	*33*	*23*	*95*	*30*	*8*	*52*	*8*	*9*	*0*	

* COLO=Common Loon, COME=Common Merganser, BEKI=Belted Kingfisher, OSPY=Osprey, BAEA=Bald Eagle

Appendix II. Water chemistry parameters for selected lakes

Lake	*Midas*	*Source*	*Basin*	*Col* *PCU*	*BRI app color* *PCU*	*pH*	*BRI pH*	*Alk* *mg/L*	*BRI alk* *mg/L*	*Cond* *ms/cm*	*Sec* *m*
ALAMOOSOOK L	4336	various	1	23	22	6.89	7.22	9.80	12.766	39	4.6
ANDROSCOGGIN L	3836	MDEP	2								4.4
ATTEAN	2682	MDIFW		2		6.48	6.26				
AZISCOHOS L	3290	various	2	24	26	6.64	7.21	11.00	8.404	28	4.8
BEAVER P (LITTLE)	3312	MDEP	1			-	5.89	-		-	3.0
BERRY P	3828	MDEP	1	25		6.81		17.60		52	4.4
BOG BROOK FLOWAGE	7449	various			80		6.5				
BRANCH L	4328	various	2		9	-	6.75	-	2.047	-	7.5
BRANDY P	9651	MDIFW		2		6.05		4			
BRASSUA L	4120	MDEP	1	49		-		27.00		27	3.8
BREWER L	4284	MDEP	1	18		6.66		6.00		30	4.6
CARRY POND (WEST)	48	MDIFW		1		6.34	5.88	6.00		15	
CHAIN OF PONDS	5064	various	2	45	25	-	7.37	11.00	9.913	40	3.6
CHESUNCOOK L	662	various	2		35	-	7.3	-		-	2.0
CLEAR L	1938	MDEP	1	5		-		15.50		32	9.5
CLIFFORD L	1304	MDEP	1	40		-		6.00		25	3.5
COBBOSSEECONTEE L	5236	MDEP		18		7.04		17.45		59	3.7
COLD STREAM P	2146	MDEP		11		6.73		6.80		30	8.6
CRAIG P	4332	various	1	5	5	6.80	6.88	4.40	3.852	29	11.3
DAMARISCOTTA L	5400	MDEP	6			-		-		-	4.9
DEXTER P	3830	MDEP	1	21		7.02		17.80		59	5.0
EAGLE L	4606	MDEP	1	11		6.65		3.75		35	11.0
EAST P	5349	MDEP	1	17		7.11		7.45		31	4.8
ECHO L	4624	various	2		14	-	6.4	-	4.418	-	7.5
FLAGSTAFF L	38	BRI			26		7.36		16.238		
GRAND FALLS FLOWAGE	7437	MDEP	1			6.74		-		-	3.5
GREAT P	5274	MDEP	1	13		6.95		9.30		36	6.6
GREEN L	4294	various	2	15	14	6.66	6.68	4.40	3.679	25	6.9
HADLEY L	1352	MDEP	1	110		6.40		9.00		25	2.8

(Source=MDEP-Maine Dept. of Environ. Protec., MDIFW-Maine Dept. of Inland Fish and Wildlife, BRI-BioDiversity Research Instit. Col=true (filtered color); app color=apparent color; pH=air equilibrated pH; alk=alkalinity; Cond=conductivity; Sec=mean secchi disk)

Appendix II. Water chemistry parameters for selected lakes

Lake	Midas	Source	Basin	Col	BRI app color	pH	BRI pH	Alk	BRI alk	Cond	Sec
				PCU	PCU			mg/L	mg/L	ms/cm	m
HANCOCK P	4318	various	1	22	14	7.32	7.5	16.20	15.261	78	3.4
INDIAN P	4090	various	1	25		6.98	6.57	9.00		27	6.0
INDIAN P (LITTLE)	4070	MDIFW		1		6.18	6.53	17.00			
JORDAN P	4608	MDEP	1	9		6.89		4.90		36	12.7
KENNEBUNK P	3998	MDEP	1	9		6.10		6.00		37	6.4
LOBSTER L	2948	various	1	25		6.50		13.50		37	4.4
LONG P	5272	various	2	16	11	7.02	6.91	9.40	6.995	29	6.5
LONG P	9701	MDEP	1	8		7.29		14.00		29	6.7
MACHIAS (THIRD)	1124	MDIFW		20.24		6.33		2			
MATTAWAMKEAG L	1686	MDEP	1	65		6.65		16.35		59	3.4
MOLASSES P	4448	various	1	12	13	6.47	6.55	4.30	2.862	30	6.8
MOOSE P	3134	MDEP	1	16		6.79		6.30		29	6.8
MOOSEHEAD L	390	MDEP	10	20		7.10		8.50		30	7.80
MOOSELOOKMEGUNTIC L	3302	MDEP	1	20		6.75	6.16	7.60		30	5.4
MOULTON P	4308	MDEP	1	6		7.25		9.30		36	9.0
NORTH P	3460	MDEP	1	12		6.71		6.00		27	5.3
NORTHEAST P	3876	MDEP	1	44		6.84		11.50		59	3.7
OSSIPEE L (LITTLE)	5024	various	2		14	-	7.18	-	9.209	-	5.1
PARLIN P	2544	MDEP	1	25		6.60	6.51	7.00		30	4.5
PARMACHENEE L	3966	various	1	55	29	-	7.24	10.10	11.754	31	4.2
PEMAQUID P	5704	MDEP	1	27		6.79		7.65		41	4.7
PENNESSEEWASSEE L	3434	MDEP	2	15		7.59		-		-	5.1
PEPPERPOT	3298	MDIFW		1		6.30		5		38.5	
PHILLIPS (LUCERNE) L	4300	various	1	10	10	7.00	6.97	5.50	5.976	45	8.4
PIERCE P	86	MDEP	1	18		-	6.54	45.50		30	8.8
PLEASANT RIVER L	1210	MDEP	1	-		-		-		-	5.1
POCASSET L	3824	MDEP	1	16		7.03		12.90		43	5.6
RANGE P (LOWER)	3760	MDEP	1	11		6.56		11.80		45	6.3
RANGE P (MIDDLE)	3762	MDEP	1	13		6.83		11.50		32	5.6
RANGELEY L	3300	various	1	11	11	7.27	7.24	7.50	6.146	32	6.0
RICHARDSON LAKES	3308	MDEP	1	17		6.96	6.62	9.00		29	6.1
RICHARDSON P (LO E)	3296	MDIFW		1		6.22	5.59	2			

Appendix II. Water chemistry parameters for selected lakes

Lake	*Midas*	*Source*	*Basin*	*Col*	*BRI app color*	*pH*	*BRI pH*	*Alk*	*BRI alk*	*Cond*	*Sec*
				PCU	*PCU*			*mg/L*	*mg/L*	*ms/cm*	*m*
RICHARSONS P (UP E)	3294	MDIFW		1		6.39		2			
ROWE	4002	MDIFW				6.30					
SAND P (TACOMA LKS)	5238	MDEP	1	15		6.86		15.00		58	6.5
SCRAGGLEY L	9649	MDEP	1	26		-		6.00		27	4.6
SEAL COVE P	4630	various	1	12	9	6.36	6.57	4.80	3.091	39	6.8
SEBAGO L (LITTLE)	3714	MDEP	1	32		6.59		10.40		35	5.3
SEBASTICOOK L	2264	MDEP	1	40		7.66		33.50		110	1.8
SEBOOMOOK L	4048	MDIFW		4		6.67					
SQUARE P	3916	BRI					6.98		7.343		
TODDY P	4340	various	1	22	19	6.29	6.93	3.70	3.534	27	6.0
UMBAGOG L	3102	various	1	19	27	6.85	6.86	6.80	6.254	24	4.4
WALKER P	4640	MDEP	1	6		6.62		5.80		40	7.1
WILSON P	3832	MDEP	1	17		6.87		13.90		-	5.3
WOODBURY P	5240	MDEP	1	15		6.94		15.40		55	6.0
WYMAN L	7122	MDEP	1			-		-		-	4.7

Appendix III. Lake Morphometric Information

Lake Type = determined by the Department of Inland Fisheries and Wildlife (1 = Oligotrophic, 2 = Eutrophic, 3 = Mesotrophic, 4 = Dystrophic)
Dam Class=Department of Inland Fisheries and Wildlife (1 = no functional dam present, all natural flowage; 2 = > 50% arera man-made flowage 3 = < 50% area man-made flowage)
Stratification Indicator = (1=yes, 2=no) **Boldface Lakes** = Lakes sampled for REMAP (Regional Environmental Monitoring and Assessment Program)

LAKE	Midas	Elevation	Surface area		Drainage Area		Depth (ft)		Shoreline	Lake Type	Stratification	Volume	Runoff	Flush rate	Dam
		feet	*acres*	*hectares*	*mi^2*	*km^2*	*mean*	*max*	Length (ft)		Indicator	*m^3*	factor	*(#/year)*	class
ALAMOOSOOK L	4336	20	1133	399.0		210.57	16	28		2	2	18869554.0	0.5580	6.227	3
ANDROSCOGGIN L	3836	269	3980	1616.0	83.00	214.97	15	38		2	2	69982395.0	0.5080	1.560	3
ATTEAN P	2682	1157	2745	1089.0		689.72	15	54		3	1	45684548.6	0.4100	6.190	1
AZISCOHOS L	3290	1514	6700	2506.0	214.00	554.26	31	60		3	1	194820752.0	0.7620	2.168	2
BEAVER P	3588	1976	20	8.0	0.00	0.75	5	19	5577	2	1	94371.8	0.6096	4.852	3
BEAVER P (LITTLE)	3312	1490	50	20.0	4.00	9.30	16	51	6552	3	1	876615.1	0.6731	7.139	1
BERRY P	3828	242	174	68.0	8.00	20.02	14	25		3	1	1842080.0	0.5080	5.521	1
BOG BROOK FLOWAGE	7449	250	565	9.9		0.99	99			2					2
BREWER L	4284	115	881	371.0	12.00	31.08	26	48		3	1	28405104.0	0.5080	0.556	3
CARRY P (WEST)	48	1317	675	288.0	5.00	12.77	37	96	28497	1	1	31766491.3	0.5080	0.204	1
CHAIN OF PONDS	**5064**	**1273**	**700**	**282.0**	**65.00**	**166.95**	**24**	**106**	**86338**	**1**	**1**	**24093787.0**	**0.6167**	**4.273**	**3**
COBBOSSEECONTEE L	**5236**	**165**	**5543**	**2120.0**	**131.00**	**339.29**	**37**	**100**		**2**	**1**	**157109008.0**	**0.5080**	**1.097**	**3**
CRAIG P	4332	215	218	90.0	1.00	3.16	36	69	18500	1	1	9095924.1	0.5710	0.198	3
DEXTER P	3830	242	111	42.0	9.00	22.90	13	25		3	1	1227051.0	0.5080	9.479	1
EAGLE L	4606	274	436	177.0	4.00	9.71	44	110	26000	1	1	22399242.0	0.6350	0.275	3
EAST P	**5349**	**263**	**1823**	**698.0**		**17.40**	**18**	**27**		**2**	**2**	**33682695.0**	**0.4700**	**0.243**	**3**
ECHO L	4624	84	237	92.0	2.00	5.93	28	66	19008	1	1	6248144.4	0.6350	0.603	3
FLAGSTAFF L	38	1146	20300	7588.0	516.00	1336.43	18	50		2	2	322385990.3	0.5080	2.106	2
GREAT P	5274	248	8239	3313.0	83.00	214.71	21	69		3	1	240649445.0	0.4830	0.431	3
GREEN L	4294	159	2989	1210.0	59.00	148.92	44	170		1	1	131000000.0	0.5715	0.650	3
HANCOCK P	4318	99	59	24.0	1.00	3.73	17	25	6864	3	2	1070371.1	0.5460	1.902	1
HANCOCK P	3132	502	858	308.0	9.00	24.55	17	59	80844	2	1	17353184.0	0.5588	0.791	3
HOWARD P	3520	1084	128	52.0	4.00	9.89	34	118	12140	1	1	5112279.3	0.6096	1.180	3
INDIAN P	4090	955	3746	1335.0	1384.00	3584.54	21	118		1	1	79057440.0	0.5080	23.033	2
INDIAN P (LITTLE)	4070		25		0.00										
JORDAN P	4608	274	187	72.0	2.00	4.97	84	150	14256	1	1	17388142.9	0.6350	0.182	3
KENNEBUNK P	3998	273	224	80.0	1.00	2.95	21	43	19536	2	1	5035084.3	0.5588	0.328	3
LOBSTER L (LITTLE)	2948	982	230	90.0	5.00	11.99	14	36	15644	3	1	4135016.0	0.5080	1.473	3
LONG P	5272	238	2714	1079.0	121.00	253.30	35	97		3	1	90281183.9	0.4950	1.389	3
MOLASSES P	4448	210	1252	507.0		24.68	19	47	49000	3	1	25900000.0	0.6096	0.581	3
MOOSE POND	3134	418	1694	665.0	26.00	66.30	22	70		2	1	37996000.0	0.6096	1.064	3
MOOSEHEAD L	390	1029	74890	30876.0	1268.00	3284.10	55	246		1	1	5193000000.0	0.5080	0.321	3
MOOSELOOKMEGUNTIC L	3302	1467	16300	6724.0	389.00	1007.51	60	132		1	1	693360070.0	0.6096	0.886	3
MOULTON P	4308	470	45	18.0	1.00	1.42	23	35	6864	1	1	1171204.4	0.5410	0.658	3
NORTH P	3460	721	284	124.0	4.00	10.26	12	37	20275	2	1	4858359.1	0.5588	1.180	3
NORTHEAST P	3876	415	778	317.0	102.00	264.18	10	49	67760	2	1	8557333.3	0.5080	15.683	1

Appendix III. Lake Morphometric Information

Lake Type = determined by the Department of Inland Fisheries and Wildlife (1 = Oligotrophic, 2 = Eutrophic, 3 = Mesotrophic, 4 = Dystrophic)
Dam Class=Department of Inland Fisheries and Wildlife (1 = no functional dam present, all natural flowage; 2 = > 50% arera man-made flowage 3 = < 50% area man-made flowage)
Stratification Indicator = (1=yes, 2=no) **Boldface Lakes** = Lakes sampled for REMAP (Regional Environmental Monitoring and Assessment Program)

LAKE	Midas	Elevation	Surface area		Drainage Area		Depth (ft)		Shoreline	Lake Type	Stratification	Volume	Runoff	Flush rate	Dam
		feet	*acres*	*hectares*	*mi²*	*km²*	*mean*	*max*	Length (ft)		Indicator	*m³*	factor	*(#/year)*	class
OSSIPEE L (LITTLE)	**5024**	**311**	**564**	**182.0**	**6.00**	**16.68**	**21**	**74**	**31680**	**2**	**1**	**12368135.3**	**0.6096**	**0.822**	**3**
PARLIN P	2544	1605	543	224.0	18.00	45.32	14	32	33456	3	2	9981815.9	0.6100	2.770	1
PARMACHENEE L	3966	1622	912	362.0	104.00	269.36	36	93	56717	1	1	35930961.0	0.7112	5.332	3
PEMAQUID P	5704	77	1515	583.0	23.00	58.53	20	61	93200	3	1	31659000.0	0.5969	1.104	1
PENNESSEEWASSEE L	3434	397	922	384.0	22.00	57.50	18	48	68640	2	1	21974186.8	0.5588	1.462	3
PEPPERPOT P	3298	1499	50		17.00										
PHILLIPS (LUCERNE) L	4300	228	828	335.0	12.00	29.78	40	98	73000	1	1	32000000.0	0.5588	0.520	3
PIERCE P	86	1142	1650	470.0	8.00	49.21	39	120		1	1	49622892.0	0.5330	0.529	3
PLEASANT RIVER L	1210	317	949	360.0	15.00	38.33	13	52	47504	1	1	16000000.0	0.6300	1.509	3
POCASSET L	3824	284	601	229.0	59.00	152.81	16	20		2	2	8911998.0	0.5080	8.710	3
RANGE P (LOWER)	**3760**	**306**	**290**	**118.0**	**14.00**	**34.96**	**15**	**41**	**35811**	**2**	**1**	**4832600.7**	**0.5080**	**3.675**	**3**
RANGE P (MIDDLE)	3762	306	366	156.0	9.00	23.02	29	66	24288	2	1	14105577.3	0.5080	0.829	3
RANGELEY L	3300	1518	6000	2430.0	100.00	259.00	60	149		1	1	359000000.0	0.4851	0.350	3
RICHARDSON LAKES	3308	1448	7100	1824.0	479.00	1186.21	44	108		1	1	181438154.0	0.6096	3.985	3
RICHARDSON P (LO E)	3296	1761	54	22.0	1.00	3.60	9	15	6822	3	2	513403.2	0.6223	4.364	1
RICHARDSON P (UP E)	3294	1764	85	31.0	1.00	2.20	11	20	7322	3	1	858649.9	0.6223	1.596	1
RICHARDSON P (WEST)	3292	1505	423	178.0	14.00	35.74	17	41	29446	2	1	6547597.9	0.7112	3.882	3
SAND P (TACOMA LKS)	5238	176	177	106.0	12.00	29.78	31	82		3	1	8385286.0	0.5080	1.804	1
SEAL COVE P	4630	38	283	96.0	4.00	11.50	18	44		3	1	3890736.8	0.6260	1.850	3
SEBAGO L (LITTLE)	3714	285	1898	754.0	19.00	48.95	16	52		2	1	40245000.0	0.5334	0.649	3
SEVEN TREE P	5686	34	523	212.0	153.00	396.27	24	45		3	1	13640900.0	0.6096	17.709	1
SQUARE P	3916	522	910	340.0	4.00	10.39	20	44	50160	2	1	22169176.6	0.5842	0.274	3
TODDY P	4340	163	1987	949.0	25.00	65.27	27	122	79000	1	1	61660000.0	0.5842	0.618	3
UMBAGOG L	**3102**	**1245**	**7850**	**2938.0**	**600.00**	**1553.99**	**14**	**48**		**2**	**2**	**93980659.9**	**0.5588**	**9.240**	**3**
WILSON P	3832	242	582	223.0	16.00	42.48	23	42	41184	3	1	11730479.0	0.5080	1.839	3
WOODBURY P	5240	176	436	176.0	16.00	40.14	21	62		3	1	9000000.0	0.5080	2.266	3
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Appendix IV

Copies of newspaper articles about the MOHF project
"Determining mercury exposure in
Maine's Fish-eating Birds"

Maine Sunday Telegram
SUNDAY SEPTEMBER 28, 1997
Volume 110, Number 11
$1.75
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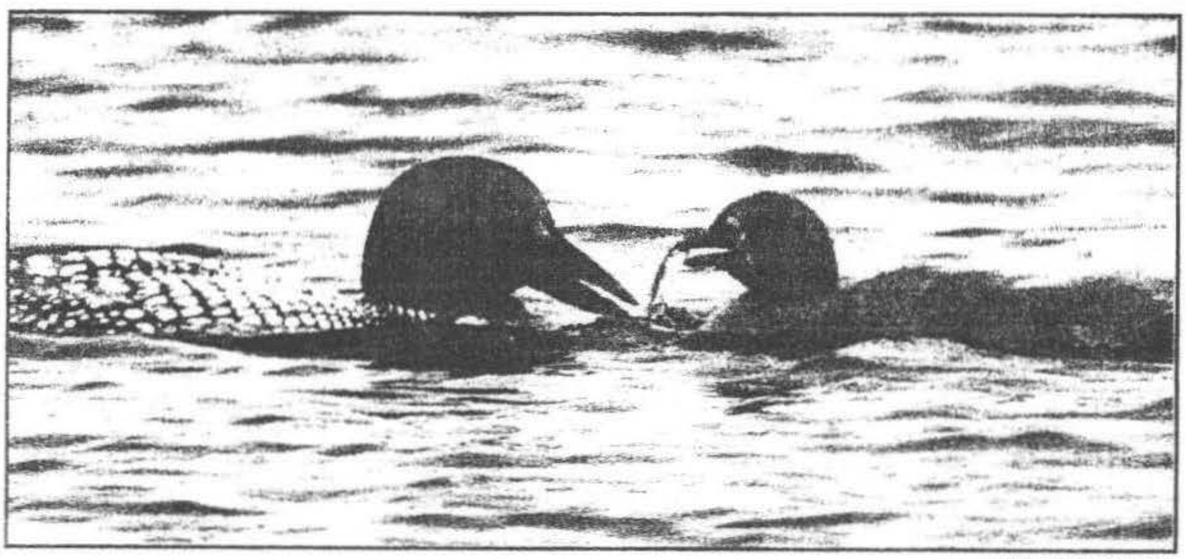
MERCURY MENACE

in the beak of a dead loon at Tufts University, where experts in loon mortality dissect and study the birds. Story, 13A

As pollution weakens Maine's beloved loons, a broader alarm sounds



Staff photos by David A. Rodgers

A loon feeds its chick a fish on New Hampshire's Squam Lake. Evidence of mercury poisoning in loons, high on the lake food chain, worries scientists about the prevalence of mercury in the environment. Since 1994, Maine has warned people to limit consumption of freshwater fish.

First of four parts

By DIETER BRADBURY
Staff Writer

They're on our license plates and in our hearts. The wild and beautiful loon, our symbol of conservation and unspoiled wilderness, shares a powerful bond with Maine's people.

Together, they face a common enemy – mercury.

Pollution from mercury, a natural element that modern industry has transformed into a serious environmental and health risk, is literally raining down on Maine's lakes, ponds, rivers and streams.

Wildlife biologists are finding growing evidence that loons, weakened by mercury, are having trouble reproducing and fighting off disease.

INSIDE

Biologists make nighttime trips to study the elusive loon, discovering evidence that mercury is destroying the birds' natural defenses.
Stories and photos, 11A-14A

And the presence of mercury in Maine's freshwater fish poses a serious human health risk – especially to women of childbearing age and to young children.

Yet, despite the fact that the federal government knows how to control it, mercury pollution is growing worse.

In a four-month investigation of mercury pollution in Maine, the Maine Sunday Telegram and Portland Press Herald found that loons are the species most at risk. But the problem runs much deeper:

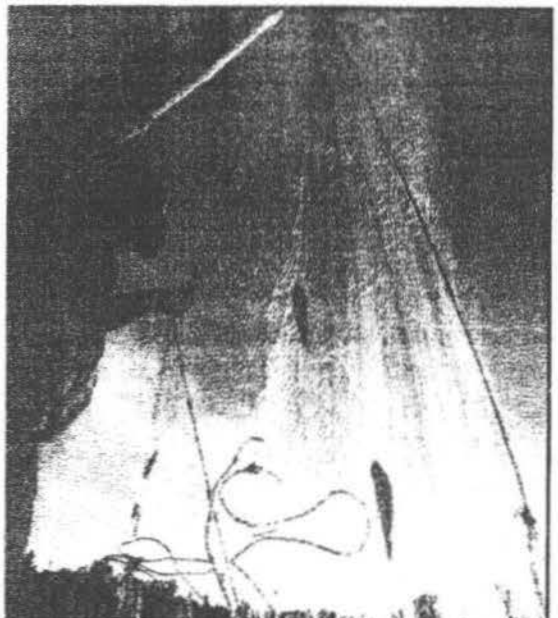
- Mercury is drifting into the state from unregulated coal-fired power plants in the Midwest and other sources closer to home. The solutions are known. In fact, the federal government has them in hand. But efforts in Washington to solve the problem have been strangled by the electrical power industry's influential lobby and by federal politics.

- Maine officials have failed in warning the public about how much freshwater fish they should eat. A new poll, conducted for this series, shows that fewer than 2 percent of Mainers know that pregnant women and nursing mothers put their children at risk of mercury poisoning by eating certain freshwater fish.

- For years, a chemical plant in Orrington that is Maine's largest source of mercury pollution has been spewing hundreds of pounds of mercury into the environment. But state regulators have allowed the plant – which serves the multimillion-dollar paper industry and provides 69 jobs – to keep running. Meanwhile, spills of mercury waste continue – two this summer alone.

Maine, other New England states and Nova Scotia have the worst mercury problems in North America, since they lie downwind from many of the major sources: coal-fired power plants, huge trash incinerators and chemical plants. But mercury has affected loons from the Atlantic Ocean to the Great Lakes.

Please see MERCURY, *Page* 11A



Drew Major, a wildlife biologist, pulls up a gill net in Rangeley Lake to study mercury levels in fish eaten by loons.

THE MERCURY MENACE

MERCURY

Continued from Page 1A

Mercury climbs relentlessly up the food chain, building to higher and higher concentrations in sediment, plankton, insects, fish and – finally – the loons that eat them.

For biologists, the loon is more than just an emblem of conservation. Because its diet consists almost exclusively of fish, which also contain high levels of mercury, the loon acts as an ecological sentinel.

Its recent problems ring alarm bells for the entire community of fish, animals and humans in Maine's northern forest region and beyond.

On every river and lake in Maine, people are warned to limit how much fish they eat because of mercury contamination. Thirty-four other states also post mercury warnings on all or some of their inland waters.

Right now, some fish are so toxic that a pregnant woman in Maine who eats them could give birth to a child who has trouble walking and talking. Children who eat too much freshwater fish could suffer damaged eyesight, sensation and muscle control.

But the most immediate threat is to the loon. As far as anyone knows, mercury itself hasn't killed any of the birds. Its effects are more subtle than a simple toxic overdose.

Weakened by their exposure to mercury, loons seem to be losing their ability to fight off diseases, elude predators and tolerate contact with humans who invade their nesting and feeding areas. That's the conclusion reached by biologists who have been studying the birds and their environment for nearly a decade.

"It won't be one of those things that becomes apparent overnight," said Neil Burgess, a biologist at the Canadian Wildlife Service. "By the time you figure it out, it may be too late."

Gov. Angus King says the mercury threat is among Maine's worst environmental problems. Yet dioxin, a toxic byproduct of papermaking that the industry has taken steps to reduce, grabs most of the public attention.

"Frankly," King said, "I think it's a more serious problem for Maine than dioxin."

But the King administration's response has been largely ceremonial. The governor has signed a resolution calling for a study and a plan. It likely will take months, or longer, before action is taken.

In the meantime, four out of every 10 Mainers don't even know a fish-consumption warning exists, according to a poll done for this series. Fewer than 2 percent of Maine residents can name the specific groups of people the warnings aim to protect.

In a recent report on mercury, the U.S. Environmental Protection Agency estimated that 85,000 women in the United States each year consume enough mercury to risk damaging their unborn children.

The EPA and other government agencies have known for decades that mercury is polluting American waters. They know where most of the mercury comes from, and they even have a pretty good idea how to control it.

But the federal government has been slow to act on what it knows.

Seven years ago, when the nation's major clean air law was updated, the EPA was required to look into mercury pollution and suggest what to do about it. Its 1,700-page report was completed in 1995, yet it still has not been released to Congress – an important step, as its release would signal the official start of the process of cracking down on polluters.

Powerful interests, including the electric utility industry and commercial fishing groups, have delayed the formal release of the EPA's findings by lobbying members of Congress and agencies in the Clinton administration.

The fishing groups worry that people will stop eating what their members catch. The power companies fear they will have to sacrifice some of their profits and spend more money on new pollution controls.

The EPA now says its mercury findings should be presented by year's end. Meanwhile, the threat from mercury pollution grows.

Coal burning, a major source of mercury pollution, is expected to increase steadily as society demands more electricity to light homes and power factories. Deregulation of the power industry could accelerate the coal-burning trend.

Deregulation will allow utility companies to compete against each other for retail customers, and whoever offers the cheapest power will win out.

Right now, some of the cheapest power available comes from coal-fired plants – especially old ones with minimal pollution controls.

Coal burning also may rise to offset the loss of nuclear power plants, which are facing shutdowns in growing numbers because of age, cost and safety concerns.

And industrial development in other growing nations, including new coal-burning plants in China and mercury-producing gold mines in Brazil, are adding to the global pool of mercury in the air.

Researchers familiar with mercury pollution wonder what it will take before government and industry finally address the threat.

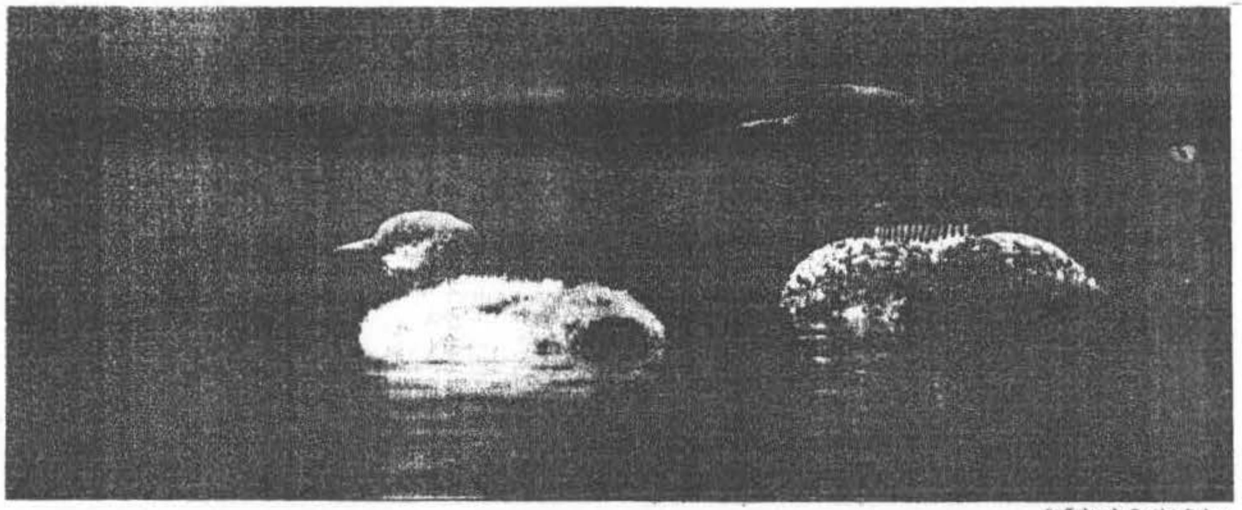
"We're seeing mercury in loons. We're seeing it in fish. And we've seen it in eagles," says Drew Major, a biologist with the U.S. Fish and Wildlife Service. "How many more nails do we need in the coffin?"

A threatened treasure

Nothing evokes the spirit of the Maine wilderness more than the melancholy cry of a loon echoing across a darkened lake.

Hundreds of Maine residents, trying to preserve what they can of that wilderness, have worked hard over the years to provide a place for the loons.

Please see MERCURY, Page 12A



Staff photo by David A. Rodgers

A loon swims with its chick on Squam Lake in New Hampshire. For biologists, the loon acts as an ecological sentinel. Mercury climbs up the food chain, building to higher concentrations in sediment, plankton, insects and fish. Loons then absorb the toxic metal by digesting the fish.

MERCURY

Continued from Page 11A

They've built nesting platforms to increase hatching rates, and they've taught many boaters to steer clear of loon breeding grounds. Others participate in an annual loon count sponsored by Maine Audubon Society.

These efforts have paid off by raising Maine's loon population to roughly 5,000 and strengthening the public's emotional bond to the bird.

When the state issued a special license plate in 1993 to raise money for conservation programs, the loon's image was stamped onto it, together with the phrase, "A Natural Treasure."

But mercury pollution threatens that treasure.

Wildlife biologists have found disturbing signs of trouble in loons in some of the most remote, undeveloped lakes and ponds in Maine.

One such place is Aziscohos Lake, a narrow, 15-mile-long body of water that twists and turns through the rugged mountains of northern Franklin County, not far below Maine's border with Quebec.

On a night in late July, a handful of researchers boarded a boat on Aziscohos. With the temperature dipping below 40 degrees, they crisscrossed the lake in the moonlight, stalking loons through a swirling fog.

They captured two birds in six hours, took blood and feather samples to be tested for mercury, then released the loons into the inky waters.

The principal researcher, David Evers, a wildlife biologist from Freeport, has been catching and testing loons from Nova Scotia to Alaska since 1991.

The loons from Aziscohos and other lakes in western Maine, such as Flagstaff and Umbagog, have some of the highest mercury levels recorded anywhere.

Seventy percent of the male loons caught in Maine and New Hampshire have mercury concentrations that biologists regard as critical – capable of damaging their health or ability to reproduce.

To make matters worse, Evers has seen mercury levels in loon feathers rise at a rate of 4 percent to 10 percent a year since his work began.

"Maine is a hot spot for mercury," Evers says. "When we do our loon work across the country, that's clearly what we find."

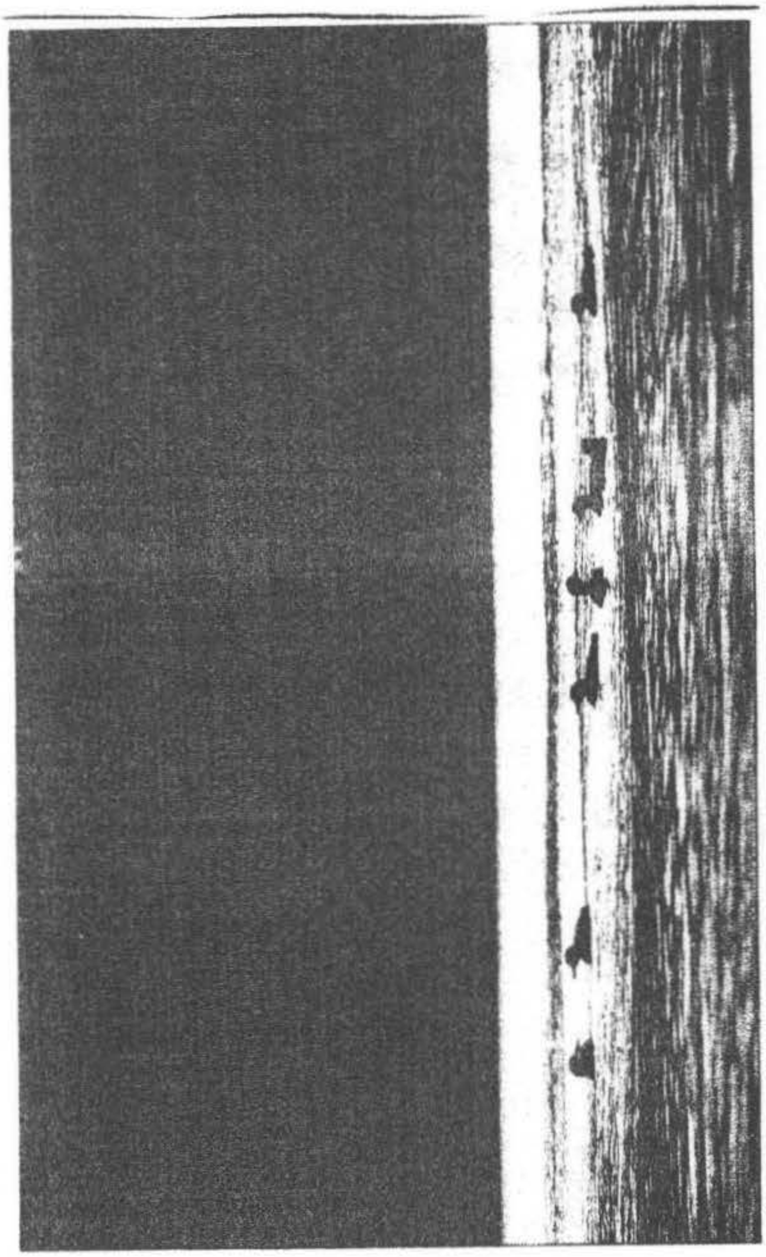
In the United States, mercury levels in loons increase from Western to Eastern states, reflecting prevailing wind currents and the concentration of industrial sources in the Midwest and Northeast.

The levels found in wildlife are measured in parts per million, a concentration so small it's difficult to comprehend. To make a concentration of 1 part per million, a tablespoon of mercury would have to be dissolved in 3,906 gallons of water.

The highest concentrations found in adult loons have been 35 parts per million, while the lowest have been less than 1 part per million.

But small amounts of mercury can have an impact:

- Last summer, at a lake in Ottawa National Park in Michigan, Evers watched a nest fail when a male loon with high mercury levels wouldn't sit on the eggs to incubate them, even after the female left to feed.
- Researchers at Tufts University, studying loon carcasses recovered in Maine and New Hampshire since 1988, found high mercury levels in birds that had suffered fatal puncture wounds in fights with other loons. That suggests that mercury may reduce the loon's ability to maneuver and defend itself.
- In the same period, Tufts researchers also found high mercury levels in birds that died of aspergellosis, a bacterial respiratory infection that kills an unusually high number of loons in the Northeast.
- When other birds in captivity are exposed to mercury at the levels found in some Maine loons – which die in captivity – the reproductive rates of the other birds drop dramatically.



HOW WE DID IT

The Maine Sunday Telegram and Portland Press Herald began looking into the mercury pollution problem last May.

During his investigation, staff writer Dieter Bradbury interviewed 40 biologists, environmental regulators, scientists and other experts about the extent to which mercury has permeated the environment. Also interviewed were 15 Maine residents, tourists and politicians.

More than 3,000 pages of government and scientific documents were reviewed during the research phase of this project.

Bradbury and photographer David A. Rodgers traveled to Ohio, where coal-burning power plants are used heavily. They went on an overnight loon hunt with a leading New England biologist, and talked to people enjoying themselves on Maine lakes where the loons are plentiful and the freshwater fishing is good.

WGME Channel 13 reporter and weekend host Marnie MacLean joined the project team in early September.

[illegible] findings portray mercury as a subtle, hidden menace. It may not kill a loon by itself, but mercury can cripple the bird's resistance to disease, predation and conflicts with humans.

In the face of a sudden, severe or prolonged stress from one or more of these other threats, the loon population could collapse, experts say.

"My gut feeling in talking with people across the country is that we're seeing an impact," Evers says. "Is the loon population able to withstand that impact? That's the coin toss right now."

Affecting the food chain

There's little doubt about where the mercury is coming from. The toxic metal settles out of the air and eventually washes into lakes and ponds. In the water, bacteria convert the mercury to an even more toxic form.

The bacterial action gets stronger when water levels fluctuate, so the highest levels of mercury are being found in lakes formed by dams. In some Maine lakes, water levels change by 30 feet over the seasons as dams open and close to release water for electric power production.

Highly acidic lakes also seem to have higher mercury levels.

Mercury is a threat not just to the loon but to other species in Maine. Since loons are a sentinel, standing atop the food chain, biologists who study them learn something about the health of the entire community of plants and animals in which the bird lives.

"If they're suffering from some problems, there's a pretty good chance the entire area is suffering from the same problems," says Major, the wildlife biologist at the U.S. Fish and Wildlife Service.

People eat fish, and face some risk from mercury as well.

Thirty-five states, including Maine, have warned people to limit their consumption of freshwater fish because of mercury contamination. In three states – Maine, Michigan and New Jersey – the warnings apply to all inland waters. Other states have advisories in selected areas.

Maine issued its warning in the spring of 1994, after an EPA program found pervasive mercury contamination in a statewide sample of 120 lakes.

Ironically, the highest mercury concentrations were found at Hodgdon Pond in Acadia National Park, a site that attracts millions of visitors a year who want to get in touch with nature at one of Maine's most beautiful spots.

Scientists and environmental regulators have known for years that mercury levels in the nation's air and water might be rising.

When the Clean Air Act was updated in 1990, Congress ordered the EPA to write a mercury study to help public officials decide whether regulations were needed to protect the environment and public health from mercury.

EPA's seven-volume report, covering 1,700 pages, estimates that U.S. industrial activity releases 245 tons of mercury into the air each year.

That's about two-thirds of total mercury emissions, with the rest coming from natural sources like volcanoes or other soil disturbances.

Ninety-eight percent of the industrial emissions are produced by household or medical waste incinerators, coal-fired power plants or commercial boilers and manufacturing processes.

Some of the mercury released into the air settles out close to its source. Some drifts for great distances.

In Maine, state regulators who have reviewed the EPA's work believe that much of the mercury found here drifts in from Midwestern or Atlantic states. But Maine also has local sources, including the state's four trash incinerators and an aging chemical plant in Orrington.

The Orrington plant uses mercury to make chlorine gas and a corrosive chemical known as caustic soda, two substances used widely by the Maine paper industry.

The company says it saves the paper industry $10 million a year in freight costs because of its proximity to Maine paper mills. It says it can't afford to switch to modern technologies that use no mercury.

And the King administration, which has courted the paper industry because of its impact on the Maine economy, allows the plant to continue releasing mercury into the air and the Penobscot River.

Criticism delays report

The EPA finished its work on mercury in 1995, and its findings have been backed by three independent groups of scientists outside the agency.

Yet the findings still have not been given to Congress. The EPA had planned to submit the report in April 1996, but the agency backtracked just days before the deadline, and held off for yet another scientific review.

The report has been heavily criticized by the National Fisheries Institute, a trade association for commercial fishermen. As a group, these fishermen provided $38.6 billion worth of seafood products to U.S. consumers in 1995.

In September 1995, the institute complained to the EPA and the Department of Health and Human Services that the report reached flawed conclusions on the health risks of mercury exposure by eating fish.

The institute said forthcoming studies of fish-eating populations will show that the EPA was overestimating the mercury risk.

It said the report "will create a problem where none exists, with the fallout being consumer confidence in our industry's products."

The institute's complaints were echoed by the Food and Drug Administration, which regulates commercial seafood. Several U.S. senators, including Majority Leader Trent Lott of Mississippi and Maine's Olympia Snowe – both Republicans – called on the EPA to withhold sections of the report dealing with seafood safety.

The senators said the EPA should wait for more scientific studies to be completed on mercury exposures from fish consumption.

The Edison Electric Institute, part of a utility lobbying group that spent $5.5 million fighting and lobbying against the EPA's new standards for smog and soot, also opposed release of the mercury findings.

It contended that the EPA overestimated the amount of mercury released by power plants. The institute also said the EPA report failed to incorporate new information downplaying the health effects of low doses of mercury.

Mercury emissions into the environment actually have declined in recent years, the electric institute says, as the toxic metal has been phased out of use in paints, many

Please see MERCURY, Page 13A

Kenneth Munney, left, a contaminants biologist for the U.S. Fish and Wildlife Service, helps wildlife biologist Drew Major bag a sediment sample from the bottom of Rangeley Lake. Airborne mercury washes into waterways, where bacteria convert it to an even more toxic form.

THE MERCURY MENACE

MERCURY

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batteries and other consumer products.

"Our feeling about the mercury report in the draft version is that they were not using the most appropriate and relevant science to date," said Linda Schoumacher, a spokeswoman for the institute.

The utility lobby's concerns have been picked up by members of Congress.

Sen. Robert Byrd, a Democrat whose home state of West Virginia is a major coal producer, urged the EPA in April 1996 to delay the release of its report.

Mary Nichols, the EPA's top air quality official, said it was prudent to delay the report for one more scientific review because of the criticism.

But others disagree.

They include Howard Fox, a lawyer for the Earthjustice Legal Defense Fund, an environmental group that has sued the EPA to submit the report to Congress. He accuses the EPA of caving in to lobbying pressure.

"I think it's unprecedented for the agency to say that new science must be created before it can issue a report," Fox said. "I think there are interests that believe it's very much to their advantage not to have any suggestion made that mercury is a problem."

Indeed, the Science Advisory Board, a federal panel attached to the EPA that reviews all agency studies, has already backed the mercury report.

MERCURY SOURCES

Here are the major sources of mercury in Maine and the estimated amount they discharge into the environment each year:

Holtra Chem Manufacturing, Orrington, 350 pounds

Regional Waste Systems, Portland, 30[illegible] pounds

Mid-Maine Waste Action Coalition, Auburn, [illegible] pounds

Maine Energy, Biddeford, [illegible] pounds

Penobscot Energy Recovery Co., Orrington, 8 pounds

Utility wood boilers (grouped together), 14.5 pounds

Commercial and industrial wood boilers (grouped together), 17 to 25 pounds

Source: Maine Department of Environmental Protection

The clock is ticking

The EPA now says it plans to submit the report by the end of this year. When that occurs, pressure will build for regulations to control emissions.

But those regulations, if enacted, may take years to go into effect.

In the meantime, the clock is ticking. The amount of mercury that drifts into Maine and settles on its lakes and ponds will almost certainly increase.

The federal government projects a steady rise in coal consumption through the year 2020, as more electrical power is produced to fuel the national economy.

Utilities stand on the verge of deregulation. They'll be competing against each other across broad geographic areas, trying to gain customers by offering the least expensive power available.

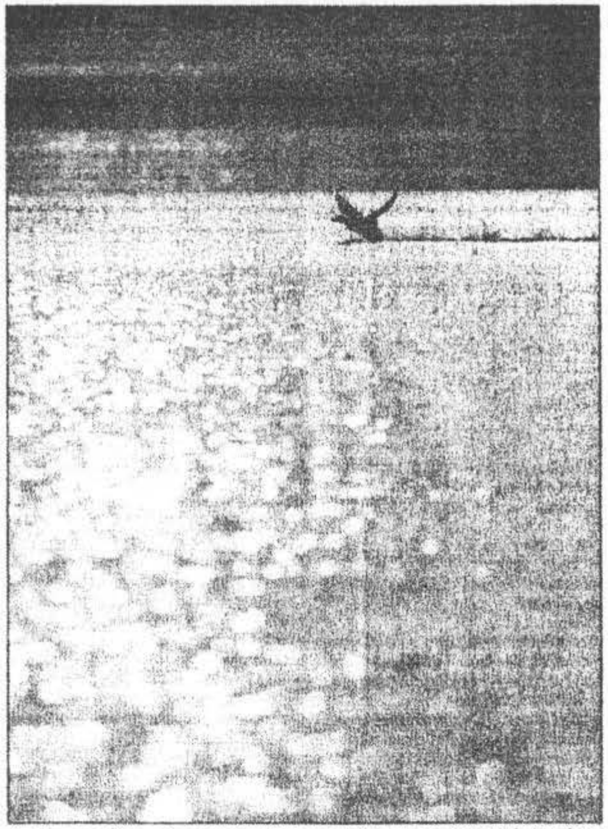
For biologists concerned about loons and other wildlife – and the ramifications their problems hold for people – the situation creates a compelling demand for more understanding, more knowledge of how mercury affects the environment.

Because of the problems found with the loon, researchers over the summer broadened their investigation by capturing live osprey in Casco Bay and testing them for mercury. Bald eagles, mergansers and kingfishers also will be watched.

At Acadia National Park, work has begun on tree swallows, which feed on insects from ponds in the park with high mercury levels.

Evers, the wildlife biologist who leads the research into mercury and Maine loons, has little doubt biologists will find that the impact of mercury pollution extends well beyond the symbolic bird.

"It may not be a crisis," he said. "But maybe we ought to regulate it now – before it becomes a crisis."



As the sun rises, a loon struggles to get airborne on Hancock Pond in Denmark. Mercury levels in loons increase in New England states, reflecting prevailing winds and sources in the Midwest and Northeast.

WGME-TV to air reports on mercury

● Marnie MacLean's series begins Monday

Marnie MacLean, a reporter and weekend host for WGME-TV Channel 13, will have three special reports on the mercury pollution problem.

Her reports will air on the 6 p.m. news shows starting Monday. The reports continue at 6 p.m. Tuesday and Wednesday.

MacLean joined staff writer Dieter Bradbury of The Portland Newspapers on the project early this month. Bradbury and photographer David A. Rodgers will be guests of MacLean's today at 8 a.m. on Channel 13's Sunday morning news program.

Press Herald Online also will make the series available via the Internet.

The online effort will provide links to other Web sites as well. For example, there will be a lake-by-lake evaluation of mercury levels. If you want to read about the issue in more depth, the address is: www.portland.com/mercury.

The newspapers, WGME and Press Herald Online are owned by Guy Gannett Communications, a Portland-based media company.

THE MERCURY MENACE

Into the night: Monitoring for mercury

● Biologists engage in nighttime forays to capture loons, which are tested for traces of the toxic metal.

By DIETER BRADBURY
Staff Writer

RANGELEY – David Evers crouches in the bow of his boat, a net clenched in his fists, as a searchlight punctures the darkness on Rangeley Lake.

Confused by the blinding shaft of light, a loon bobs nervously on the water as the boat inches closer. At the last moment the bird lowers its head, utters a loud wail and dives – too late.

Evers flicks his wrists, and the trapped loon thrashes wildly in the nylon net. "This is a big bird!" Evers grunts, nearly tumbling into the lake.

Evers, a wildlife biologist from Freeport, developed a technique several years ago for safely capturing the elusive loon in the wild.

His method gives researchers an invaluable tool for measuring mercury levels in the birds, studying how they're affected by the growing threat from the toxic metal and learning more about how mercury moves through the environment.

Until Evers came along, researchers could only speculate on how loons were affected by mercury, because no one has been able to keep the birds alive in the laboratory or any other captive setting.

Nearly 1,200 birds have been captured since the late 1980s using Evers' technique. Tests of their blood and feathers have provided information on mercury levels in freshwater lakes and ponds from Maine to Alaska.

Some of the loons have been recaptured four or five times over the years, yielding some of the most damning pollution information available. Mercury levels in the bird that symbolizes conservation in Maine are steadily rising.

Each captured loon fills in another piece of the mercury pollution puzzle. Evers' nighttime expeditions also offer a rare glimpse into the loon's furtive existence on the dark lakes of Maine's northern forest.

Rangeley Lake, encircled by mountains in western Franklin County, provides a home for at least six pairs of loons. By day, the birds share the lake with people who are paddling canoes, trolling for fish and straddling jet-skis.

But at night, Rangeley belongs to its wildlife.

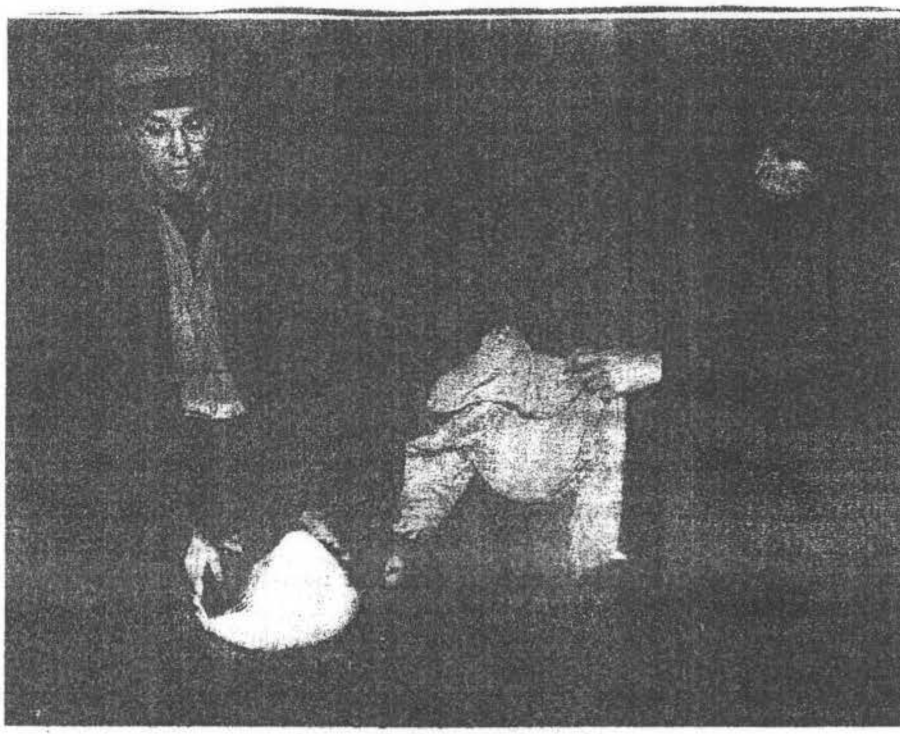
As Evers and three helpers motor across the lake in mid-June, their searchlights reveal only bats, ducks, insects and the glittery eyes of deer wandering to the shore for a midnight drink.

The crew cuts the engine and lets the boat drift. The stars admire themselves in the lake as Evers switches on a tape recorder with loon calls.

The wails drift into the night, echoing on the flanks of Bald Mountain and finally drawing an answering cry from the east.

"Over there," Evers whispers.

Behind wire-rimmed glasses and a boyish countenance, Evers, 35, possesses a deep knowledge of loons and their environment. His consulting firm, BioDiversity Inc., conducts cutting-edge research for the government and for private corporations on loons, other wildlife and toxic pollution.



ABOVE: A large male loon reacts as Kate Taylor, a biologist with the New Hampshire Loon Preservation Committee, removes a towel that had been wrapped around its head to quiet it during its brief capture on Rangeley Lake. Wildlife biologist David Evers restrains the bird. LEFT: Taylor takes notes as Evers and Rose Miconi of the Tufts University wildlife clinic take a blood sample from a loon. BOTTOM: Evers releases a loon after capturing and processing it on Lake Aziscohos.

In 1988, when he was a graduate student, Evers reasoned that loons might be caught by invading their territory during nesting season.

His technique relies on the hypnotic power of blinding light and the loon's overwhelming instinct to protect its eggs or chicks.

"Basically, we're trying to act like intruders," he explains, following the sweeping searchlight with his binoculars.

The light picks out a loon's downy white breast, and the outboard gurgles closer. Evers grabs his net, ready to pounce. But the bird pivots and dives, leaving a swirling eddy on the surface.

One of Evers' helpers guns the engine, and the boat cuts a tight circle. Evers picks up a second searchlight, and the two beams flash wildly over the water, trying to find where the loon will surface.

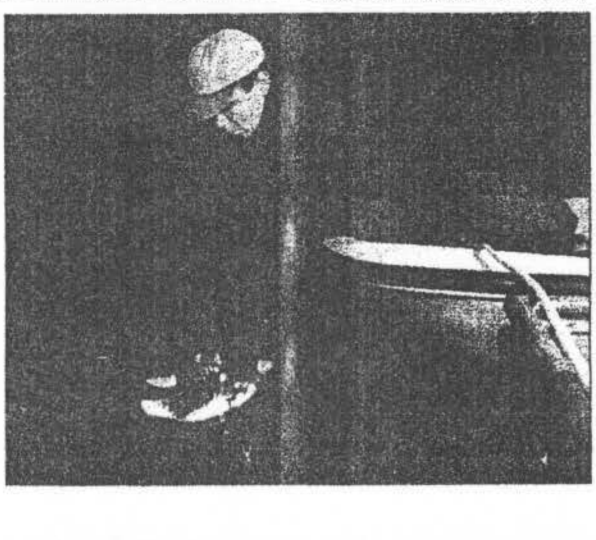
Fifteen seconds pass, then 20, then 30. The bird breaks the water 50 yards away, blowing a cloud of vapor into the air.

Again the boat closes. Again the bird dives. Again the crew circles.

After four or five tries, Evers decides the loon is too spooked. He directs the boat to another nesting territory, near South Bog Island.

"At this point it's just a crapshoot," he says.

Impatience creeps into his voice, but there is no trace of surprise. It's early in the summer yet, and the loon chicks haven't hatched. So the adults lack that powerful instinct to



protect their territories.

Loons lay one or two eggs in nests near the water's edge in early June. Both adults will sit on the nest during the incubation period – 29 days. Soon after they're born, the chicks learn to dive and catch prey.

For several weeks, they'll be fed tiny fish by their parents. Often the chicks will rest and avoid predators like snapping turtles or large fish by riding on their parents' backs.

During the chick-rearing period, Evers will catch 98 percent of the loons he pursues. Drew Major, a biologist at the U.S. Fish and Wildlife Service, has seen Evers spend hours patiently stalking a bird, refusing to give up even though it repeatedly dives to elude his net.

"It's just through sheer tenacity that he's gotten to where he is," Major says.

Out on Rangeley, tendrils of fog begin to rise from the water as the night wears on. The fog cuts visibility, and Evers knows this will probably be the last chance to catch a loon tonight.

Near the shore of the island he sights another bird, and the boat slips toward it. Three times the loon dives before Evers can reach it. Three times the crew circles for another try.

Finally, the boat makes a fourth approach, and the loon lingers on the surface a split-second too long. Evers wrestles the flapping bird into the boat, straddles it on the deck and wraps a hand around its powerful bill.

The boat's too crowded to examine the bird on board, so the crew ties up to a dock and clambers ashore near an unoccupied camp.

With Evers are Rose Miconi, from the wildlife clinic at the Tufts University School of Veterinary Medicine, and Kate Taylor, a biologist with the New Hampshire Loon Preservation Committee.

In a circle of light from one of the search lamps, the trio goes to work. They cover the loon's head with a bath towel to keep it calm and clip a feather from the back edge of each of its wings.

Miconi plunges a needle into one of its legs and draws 12 cubic centimeters of blood. Evers fastens bands on both legs for his record-keeping.

Taylor scribbles information on a data sheet, including the time and place of capture, general health observations and what was done to the bird.

Tests of the bird's blood will show how much mercury it was exposed to over the past two months, mostly from the fish it ate in Rangeley and the surrounding lakes where it might have fed.

Tests of the feathers will reveal long term mercury levels. Loons get rid of mercury by moving it into their feathers, so regular tests of feathers can shed light on how much mercury the bird has been exposed to over the years.

Evers puts the loon back into the mesh net and hangs it from a spring scale. It weighs in at 16 pounds, prompting Evers to crack a grin.

"That's the largest loon ever captured in North America," he says.

Twenty minutes after stepping ashore, the crew gathers its gear and heads back to the boat. Evers cradles the loon in his arms, wades into the lake and gently releases the bird in knee-deep water.

It paddles aimlessly for a minute or two, giving eerie cries and calls. Finally, it dives below the surface and disappears.

QUOTABLE

"It won't be one of those things that becomes apparent overnight. By the time you figure it out, it may be too late."

Neil Burgess, a biologist at the Canadian Wildlife Service, on the mercury threat

"Frankly, I think it's a more serious problem for Maine than dioxin."

Gov. Angus King

"We're seeing mercury in loons. We're seeing it in fish. And we've seen it in eagles. How many more nails do we need in the coffin?"

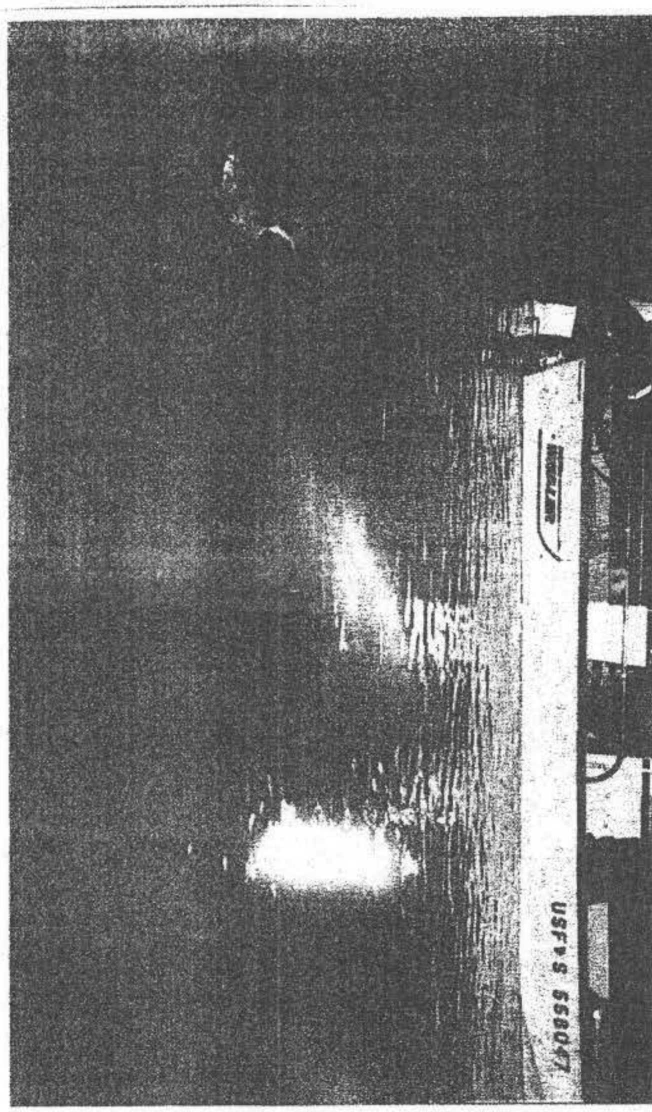
Drew Major, a biologist with the U.S. Fish and Wildlife Service

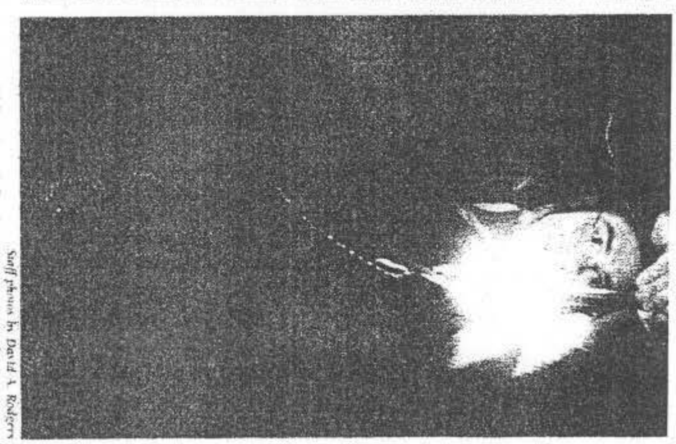
"Maine is a hot spot for mercury. When we do our loon work across the country, that's clearly what we find."

David Evers, wildlife biologist from Freeport

"I think mercury is something to be concerned about. What we have not been able to do is tie the levels we've found to a specific (problem)."

Dr. Mark Pokras, veterinarian and director of the wildlife clinic at Tufts University





Biologists keep a spotlight on a loon chick, left, after capturing one of its parents on Lake Aziscohos in northern Franklin County. Tests of blood and feathers provide information on mercury levels in lakes and ponds from Maine to Alaska. At right, wildlife biologist David Evers checks the scale as he weighs a large loon captured at night on Rangeley Lake.

Staff photos by David A. Rodgers

"Our feeling about the (EPA) mercury report in the draft version is that they were not using the most appropriate and relevant science to date."

Linda Schoumacher, Edison Electric Institute

"I think there are interests that believe it's very much to their advantage not to have any suggestion made that mercury is a problem."

Howard Fox, a lawyer for the Earthjustice Legal Defense Fund