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Assessment of mercury exposure and potential effects on common loons (*Gavia immer*) in Québec

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Abstract

Results from recent studies report increases in mercury in the environment and increased bioaccumulation in aquatic food webs. The Canadian Wildlife Service (CWS) and the Canadian National Park Service initiated this study to determine whether common loons (*Gavia immer*) are exposed to sufficiently high mercury concentrations in prey fish to impair their reproduction and survival. Monitoring of loon reproduction, measurement of lake physicochemistry, and fish sampling for mercury analysis were conducted in various regions in Québec, Canada, during summers from 1997 to 2002. Reproductive success was assessed and loons were captured at night and banded. Blood and feathers were collected to measure mercury. Mean blood and feather Hg concentrations in males (2.6 μg/g w.w and 17.6 μg/g d.w.) and females (1.8 μg/g w.w and 8.9 μg/g d.w.) were within the normal range of samples from north-eastern North America. However, one third (33%) of the loons sampled had mercury levels in blood or feathers exceeding the high risk levels for health and reproduction. Loons from western Québec showed significantly lower Hg levels than those from eastern Québec, both in blood and feathers. This study will help to determine the potential effects of mercury on the Québec and North-American loon population and provide information to assist in decisions on pollution abatement policies.

Introduction

Many recent studies report increases in mercury (Hg) from anthropogenic sources in the environment and increased bioaccumulation in aquatic food webs (Fitzgerald et al., 1998; Scheuhammer & Graham, 1999). Analysis of sediment cores from lakebeds indicates that current rates of Hg deposition are greater than pre-industrial levels (Lucotte et al., 1995; Kamman & Engstrom, 2002). Studies comparing fish Hg concentrations with rates of atmospheric deposition have found that these sources account for much of the Hg loading into aquatic ecosystems (Fitzgerald, 1995; Lucotte et al., 1995; Rudd, 1995). Levels of mercury in fish in many regions of eastern North America are high enough to affect reproductive success and health of piscivorous birds like the common loon *Gavia immer* (Brunnich) and mammals. Elevated methylmercury (MeHg) levels have been demonstrated to affect the behavior, reproduction, and survival of wildlife (Eisler, 1987; Thompson, 1996; Wiener & Spry, 1996), are related to neurological, immunological, and genetic toxicosis (Wolfe & Norman, 1998), and disrupt the biochemical functions with cortisol (Friedmann et al., 1996) in fish and cholinesterase in quail (Dieter, 1974). Organisms at the top of the aquatic food chain can be affected by higher mobilization of metals caused by acidity and their

accumulation in fish, in addition to being affected by ecological changes resulting from acidification (Scheuhammer, 1991; Wiener & Spry, 1996). Although sulfate depositions have been declining markedly since 1990, current deposition levels are still above the critical load in sensitive regions of eastern Canada and southwestern Québec (Jeffries et al., 2003). The common loon is a useful indicator of mercury in the environment (Meyer et al., 1995; Burgess et al., 1998a, b; Evers et al., 1998; Evers et al., 2003) and of recovery of aquatic food chain from acidification because of its longevity, fidelity to breeding territory on freshwater lakes, obligate piscivorous diet and ease of observation (McNicol, 2002). Although mercury exposure in loons has been reported from various regions across North America (Meyer et al., 1995; Burgess et al., 1998a, b; Meyer et al., 1998; Scheuhammer et al., 1998; Evers et al., 1998), no study has focused on regions of high acid deposition in Québec.

This paper presents the results of a study initiated in 1997 to document Hg contamination in loons in regions of high acid deposition in Québec and determine whether they are exposed to Hg concentrations in prey fish sufficiently high to impair their reproduction and survival. We present Hg concentrations in loon blood, feathers and eggs as well as in prey fish. We examine the relationships between Hg contamination, lake pH and characteristics, and loon productivity.

Methods

Sample collection

From 1997 to 2002, common loons were surveyed and sampled on 24 lakes from various regions in Québec: Outaouais, La Mauricie and the Laurentides. Sites were selected on the basis of available information on productivity and included La Mauricie National Park (LMNP), three wildlife provincial reserves, Portneuf, Mastigouche and St. Maurice Reserves, Mont-Tremblant Park and lakes outside the parks (Fig. 1). Most lakes were situated on the Precambrian shield and remote from point source Hg emissions. Loons were captured from canoes and small motorboats using the night lighting capture technique developed by BioDiversity Research Institute (Evers, 2001). A million-candlepower spotlight, tape recordings and mimicked vocalizations of loon calls attracted family groups to the boat. Individual loons were caught with a large landing net, restrained, and brought to shore. Both second secondary flight feathers were removed from adult birds by cutting at the calamus (below the base of the feather vane). Blood samples were taken from the medial metatarsal vein with 20–25 gauge butterfly needles fitted with multiple sample Luer Adapter into 7 cc Vacutainers® containing powdered sodium heparin (green top), 5 cc Vacutainers® containing calcium EDTA (purple top), and 5 cc Vacutainers® containing no additive (red top). All loons were uniquely marked with an aluminum USFWS band and 1–3 colored leg bands glued with an acetone-based adhesive. Finally, each individual was weighed prior to being released unharmed in its respective territory. Each family was monitored to ensure that adults and juveniles regrouped after capture. Unhatched eggs from failed nesting attempts were also collected opportunistically. Detailed productivity information on breeding loons was available for lakes in LMNP since 1987 as well as for lakes from the Canadian Lakes Loon Survey (McNicol et al., 1995). On other lakes, productivity data were collected as much as possible through the study period.

Small fish of various species representative of loon prey (10–20 cm; Barr, 1996), were collected from the lakes using minnow traps, nets or angling with worms. Fish were sacrificed with a blow on the head, stored in whirl-paks, placed on ice and frozen within 48 h of collection. Fish were later thawed, measured (total length), weighed and homogenized in composite samples of 3–5 whole fish of like species for Hg analysis.

Detailed lake physicochemical data were available from LMNP and a few others. On other lakes, an integrated water sample (generally 1–5 m depth) was collected in the middle of the lake with a van Dorn sampler. pH was measured in the field with a portable Oakton pH-meter and secchi depth was also taken. In addition to those sampling efforts, data on loon productivity and physicochemistry were collected and small fish were sampled on an additional set of lakes to

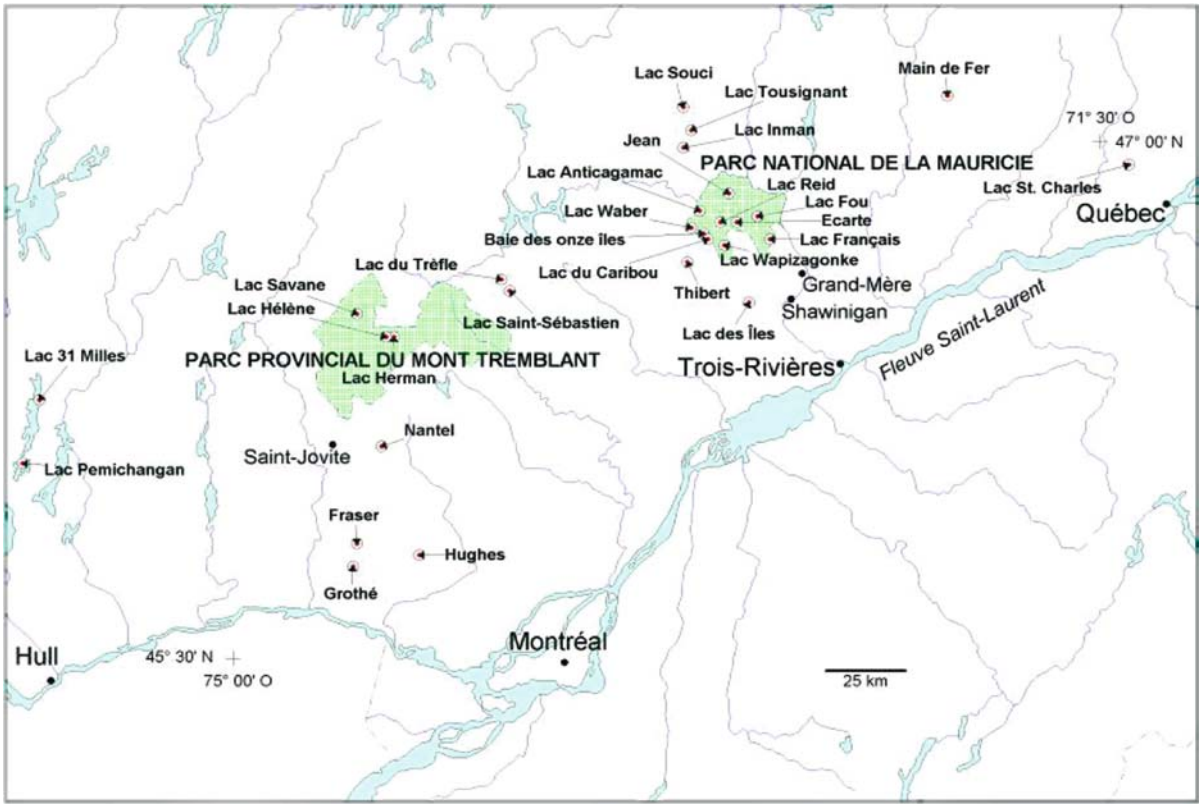

Figure 1. Common loon study sites and lakes sampled in Québec, 1997–2002. Location of major cities also shown.

increase sample size, in order to further document factors responsible for variation in loon productivity.

Sample analysis

One feather from each adult and a blood sample from each individual loon were analyzed for total Hg concentrations at the National Wildlife Research Centre (NWRC, Ottawa, Canada) of the Canadian Wildlife Service, following the standard procedure described in the Laboratory Services Manual under MET-CHEM-AA-03D and MET-CHEM-AA-03E (Neugebauer et al., 2000). The NWRC also analyzed all fish and egg samples. Feathers were cut (calamus discarded) and washed in Triton X, acetone and deionized water, dried in a clean air station, digested overnight and diluted to volume. An aliquot of the sample was then taken and analyzed for total Hg by cold-vapor atomic absorption spectrometry (3030-AAS, Perkin-Elmer). A 100 mg aliquot of each homogenized whole blood sample was digested with 2 ml conc. HNO_3 overnight, diluted to volume with ultra pure water, and analyzed by cold-vapor atomic absorption spectrometry. Eggs and fish samples were freeze-dried, digested and analyzed. After 2001, total mercury in the blood, fish and egg samples was determined without acid digestion on the AMA-254 (Advanced Mercury Analyzer, ALTEC, Czech Republic) which employs direct combustion of sample in an oxygenated decomposition furnace, and feather samples were acid digested and analyzed on the AMA-254. Quality assurance results on reference materials and interlab check samples from the CFIA (Canadian Food Inspection Agency) gave confidence that the instrument gives accurate readings comparable to CVT-AAS. The accuracy was determined by concurrent analysis of standard reference materials (SRM DOLT-2 and DORM-2, National Research Council of Canada, Ottawa, Canada), procedural

blanks and random duplicate samples. All recoveries of Hg from reference materials were within the certified range. The mean (±SE) recovery of 26 SRM analyses was 97.5 ± 8.4 with a range of 80–116%. Both methods' detection limits were 1.0 ng/g. A few chick blood samples as well as samples from the Outaouais region were analyzed at the Animal Health Diagnostic Laboratory at Michigan State University in 1997 and the University of Pennsylvania in 1998, 1999 and 2001 following comparable protocols.

Statistical analysis

Normal distribution of data was tested prior to other analyses and was found to be abnormal for most variables. Mean Hg levels in blood and feathers were compared between adults, chicks, sex, lake and regions using the non-parametric Kruskall–Wallis test. Mercury levels of adults captured twice were averaged. For lake and region comparisons, Hg levels of males, females and chicks were averaged by lake. Non-parametric Spearman rank correlations were calculated among variables. Loon and fish Hg concentrations were log-transformed to calculate linear regressions. All statistics were calculated using JMP™ Software (SAS Institute, 1999).

Results

Lake morphometry and physicochemistry

Lakes surveyed had a surface area varying from 0.1 to 49.7 km^2 and a drainage area between 1.3 and 165 km^2 (Table 1). Mean pH was 6.30 for the 24 lakes where loons were sampled and 6.74 for all the lakes monitored. pH was higher in the western region of Outaouais, probably because of catchment geology.

Mercury in loon blood, feathers and eggs

Between 1997 and 2001, 85 loons were sampled on 24 lakes. Of those, 58 were adults (34 males four of which were recaptures and 24 females) and 27 chicks. Blood and feather Hg concentrations for adults and chicks are presented in Table 2. Adult males had significantly higher feather Hg concentrations than females ($p < 0.001$). Chicks had significantly lower blood Hg concentrations than males ($p < 0.0001$) and females ($p < 0.0001$). A significant difference also appears among regions: loons from western Québec (Outaouais region: lakes Pemichangan and Trente-et-un-Milles) show lower Hg levels than those from eastern Québec, both in blood (males: $p < 0.001$; females: $p < 0.001$) and in feathers (males: $p < 0.01$; females: $p < 0.04$). This difference was not related to difference of size, since males and females from both regions were not different in size ($p = 0.32$). Mean mercury concentrations in 10 eggs collected from 9 lakes in the eastern region was 0.74 μg/g w.w. (range 0.42–1.55 μg/g w.w.).

At Lac des Iles, in La Mauricie region, adult and juvenile blood Hg concentrations were double those at other sites in Québec. The only chick for which Hg was measured in feathers came from that lake and showed a high level for a chick despite its large weight (blood: 1.80 μg/g; feather: 26.68 μg/g). One male from Lac Caribou, captured twice, had a feather Hg concentration more than two times higher than any other loon in this study (54.9 and 83.04 μg/g, mean 68.97 μg/g).

Feather Hg levels were positively related to blood Hg levels in both males (Spearman $r = 0.77$, $p < 0.0001$) and females (Sr = 0.73, $p < 0.001$). Male blood Hg levels were positively related to female blood Hg levels (Sr = 0.83, $p < 0.001$), however, male feather Hg levels were not related to female feather Hg levels. Egg Hg levels showed a significant relation with female blood Hg (Sr = 0.81, $p = 0.05$), while chick Hg levels were marginally related to female blood Hg levels (Sr = 0.58, $p = 0.06$).

Loon productivity

Productivity information on breeding loons in LMNP has been collected for 16 years. Productivity information has also been collected for many other lakes in Québec by volunteers in the Canadian Lakes Loon Survey, a program administered by Bird Studies Canada (McNicol et al., 1995). CWS also monitored a number of other lakes. The mean productivity (number of chicks fledged per territorial pair per year) in Québec for the past 6 years (1997–2002, minimum 3 years of data per lake needed to use the data) is 0.57 ± 0.38 ($n = 76$

Table 1. Morphometry and physicochemistry data for lakes sampled and monitored in Québec

	Lake sampled ($n=24$)					Lake monitored ($n=77$)				
	n	Mean	SD	Min	Max	*n*	Mean	SD	Min	Max
Lake area (km^2)	24	3.9	9.8	0.1	49.7	76	2.3	6.1	0.1	49.7
Drainage area (km^2)	11	36	48	1	166	28	18	33	1	166
Altitude (m)	24	311	106	152	511	76	320	137	151	804
Maximum depth (m)	20	32	17	6	88	41	30	18	5	88
pH	23	6.30	0.67	4.59	8.28	76	6.73	0.87	4.59	8.84
Alkalinity (mg/L)	11	3.7	5.2	−0.9	20.1	30	2.8	3.4	−0.9	20.1
Secchi depth (m)	23	5.0	1.5	2.3	7.6	72	4.8	1.5	1.3	8.0
DOC (mg/L)	11	3.8	1.1	2.5	6.7	30	4.5	1.4	2.5	8.2

territories, range 0–1.67). The mean productivity for the 24 lakes where loons were sampled was 0.68 ± 0.35 (range 0–1.5). No relationship was observed between loon productivity and associated loon Hg levels for the territories sampled in Québec.

Mercury in fish

Mean Hg concentrations in prey size fish (10–20 cm) from the 24 lakes where loons were sampled was 0.15 ± 0.06 μg/g w.w. (range 0.06–0.32). Mean Hg levels in prey size fish from all the lakes where small fish were sampled was 0.14 ± 0.07 μg/g w.w. (range 0.03–0.34, $n=56$). Most common fish species collected were Yellow Perch, *Perca flavescens* (Mitchill), Creek Chub, *Semotilus atromaculatus* (Mitchill), Pumpkinseed, *Lepomis gibbosus* (L.), and Brook Trout, *Salvelinus fontinalis* (Mitchill). Yellow perch was the target species and was used wherever possible, but was obtained in only 6 of the 24 lakes. Fish from Lake Pemichangan, in Outaouais, where loon Hg levels were lower, had Hg levels in the lower portion of the range but comparable to other lakes from eastern Québec (18.5 cm yellow perch: 0.10 μg/g w.w.; 12.9 cm pumpkinseed: 0.05 μg/g w.w.). There was a significant positive relationship between Hg levels in fish and Hg levels in male, female and chick blood (Fig. 2) as well as in female feathers, but not between Hg levels in fish and loon productivity (Table 3).

Table 2. Mean (standard deviation and range) weight and blood and feather mercury concentrations for adult common loons and chicks in Québec

	N	Weight (g)	Blood Hg (μg/g w.w.)	Feather Hg (μg/g d.w.)
Males	34	4735 (671)	2.55 (2.19)	17.59 (14.88)
		2650–5750	0.32–11.19	5.00–83.04
West	10		0.69 (0.29)	9.86 (3.37)
East	24		3.32 (2.18)	20.81 (16.63)
Females	24	3804 (424)	1.77 (1.94)	8.87 (4.06)
		3250–4700	0.17–8.29	3.30–20.86
West	8		0.51 (0.23)	6.21 (2.34)
East	16		2.40 (2.12)	10.04 (4.16)
Chicks	27	1779 (810)	0.35 (0.37)	26.68 ($n=1$)
		400–3700	<0.0125–1.80	
West	1		0.01	–
East	26		0.36 (0.37)	26.68 ($n=1$)

Relationships with lake parameters

Within the 24 lakes where loons were sampled, pH show significant negative relationships were detected between pH and Hg levels in male blood (Fig. 3a) and feathers (Table 3). No significant relationship was detected between Hg levels in fish and loon productivity at these lakes. Lake area, perimeter, altitude and dissolved organic carbon (DOC) all show significant relationships with loon Hg levels (Table 3). Hg levels tend to decrease with increasing lake area and perimeter, and increase with increasing altitude and DOC. Adding the additional lakes allowed the detection of other relationships. With 77 lakes, we find that loon productivity tends to increase with lake drainage area ($Sr=0.47$, $p<0.01$) and pH ($Sr=0.30$, $p<0.01$), and fish Hg tend to increase with DOC ($Sr=0.48$, $p<0.01$) and decreasing pH ($Sr=-0.43$, $p<0.001$; Fig. 3b).

Table 3. Spearman correlations ($p < 0.05$) between loon mercury concentrations and other variables ($n = 24$ lakes)

	Fish Hg	Male blood Hg	Male feather Hg	Female blood Hg	Female feather Hg	Chick blood Hg
Fish Hg		0.45		0.79**	0.74*	0.73*
Lake area	−0.39			−0.49	−0.51	−0.64*
Perimeter					−0.49	−0.56
Altitude		0.43				
DOC				0.75		
pH		−0.78**	−0.65*			

*$p < 0.01$.
**$p < 0.001$.

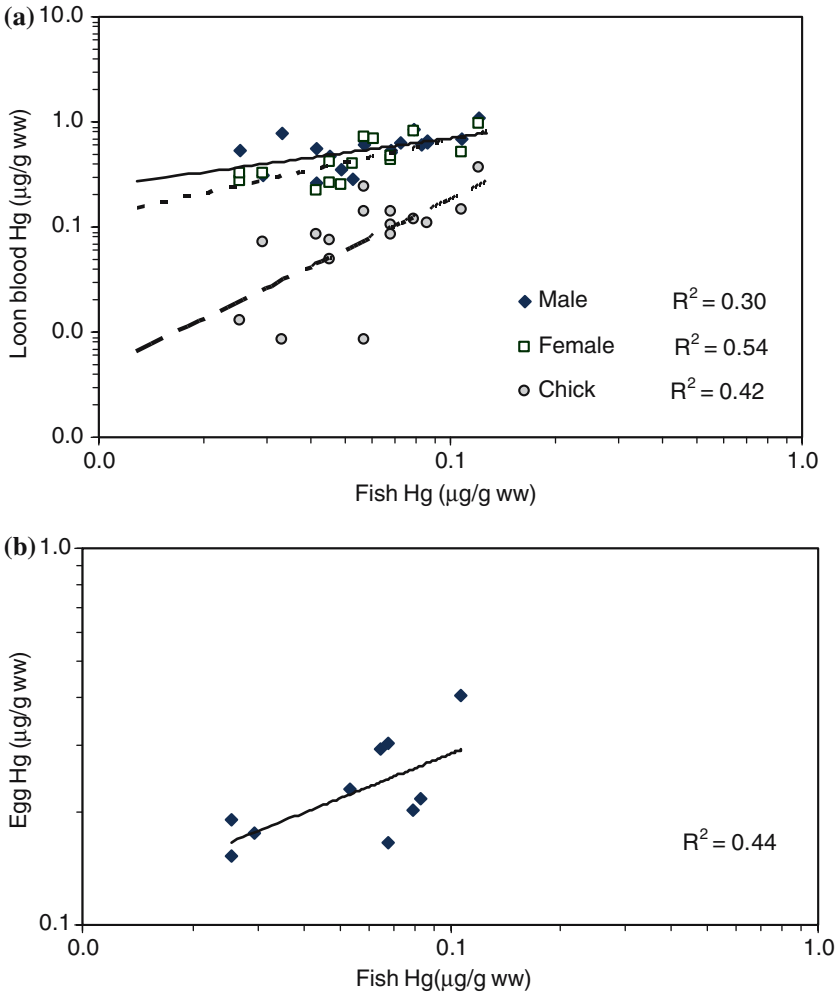

Figure 2. Fish mercury concentrations in relation to: (a) loon blood mercury concentrations (males, females and chicks); (b) loon egg mercury concentrations.

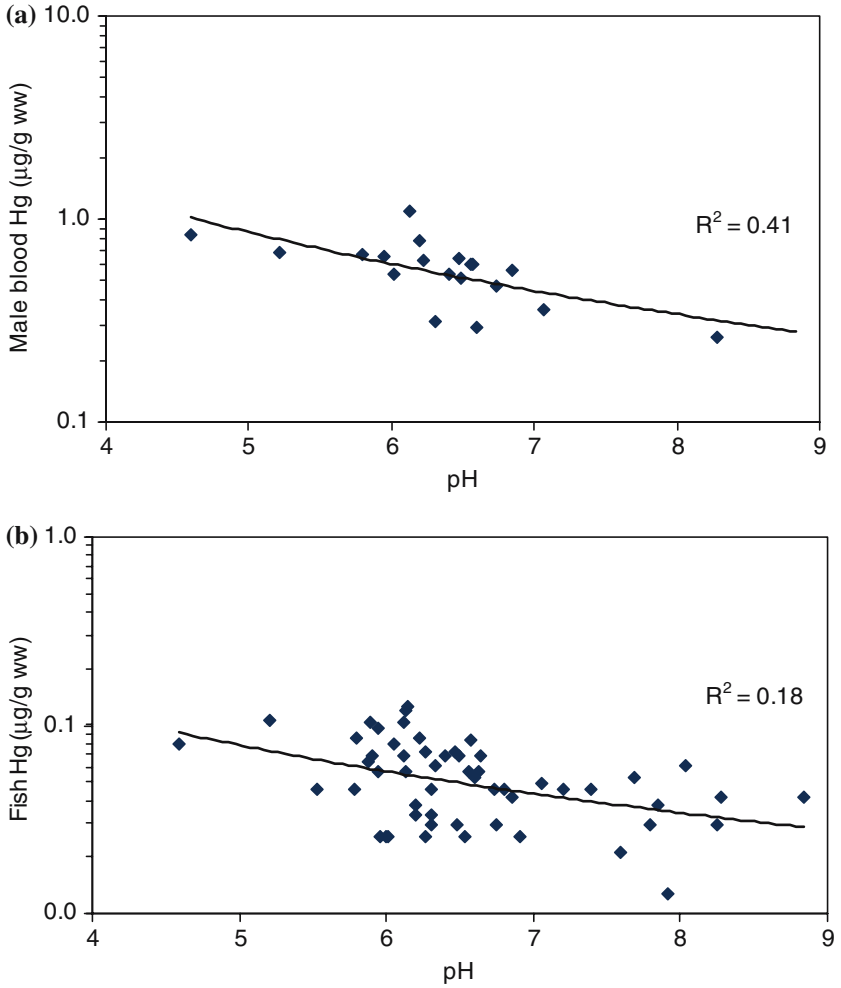

Figure 3. Lake water pH in relation to: (a) male loon blood mercury concentrations; (b) fish mercury concentrations.

Risk evaluation

Previous studies by the authors and their collaborators as well as literature were used to develop risk categories for three matrices (Evers et al., 2002, 2003; Table 4). Low risk indicates background levels. Moderate risk comprises loons from territories with elevated MeHg availability but levels most likely do not impact individuals. Loons in the high risk category are exposed to toxic levels of Hg that have potential effects on the organism. The extra high category comprises Hg levels with known impacts on loons and other birds. Mean concentrations in Québec loons are moderate and within the normal range of Northeast samples, however, 33% of individuals (26% of adults and 48% of chicks) exceeded the threshold level for high risk in blood and, 17% (15% of adults and 22% of chicks) exceeded the threshold for extra high risk in blood. Loons from eastern Québec appear to be second after Nova Scotia's loons in terms of risk from the negative effects of Hg exposure in North America (Fig. 4).

Discussion

Adult male loons typically have higher Hg levels than females in both blood and feathers (Evers et al., 1998). The differences in Hg concentrations between sexes could be attributed to different prey selection by the two sexes. Male common loons are

Table 4. Risk categories for methylmercury availability in the Common Loon

Matrix	Low	Moderate	High	Extra high	Reference
Eggs (μg/g w.w.)	0–0.6	0.6–1.3	1.3–2.0	>2.0	Barr, 1986; Evers et al., 2002
Blood-adult (μg/g w.w.)	0–1.0	1.0–3.0	3.0–4.0	>4.0	BRI[a]
Blood-juvenile (μg/g w.w.)	0–0.1	0.1–0.3	0.3–0.4	> 0.4	Meyer et al., 1998
Feather (μg/g d.w.)	0–9.0	9.0–20.0	20.0–35.0	>35.0	BRI[a], Thompson, 1998

[a]BRI: Biodiversity Research Institute.

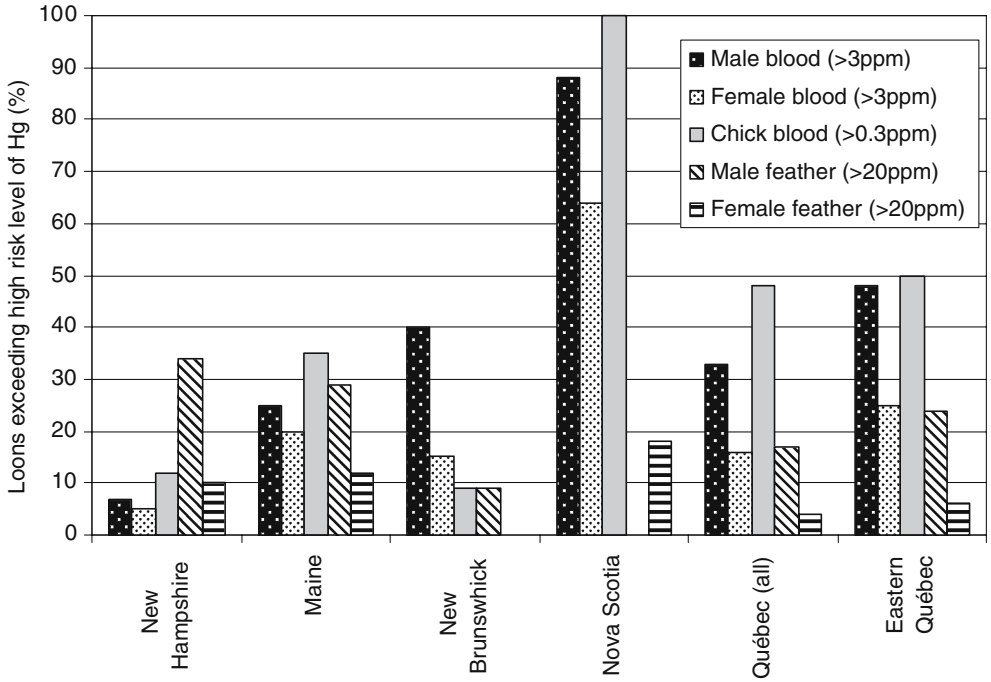

Figure 4. Common loons exceeding high-risk level of mercury in blood and feathers across North America.

bigger than the females and therefore may select and consume bigger fish with higher Hg concentrations. In addition, females can depurate some of their Hg burden in eggs.

On average, blood and feather Hg concentrations in loons from Québec are comparable to the mean of the Northeast but are elevated in comparison with control sites in the Northwestern United States and Alaska (Evers et al., 1998). Hg concentrations in loons from western Québec are low and similar to Alaska concentrations, while those from eastern Québec are higher than in other northeast areas except Nova Scotia. Many factors may be playing a role in this difference among the two regions. Only two very large lakes with many loon territories were sampled for loons in the western region. Those lakes have a basic pH (8.28), probably because of a different catchment geology. Those factors may well explain the lower biomagnification of Hg in the food chain of those two lakes.

Adult whole blood and feather Hg concentrations across North America show a highly significant positive relationship ($F = 55.4$, $p < 0.001$), however, the correlation coefficient is weak ($r^2 = 0.20$; Evers et al. 1998). The significance of the blood–feather relationship increases from west to east with increasing Hg concentration.

Blood represents a good indicator of recent dietary Hg uptake while feathers are recognized as

a major excretory pathway for Hg (Evers et al., 1998). 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, 1988), it is one of the better matrices for determining exposure on a breeding lake. Wolfe & Norman (1998) showed a significant correlation between blood and brain Hg. Feather Hg, which is sequestered in the winter during a full remigial molt, is directly related to breeding ground Hg ingestion at sites with high Hg concentrations in the prey. Loons breeding on lakes with low Hg levels do not bioaccumulate high amounts of Hg and therefore do not have extra Hg to excrete into their feathers.

Blood Hg concentration in juveniles is an excellent indicator of local Hg availability, since loon chicks are fed exclusively from the natal territory. The chicks large enough to sample had high blood Hg burdens for their age compared with those presented in Evers et al. (1998) for North America (mean 0.16 μg/g, range 0.03–0.78 μg/g). However, other piscivorous species also had similar or higher levels. Great Blue Heron chicks, *Ardea herodias* (L.), from the St. Lawrence River had mean blood and feather Hg concentrations of 0.66 and 5.21 μg/g (Champoux et al., 2002). Mean blood and feather Hg concentrations in Osprey chicks, *Pandion haliaetus* (L.), from hydroelectric reservoirs were 1.94 and 37.35 μg/g (DesGranges et al., 1998).

Adult loons from Lac des Iles had extremely high blood Hg levels but moderate feather concentrations, suggesting that the breeding adults were relatively young birds, and had not had time to bioaccumulate Hg. The high Hg levels in birds from Lac des Iles could be explained in part by the fact these birds were among the heaviest loons captured and hence may consume larger fish with higher Hg levels. One 16 cm Yellow Perch from this lake had a Hg concentration of 0.32 μg/g. Lac des Iles is a relatively small lake (0.6 km^2), moderately acidic (pH = 6.1) and with a moderate secchi depth (4.1 m), factors that may contribute to some biomagnification of Hg but do not explain completely the high levels observed.

Egg Hg levels are comparable to those from New England (Evers et al., 2003) and Canada (Scheuhammer et al., 2001). The significant positive relationship between female blood Hg and egg Hg reflects the depuration route of MeHg from females to eggs (Evers et al., 2003). Although these authors found that egg Hg concentrations reflect prey Hg from the lake, this relation was not significant for our small dataset ($n = 10$, $Sr = 0.58$, $p = 0.08$). One other factor that may explain this weak relation is that although eggs and females came from the same lake, they were not necessarily from the same territory or sampled the same year.

Productivity information on breeding loons in Québec has been collected for the past several years. In northern Saskatchewan, stable populations produce 0.535 fledged young/pair/year (McIntyre & Barr, 1997). The 25-year mean loon productivity for New Hampshire is 0.52 ± 0.09 birds/territorial pair/year (K. Taylor, pers. com.). For comparison, the number of fledged chicks/territorial pair/year in Kejimkujik National Park, Nova Scotia was 0.28, the lowest productivity among sites currently included in the North American Loon Biomonitoring Program (Kerekes & Masse, 2000). The blood mercury levels in Kejimkujik Park were significantly greater than those in all other study areas. In the Maritimes, the maximum productivity of loons with low blood mercury (<2.5 μg/g) was 1.0 fledged young per territorial pair, while loons with high blood mercury (>6.0 μg/g) produced only 0.2 fledged young per pair (Burgess et al., 1998b). These authors observed a pattern between productivity and loon blood Hg similar to that observed in Québec: although it was clear that loons with high Hg levels always had poor reproductive success, the correlation was not significant. In this study, Hg appeared to limit the nesting rate of territorial pairs and their hatching success (Burgess et al., 1998b). Many factors may affect chick survival and no apparent relationship was observed between productivity and associated Hg levels for the territories sampled in Québec. Meyer et al. (1998) found that four to 8 week old loons with blood Hg levels of 0.30 μg/g or higher were associated with territories where fewer chicks hatched or survived to 8 weeks of age.

Barr (1986) found reproductive impairment in loons (e.g., reduced egg laying and territorial fidelity) feeding on fish with 0.30 μg/g Hg and no reproduction in loons feeding on fish with 0.40 μg/g or more. Evers et al. (2002) present evidence to suggest that the threshold prey Hg concentration in is closer to 0.15 μg/g w.w. Although forage fish with Hg concentrations higher than

0.3 μg/g have been found in many areas (Evers et al., 1998; Burgess & Hobson, 2004), we only found three samples with this level and mean lake fish Hg levels were below 0.3 μg/g. A total of 24 lakes out of 56 (43%) have fish Hg levels over 0.15 μg/g. The different trophic levels occupied by the various species of fish that we were able to sample in our lakes explain the weakness of some of the relationships observed. Yellow perch is considered the preferred prey of loons (Barr, 1996) and is known to accumulate Hg, however, it could not be sampled on all lakes. Other common species like the brook trout generally have lower Hg levels at loon prey size, although bigger specimen can accumulate higher levels. Fish community structure and benthic invertebrate populations may also influence Hg bioaccumulation (Wong et al., 1997).

Threshold blood Hg levels of effects in adults are relatively unknown. Evers et al. (2002) have categorized adult loon blood Hg levels based on qualitative observations of effects in the wild and associations with highly contaminated lakes. Adult loons with blood Hg levels of 2–3 μg/g are considered at moderate risk and those over 3 μg/g are at high risk to effects from Hg contamination. Fourteen (10 males and 4 females) of the 54 adult loons sampled (26%) and 13 (48%) of the 27 chicks sampled in Québec were in the high-risk category. All loons captured on Lac des Iles were at extra high risk to Hg contamination.

Feather Hg threshold levels vary according to feather type and bird species. Few species other than seabirds and raptors typically have feather Hg concentrations greater than 15 μg/g (Burger, 1993). Eisler (1987) considered 5 μg/g while Heinz (1979) suggested 9 μg/g Hg as a LOAEL for feathers. Scheuhammer (1991) and Thompson (1996) consider a higher risk threshold of 20 μg/g and the co-authors have observed abnormal behavior in loons with feather Hg above 30 μg/g (Evers and Lane, pers. com.). Of the 30 adult male birds sampled 5, or 17%, exceeded 20 μg/g in Québec. The high feather Hg level in the male from Lac Caribou is the highest known feather Hg of any loon tested in North America. Only one female loon exceeded the 20 μg/g threshold. One juvenile loon captured on Lac des Iles had a feather concentration of 26.7 μg/g, the highest concentration ever recorded in a hatch year loon. Four of the ten eggs collected in Québec (40%) were in the moderate class and one (10%) in the high class.

Lakes that pose a high risk to loons are those with high fish Hg concentrations, which is influenced, among others, by low pH, high dissolved organic carbon and large watersheds (Scheuhammer & Blancher, 1994; Evers et al., 1998; Meyer et al., 1998; Scheuhammer et al., 1998). Meyer et al. (1998) found a negative linear relationship between log of chick and adult blood Hg and pH. Addition of acid-neutralizing capacity and lake area improved the relationship for chicks but not for adults. Meyer et al. (1998) also found a negative linear relationship between chick blood Hg and productivity. In a controlled study, Kenow et al. (2003) observed a lake-source effect, chicks from low pH lakes showed a lower growth rate than chicks from neutral pH lakes. Authors attributed this finding to in ovo exposure to MeHg. Our data also confirm the importance of fish Hg, pH, lake area and DOC, however, other environmental and ecological processes like fish and invertebrate populations also need to be considered.

Conclusion

Mean blood and feather Hg concentrations in loons from Québec are comparable to those from other locations in Northeast North America but are elevated in comparison with control sites in the North-western United States and Alaska. However, 26% of the adult loons and 48% of juvenile loons exceeded the threshold level for high risk in blood. Loons from eastern Québec appear to be second after those from Nova Scotia in terms of risk to the negative effects of Hg exposure in North America. High Hg levels were linked to high lake acidity. Further research and monitoring are needed to clarify the relative importance of environmental and ecological processes in Hg transfer and adequately protect loons and aquatic ecosystems.

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