Monitoring Mercury in Common Loons:

New York Field Report, 1998-2000

(BRI 2001-01)

BIODIVERSITY
RESEARCH INSTITUTE

Monitoring Mercury in Common Loons:

New York Field Report, 1998-2000

(BRI 2001-01)

Submitted to:

Drew Major
U.S. Fish and Wildlife Service
70 Commercial St., Suite 300
Concord, NH 03301

&

New York State Department of Environmental Conservation
Nongame and Habitat Unit
625 Broadway
Albany, NY 12233

Submitted by:

Nina Schoch and David C. Evers

Revised and Submitted on:

June 24, 2002

Please cite this report as: Schoch, N. and D. C. Evers. 2002. Monitoring Mercury in Common Loons: New York Field Report, 1998-2000. Report BRI 2001-01 submitted to U.S. Fish Wildl. Serv. and New York State Dept. Environ. Conservation. BioDiversity Research Institute, Falmouth, ME.

BioDiversity Research Institute is a Maine-based nonprofit research group dedicated to progressive environmental research and education that furthers global sustainability and conservation policies. Fundamental studies involve avian conservation and aquatic toxicology. We believe high trophic level piscivorous wildlife are vital indicators of aquatic integrity.

For correspondence or to obtain copies of this report contact:

BioDiversity Research Institute
411 US Route One, Suite 1
Falmouth, ME 04105
(207) 781-3324

staff@briloon.org
www.BRIloon.org

Adirondack Cooperative Loon Program
P.O. Box 195
Ray Brook, NY 12977
aclp2@juno.com

EXECUTIVE SUMMARY

Anthropogenic inputs of mercury into the environment have resulted in an increasing gradient of mercury from west to east across North America. In conjunction, the current availability of methylmercury (the form of mercury toxic to animals and humans) in aquatic ecosystems is at levels posing risks to human and ecological health. Risk levels vary considerably in response to methylmercury availability, which is affected by lake hydrology, biogeochemistry, habitat, topography, and proximity to airborne sources. The Common Loon was selected as a suitable bioindicator of aquatic mercury exposure, based on ecological, logistical, and other criteria, including public valuations of natural resources.

In New York State, loons were sampled opportunistically in the Adirondack Park from 1998-2000. Based on risk categories developed from the literature and *in situ* studies by BioDiversity Research Institute and their collaborators, 17% (16/93) of loons sampled in New York were estimated to be at risk for harmful effects from mercury contamination. All loons in the highest risk mercury category were captured on acidic, low alkalinity lakes in the Adirondack Park. As has been found elsewhere in the Northeast, blood mercury levels in adult birds were higher than those in juvenile loons, and adult male loons had significantly higher blood and feather mercury levels than adult females. Higher blood and feather mercury levels in male loons primarily reflect the tendency of males to eat larger fish which have elevated mercury levels, and the ability of female loons to depurate mercury into eggs.

Results of the sampling efforts in New York were coordinated with contaminant sampling in loons throughout the Northeast to better assess the neurologic, behavioral, and physical impacts of mercury exposure on loons. Population models based on related studies in the Northeast indicate that mercury toxicity could negatively impact breeding loon populations by reducing overall reproductive success. Thus, in New York, it is recommended that population and productivity monitoring, in conjunction with contaminant sampling of breeding loons continue through the efforts of the newly established Adirondack Cooperative Loon Program. Such population monitoring programs and continued refinement of population models enable the early detection of population trends and the implementation of management efforts, as well as assisting the development of state and national policies and regulations that reflect the ecological injury mercury and other contaminants can have on freshwater ecosystems.

TABLE OF CONTENTS

SUMMARY OF TABLES

SUMMARY OF FIGURES

SUMMARY OF APPENDICES

INTRODUCTION

This report presents the results of research conducted in the Adirondack Park in New York State by BioDiversity Research Institute (BRI), in cooperation with the New York State Department of Environmental Conservation and the U.S. Fish and Wildlife Service, from 1998-2000. Over the last decade, BRI has evaluated the levels and effects of mercury in piscivorous birds, primarily the Common Loon (*Gavia immer*), in the Northeast (Burgess et al. 1998, Major et al. 1998, Evers et al. 2001) and throughout North America (Evers et al. 1998).

Mercury and Loons

Mercury is released as a gas from a variety of anthropogenic sources (e.g., coal burning plants and municipal incinerators), and is carried in the atmosphere across North America to New England and eastern Canada. Mercury is deposited on the landscape, where it can be methylated and then bioaccumulate and biomagnify in a variety of aquatic environments. Many other factors, including geologic formations, hydrology, biogeochemical processes, and land use also contribute to varying levels of mercury availability. Contamination is highest in water bodies with low acid neutralizing capacity, high dissolved organic carbon, and fluctuating water levels. These situations are likely to enhance the conversion of elemental mercury to methylmercury (the toxic form).

Recent research by BRI has revealed that mercury levels in loons generally increase from west to east across North America, with the highest levels occurring in birds breeding in New England and eastern Canada (Evers et al. 1998). In Maine, it was estimated that 30% of the breeding loon population had unacceptable levels of risk due to mercury accumulation and that 46% of loon eggs were potentially impacted (Evers et al. 2001).

High levels of mercury are correlated with behavioral changes in Common Loons that lead to decreased productivity, decreased survival of juvenile loons, and may be related to increased susceptibility to other diseases (Evers et al. 2001). Significant behavioral differences occur in immature loons with high mercury levels, including increased preening and decreased time spent riding on the parents' backs (Nocera and Taylor 1998, Counard 2001). These behavioral changes result in increased exposure to predators and increased energy expenditure, contributing to decreased survival of young loons. In Maine, loons in the highest mercury risk category fledged 37% fewer young than low risk pairs (Evers et al. 2001).

Blood and feather mercury levels in loon chicks are indicative of mercury levels obtained from prey items acquired almost entirely on their natal lakes, since foraging elsewhere by parent birds is uncommon (McIntyre 1988, Parker 1988). In contrast, adult blood mercury levels reflect recent dietary uptake, while feather mercury levels reflect mercury that has been acquired over their lifetime.

Loons can rid their bodies of mercury through deposition of mercury in feathers and eggs. Thus, with every molt, and for females, with every egg laid, body burdens of mercury are decreased. However, through continued ingestion of fish with a high mercury content, loons accumulate mercury faster than they can rid their bodies of it through depuration in feathers or eggs. This is particularly true for male loons, since they lay no eggs and, because of their larger size, they tend to eat larger fish than females. Scheuhammer and Blancher (1994) documented a significant correlation between fish size (i.e., an indicator of age) and mercury accumulation within a given fish species. Mercury levels in loons increase annually at a rate that is predicted to reduce individual lifetime reproductive success and survival (Evers et al. 2001).

METHODS

Sampling of loons in the Adirondack Park of New York State was conducted during the summers of 1998-2000. Due to logistical considerations and presence of loon pairs with young, lakes were opportunistically (not randomly) selected. Birds were captured using playback tapes and night-lighting techniques developed and refined by BRI (Evers 2001). Blood and feather samples were collected for mercury, lead, and genetic analysis. Age (adult vs. juvenile) and sex (if possible) were determined based on external characteristics. Body weight and bill and wing dimensions were measured.

Loons were banded with aluminum U.S. Fish and Wildlife Service (FWS) bands. In addition, adult and juvenile loons were banded with a unique combination of color bands (using blue, green, orange, red, white, and yellow plastic bands) to enable individual identification for population monitoring studies. However, young juvenile birds were not banded if their legs were too small to hold adult-sized bands. In years subsequent to banding, re-observations were conducted to determine if the color-banded loons returned, and to determine the reproductive success of the returning banded loons. Reobservation results will be reported at a later date.

Analytical methods for blood and feather (standardized to the second secondary feather) samples followed those of Evers et al. (1998) and met quality assurance and quality control requirements used by the U.S. Fish and Wildlife Service and the U.S. Environmental Protection Agency. Analysis of blood, feathers, and eggs was for total mercury levels because methylmercury comprises 95% or more of the total mercury in these tissues (Thompson, 1996; BRI unpubl. data). Blood and feather samples were analyzed for total mercury levels using cold-vapor atomic absorption (CVAA) spectroscopy at the Univ. of Pennsylvania's Toxicology Laboratory (Evers, et al., 2001). Detection limits were at 0.025 ppm. Blood samples were submitted for analysis of lead levels at the U.S. Geological Survey-Biological Resources Division National Wildlife Health Center. Results of lead analyses will be presented in a separate report. Genetic samples are currently under analysis by Dr. Amy McMillan at the U.S. EPA, Atlantic Ecology Division, Narragansett, Rhode Island, to evaluate the genetic structure of the loon metapopulation in eastern North America. Results of this work will also be reported at a later date. Loon eggs that failed to hatch were also collected for analysis. Egg contents were analyzed for total mercury levels by the Texas A&M University Trace Element Research Laboratory.

Risk categories for mercury accumulation in Common Loons (Table 1) were based on literature and *in situ* studies by Evers et al. (2001). The low risk category indicates background mercury levels in loons that are minimally impacted by anthropogenic inputs. The upper limit of the low risk category represents the "no observed adverse effect level" (NOAEL). Loons in the moderate risk category have elevated mercury levels but the impacts on adult birds are not fully understood or documented. Loons in the high risk category have mercury levels that potentially cause molecular, organism, and/or population effects. The lower limit of the high risk category represents the "lowest observed adverse effect level (LOAEL). The extra-high risk mercury category is based on known behavioral and reproductive impacts on loons and other birds (Evers et al. 2001).

Table 1: *Risk categories for mercury (ppm, ww) in the Common Loon.*

Matrix	Low	Moderate	High	Extra-High	Reference Base
Egg	0-0.5	0.5-1.0	1.0-2.0	>2.0	Barr, 1986
Blood-Adult	0-1.0	1.0-3.0	3.0-4.0	>4.0	BRI[1]; inferred by Barr, 1986[2]
Blood-Juv.	0-0.1	0.1-0.3	0.3-0.4	>0.4	Meyer et al., 1998[3]
Feather	0-9	9-20	20-35	>35	Thompson, 1996; BRI[1]
Prey Fish	0-0.1	0.1-0.3	0.3-0.4	>0.4	Barr, 1986; Evers and Reaman, 1998

[1] BRI refers to unpublished data by BioDiversity Research Institute.
[2] Adult blood mercury levels are generally 10x higher than prey mercury levels (Evers and Reaman, 1998) and Barr (1986) found lower reproduction of loons with prey mercury levels of 0.3ppm and no reproduction at 0.4ppm.
[3] Applies to 3-5 week-old juveniles only.

Water quality information was provided by the Adirondack Lake Survey Corporation (ALSC; Appendix 1). These data were from ALSC's 1984-1987 comprehensive survey of Adirondack lakes.

RESULTS

Sampling effort

A total of 96 loons (57 adults and 39 juveniles) were captured and sampled from 1998-2000 on 43 lakes in the Adirondack Park (Appendix 2). Of the adults, 29 were sexed as female and 28 were sexed as male. Sex was unknown in the juvenile loons. Fifty-seven of the adults and 26 of the juvenile loons were banded, for a total of 83 banded loons. Thirteen juveniles were not banded because their tarsus was too small for the bands. One adult loon that was originally captured and sampled in 1999 was recaptured and resampled during the summer of 2000.

Water chemistry

Water quality data for all sample lakes are listed in Appendix 1. Air equilibrated pH (Air Eq pH) values were available for 42 of the 43 sample lakes, and ranged from 4.89 to 7.57, with a mean Air Eq pH of 6.55. Acid neutralizing capacity (ANC) values were available for 42 of the 43 lakes, and ranged from –6.0 µeq/L to 482.2 µeq/L, with a mean ANC of 95.22 µeq/L. Dissolved organic carbon (DOC) values were available for 36 of the 43 lakes, and ranged from 1.8 mg/L-C to 14.4 mg/L-C, with a mean DOC of 4.87 mg/L-C (Appendix 1).

Blood mercury levels

The mean blood mercury level for all adult loons was 1.78 ± 1.21 (SD) ppm (Table 2). Respectively, mean blood and feather mercury levels were significantly greater in adult males vs. adult females ($t=2.92$, $df=55$, $p=0.005$ and $t=3.20$, $df=55$, $p=0.002$). The mean chick blood mercury level was 13 times lower than that of adult blood mercury levels ($t=8.13$, $df=91$, $p<0.001$).

Table 2. Mercury levels (ppm) in Common Loons sampled in Adirondack Park, New York, 1998-2000.

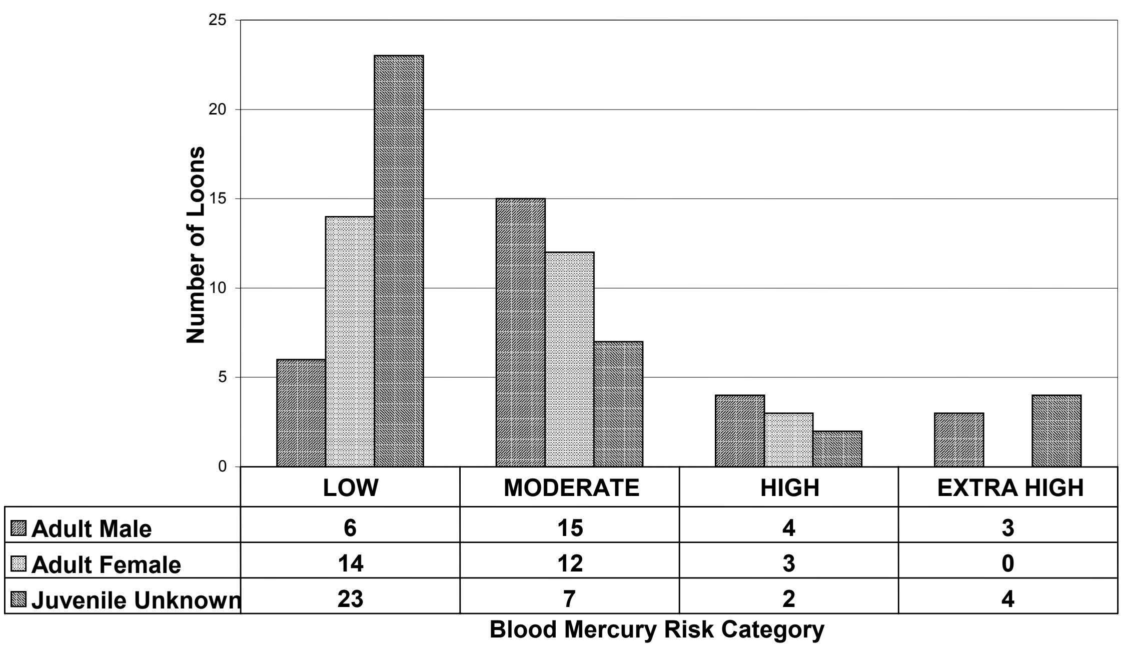
	Adult Blood (ww)[1]	Adult Feather (fw)[2]	Female Blood (ww)	Female Feather (fw)	Male Blood (ww)	Male Feather (fw)	Chick Blood (ww)
Mean	1.78	11.92	1.34	9.58	2.22	14.35	0.13
SD	1.21	6.08	1.03	3.25	1.23	7.32	0.17
Minimum	0.11	3.96	0.11	3.96	0.48	5.62	0.01
Maximum	5.36	36.50	3.62	16.20	5.36	36.50	0.70
Sample Size	57	57	29	29	28	28	36

[1] ww = wet weight
[2] fw = fresh weight

Mercury risk

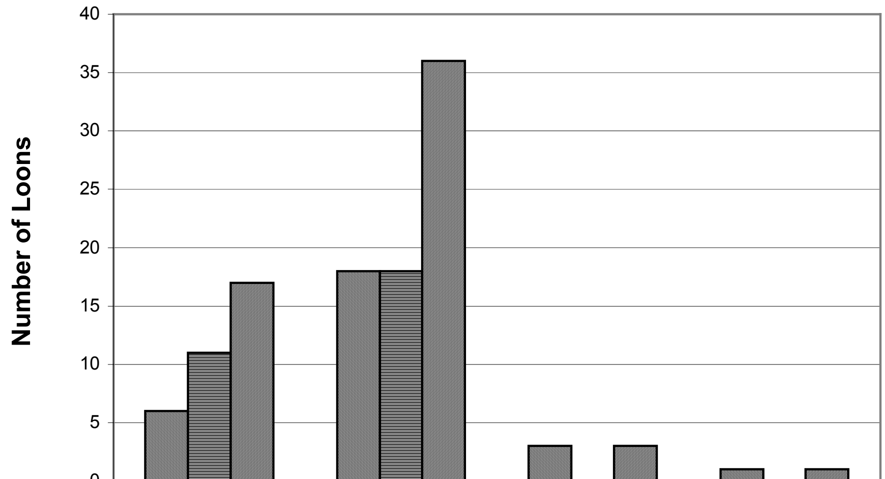
Loons were classified into four risk categories based on their blood mercury levels. Forty-three loons (45%) were classified into the low risk category and 34 loons (37%) were included in the moderate category. Nine loons (10%) were classified in the high and 7 (8%) in the extra high risk categories (Figure 1, Appendix 3). No female loons had blood mercury levels in the extra-high risk category. Thus, 17% of the loons (16/93) opportunistically sampled in the Adirondack Park from 1998-2000 were classified as having high or extra-high blood mercury levels (i.e., greater than the LOAEL).

Figure 1. Common Loon blood mercury levels separated into four risk categories.



Adult loon feather mercury levels were also classified into four risk categories: 17 loons (30%) were designated in the low risk feather category and 36 loons (63%) were included in the moderate risk category. The high risk category included 3 loons (5%), and the extra high risk feather category had one loon (2%) (Figure 2, Appendix 4). No female loons had feather mercury levels in the high or extra-high risk category. Thus, 7% of the loons (4/57) opportunistically sampled in the Adirondack Park from 1998-2000 were classified as having high or extra-high feather mercury levels (i.e., greater than the LOAEL). No feathers were collected from juvenile loons.

Figure 2. Common Loon feather mercury levels separated into four risk categories.



	LOW	MODERATE	HIGH	EXTRA HIGH
Adult Male	6	18	3	1
Adult Female	11	18	0	0
Total # Adults	17	36	3	1

Feather Mercury Risk Category

Loon territories sampled were classified in their associated mercury risk categories based on the highest blood mercury level of loons sampled within the lake (Appendices 3 and 5). Thirty-two percent of the lakes (n=15) contained loons with blood mercury levels classified in more than one blood mercury risk category. However, agreement within lakes was high (90%) when comparing blood mercury levels categorized above or below the LOAEL (i.e., if a loon blood mercury level was in a high risk category, only 10% of the time were loon blood mercury levels from the same lake in a low or moderate risk category).

Relationship between blood mercury levels and water chemistry

Lake Air Eq pH was compared with adult and juvenile blood mercury levels. A significant inverse relationship was found with pH and increasing blood mercury levels for adults (F=21.2, df=51, p<0.001; Figure 3). There was a similar significant increase with juveniles (F=5.1, df=33, p=0.03; Figure 4). Variability between blood mercury levels and lake Air Eq pH was high for both adults and juveniles, which indicates other factors are important in rates of methylmercury availability.

Figure 3. Relationship between adult loon blood mercury levels and Air Eq pH.

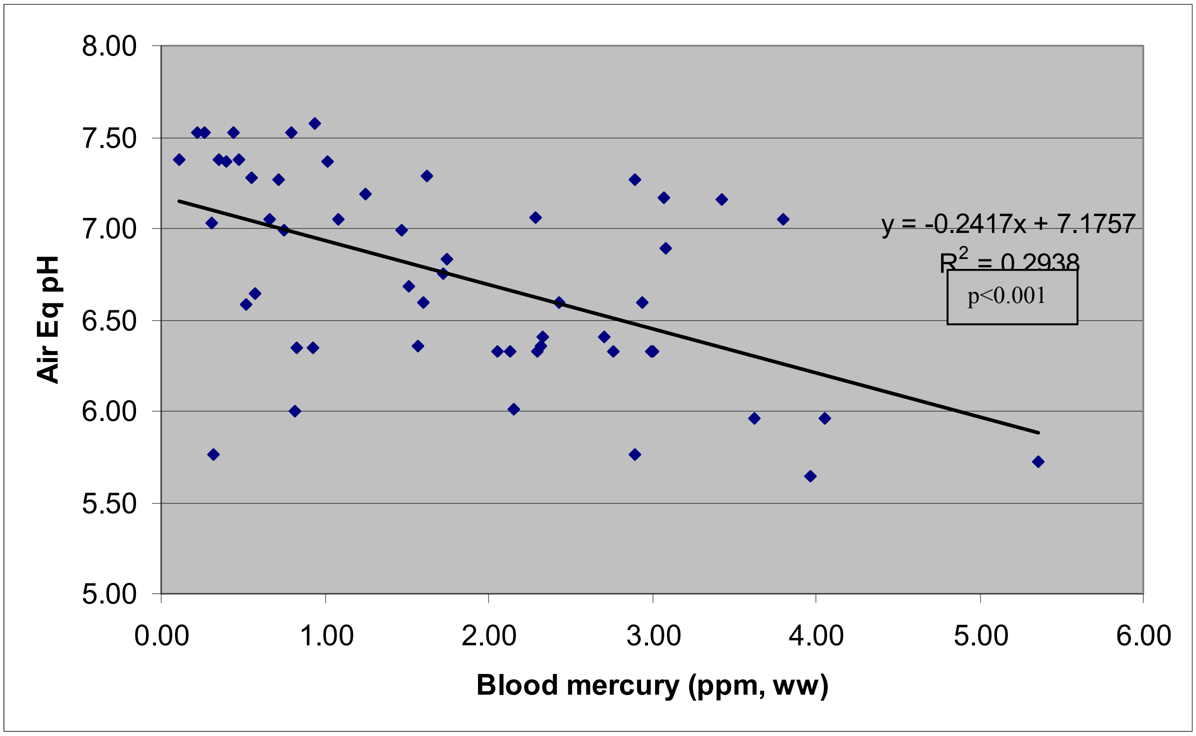
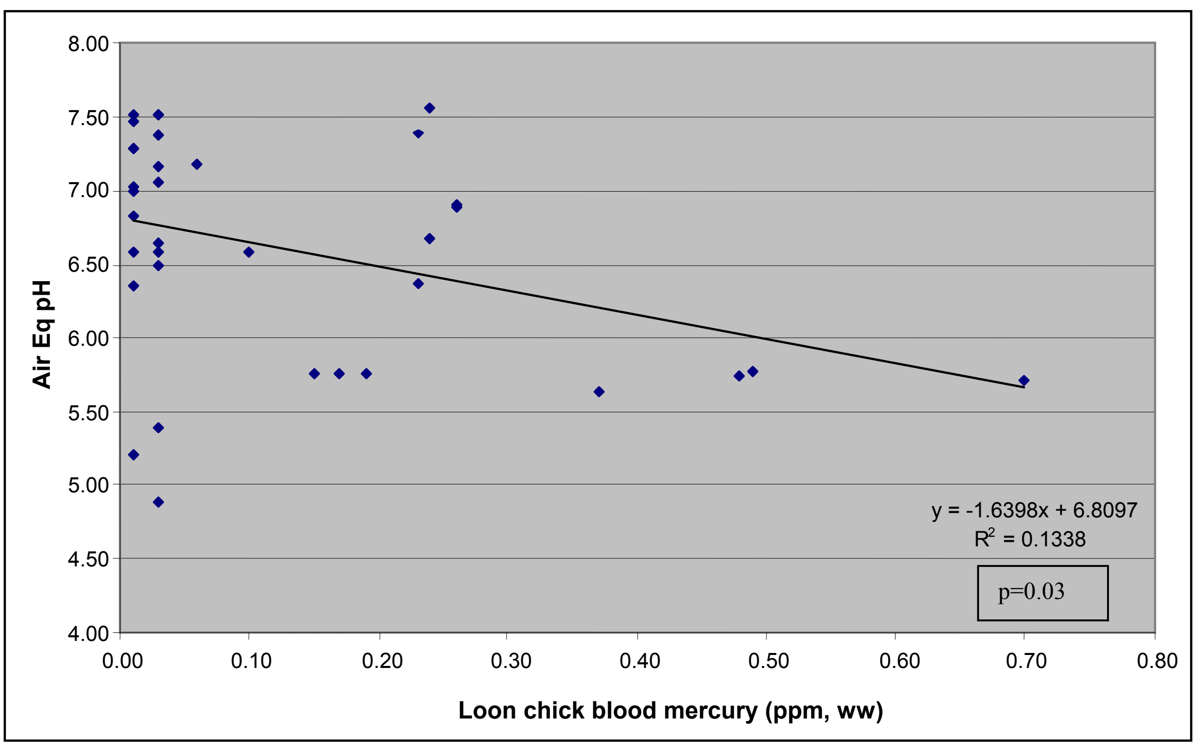
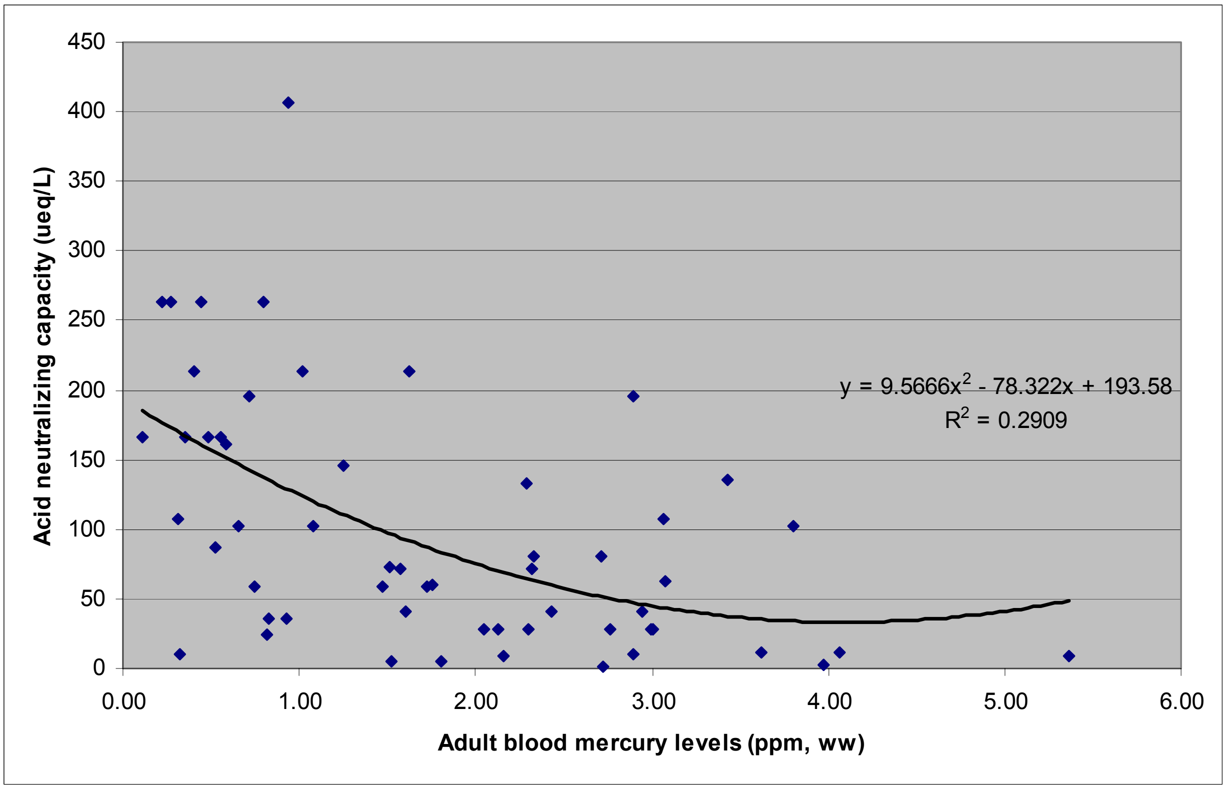


Figure 4. Relationship between loon chick blood mercury levels and Air Eq. pH.



Lake acid neutralizing capacity (ANC) had a significant inverse relationship with adult blood mercury levels ($F=18.6$, $df=54$, $p<0.001$; Figure 5) and a marginally significant inverse relationship with juvenile blood mercury levels ($F=3.2$, $df=33$, $p=0.08$). Respectively, adult and juvenile blood mercury levels were not significantly related with lake dissolved organic carbon (DOC) levels ($F=0.14$, $df=41$, $p=0.71$; $F=0.47$, $df=27$, $p=0.50$).

Figure 5. Relationship between adult loon blood mercury levels and ANC.



Egg mercury levels

A total of 9 abandoned eggs were collected from 1998-2000 and the contents were evaluated for mercury level. Wet weight mean (± SD) mercury level was 0.62 ± 0.28ppm with a range of 0.35 to 1.23ppm[1]. Fifty-five percent (5/9) of the eggs collected were in the low risk category, while 33% (3/9) were in the moderate and 11% (1/9) were in the high risk category. No egg collected during 1998-2000 was in the extra-high risk category.

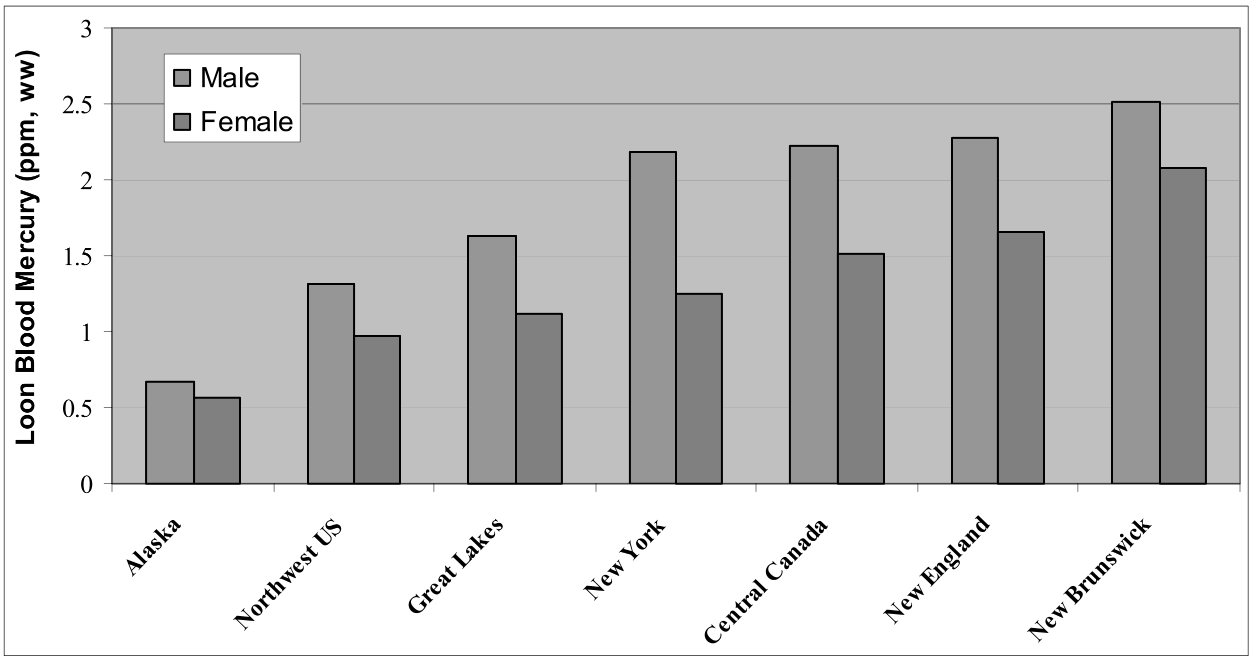
[1] Dry weight mercury analysis was not available for all 9 eggs collected 1998-2000.

DISCUSSION

Mercury and Loons

Mercury levels obtained from Common Loons captured in New York from 1998-2000 were similar to those observed throughout the northeastern United States and Canada. Adult and juvenile loon blood and feather mercury levels in New York were comparable to those observed in Ontario, Canada, higher than levels observed in birds further to the west, and generally lower than those found in loons further east in North America (Figure 6; Evers et al. 2001). This gradient correlates with the deposition of mercury from anthropogenic sources in the Midwestern United States (Evers et al. 1998).

Figure 6. Geographic trend of adult blood mercury levels (ppm, ww), 1992-2001.



Blood mercury levels in adult birds were approximately 13 times higher than those in juvenile loons, and adult male loons had significantly higher blood and feather mercury levels than did females. Loon feather mercury levels indicate lifetime mercury exposure (Burger 1993), while blood mercury levels are an indication of recent dietary mercury uptake (Evers et al. 1998). Higher blood and feather mercury levels in male loons reflect the tendency of males to eat larger fish (i.e., older fish with higher mercury levels) than females. Depuration of mercury into eggs is a well-known mechanism for female birds (Braune and Gaskin 1987; Lewis et al. 1993). However, recent research shows that the contribution from the body burden is minimal, and that dietary uptake of mercury post egg-laying raises blood mercury to pre-laying levels (Evers et al. unpubl. data).

The geometric mean mercury (ww) level in eggs collected from 1998-2000 in this study (0.62 ppm) was somewhat lower than that collected by McIntyre et al. (1992) between 1978-1986 (geometric mean mercury = 0.88 ppm). Lakes sampled did not overlap between the two studies, thus the results may not reflect temporal changes in mercury availability.

Seventeen percent (16 of 93 birds) of the loons sampled in New York as part of this study had blood mercury levels in the high or extra-high risk categories (i.e., those mercury levels above the LOAEL). Loons in these risk categories may exhibit behavioral changes associated with elevated mercury levels including decreased normal activities (e.g., foraging and incubation) as well as decreased reproductive success, when compared to loons in low or moderate mercury risk categories (Meyer et al. 1998, Nocera and Taylor 1998, Evers et al. 2001).

In Maine, current population models for Common Loons indicate a negative growth rate due to the combination of high mercury exposure of a significant part of the breeding population and the impact of reducing overall reproductive success (Evers et al. 2001). Although the percent of loons in our sample in the high and extra-high mercury risk categories was lower than that in Maine (30%), this study suggests that mercury exposure may negatively impact some local breeding populations of loons in New York. However, it is unknown if the sampling effort was representative of loon populations throughout the Adirondack Park because the birds were captured opportunistically in this study, and were not a true random sample of the breeding population in the Park.

Loons in the highest blood mercury risk categories were captured on lower pH and lower alkalinity lakes than those birds in the lower blood mercury risk categories. Mercury levels in yellow perch (*Perca flavescens*), an important prey item for loons (Barr 1996), are correlated with levels of Air Eq pH, DOC, and ANC in Adirondack lakes, with higher fish mercury levels observed on low pH, low alkalinity lakes that had lower levels of dissolved organic carbon. Mercury levels in yellow perch were also related to the age and size of the fish, reflecting the bioaccumulation of mercury in a predatory piscivorous species over time (Simonin et al. 1994, Driscoll et al. 1995).

The USEPA has recently issued a national fish consumption advisory for women and children to reduce their exposure to fish containing mercury (USEPA 1997). In addition, the NYS Department of Health (DOH) issues advisories recommending limited human consumption of fish from specified waterbodies in New York. The 2000-2001 advisories include the following Adirondack lakes sampled in this study: Beaver Lake (Lewis County), Ferris Lake, Moshier Reservoir, and Cranberry Lake (New York State Dept. of Health, 2000). Most (7/11) loons inhabiting these lakes were in the high or extra-high blood mercury risk levels. Behavioral and reproductive impacts from elevated mercury levels are likely exhibited by the loons living on these lakes. It is recommended that fish mercury levels be determined for additional lakes included in this study that had loon blood mercury levels in the high and extra-high risk categories. If the fish mercury levels are also elevated, then advisories for human fish consumption should also be issued for those lakes.

The USEPA has used the results of long-term loon contaminant research as one line of evidence in determining the risk that atmospheric mercury poses to the environment. Based on those data, and other ecological and human health studies, USEPA plans to regulate and limit airborne mercury emissions from coal-fired power plants.

Research by Biodiversity Research Institute is expanding to look at mercury levels in loons on their wintering water bodies, and to determine mercury and other contaminant levels in other fish-eating animals, including mergansers, kingfishers, cormorants, mink, and otters. The results of these research efforts will provide for more defined management of waterbodies and populations of fish-eating animals, as well as to further promote more stringent regulation of airborne contaminants.

This three-year research study on mercury levels in loons in the Adirondack Park of New York State has resulted in the development of the Adirondack Cooperative Loon Program (ACLP). The ACLP is a cooperative research and education effort studying the natural history of the Common Loon and the effects of contaminants and human interactions on loon populations in the Adirondack Park. The ACLP is a partnership of the Wildlife Conservation Society, the Natural History Museum of the Adirondacks, the New York State Department of Environmental Conservation, BioDiversity Research Institute, and the Audubon Society of New York, Inc.

Contaminant sampling and banding of loons has continued in the Adirondack Park in coordination with BioDiversity Research Institute. The Adirondack Cooperative Loon Program monitors the return rate and reproductive success of loons color-banded as part of the contaminant research. The work of the Adirondack Cooperative Loon Program is coordinated with other research projects studying loons and water quality throughout New York State and North America.

RECOMMENDATIONS

1. **Coordinate loon mercury research with fish mercury and relevant water quality research in the Adirondack Park:** The results of this research should continue to be correlated with water quality and fish contaminant data from other research projects throughout the Adirondack Park. Mercury risk levels in prey fish should be evaluated in relation to loon mercury risk levels for a given waterbody. Evaluating mercury levels at a variety of trophic levels will provide a more thorough understanding of the effects of mercury and other factors, such as acid rain, on the environment and its inhabitants.

2. **Continue collecting demographic information based on color-marking of loons:** Long-term contaminant sampling and intensive population monitoring of marked loons in New York should be continued to aid in modeling loon population trends, thus enabling management efforts to be implemented promptly if indicated. Coordination and standardization of loon reproductive parameters collected in New York with those collected in other northeastern states and provinces will enhance the ability of researchers to track the impacts of mercury on breeding loons in Northeastern North America. Protocols for monitoring loon productivity utilized by the ACLP in New York are based on those used by BRI, NH Loon Preservation Committee, and the Vermont Institute of Natural Science.

3. **Determine potential impacts of mercury through juvenile recruitment rates:** Recruitment of juvenile loons into New York's breeding loon population, an additional indicator of population trends and potential mercury impacts, can be evaluated through continued banding efforts and satellite telemetry.

4. **Determine the genetic structure of the breeding loon population in the Adirondack Park:** The collection and analysis of genetic information from the Adirondack Park loon population will enable the identification of the genetic structure of the population and will determine if it is distinct from neighboring subpopulations. This information can ultimately be used to identify and protect key wintering habitat for local breeding populations.

5. **Use EMAP template to achieve a statistically relevant sampling strategy:** Sampling efforts in future years will be directed toward lakes that were included in the USEPA's Environmental Monitoring and Assessment Program (EMAP) in order to utilize a more statistically valid random sampling strategy. This approach is also being used on REMAP (Regional Environmental Monitoring and Assessment Program) lakes in Maine, New Hampshire and Vermont.

LITERATURE CITED

Barr, J.F. 1986. Population dynamics of the Common Loon (*Gavia immer*) associated with mercury-contaminated waters in northwestern Ontario. Occ. Paper 56, Canadian Wildl. Serv., Ottawa, ON, Canada.

Barr, J.F. 1996. Aspects of common loon (*Gavia immer*) feeding biology on its breeding ground. Hydrobiologia 32, 119-144.

Braune, B.M. and Gaskin, D.E. 1987. Mercury levels in Bonaparte's Gulls (*Larus philadelphia*) during autumn molt in the Quoddy Region, New Brunswick, Canada. Arch. Environ. Contam. Toxicol. 16, 539-549.

Burger, J. 1993. Metals in avian feathers: Bioindicators of environmental pollution. Rev. Environ. Toxicol. 5, 203-311.

Burgess, N. M., D. C. Evers, J. D. Kaplan, M. Duggan, and J. J. Kerekes. 1998. Mercury and reproductive success of Common Loons breeding in the Maritimes. Pp. 104-109 in Mercury in Atlantic Canada: A progress report. Environment Canada-Atlantic Region, Sackville, New Brunswick.

Counard, C.J. 2001. Mercury exposure and effects on Common Loon (*Gavia immer*) behavior in the upper midwestern United States. Unpubl. M.S. Thesis. Univ. Minn., St. Paul, MN.

Driscoll, C.T., V. Blette, C. Yan, C. L. Schofield, R. Munson, and J. Holsapple. 1995. The role of dissolved organic carbon in the chemistry and bioavailability of mercury in remote Adirondack Lakes. Water, Air, and Soil Pollution 80: 499-508.

Evers, D.C. 2001. Common Loon population studies: Continental mercury patterns and breeding territory philopatry. Ph.D. dissertation, Univ. Minn., St. Paul.

Evers, D.C. and P.S. Reaman. 1998. A comparison of mercury exposure between artifical impoundments and natural lakes measured in Common Loon and their prey. Unpubl. Rept., submitted to Central Maine Power Co. by BioDiversity Research Institute, Freeport, Maine. 40pp.

Evers, D.C., C. DeSorbo, and L. Savoy, 2001. Assessing the impacts of methylmercury on piscivorous wildlife as indicated by the Common Loon, 1998-2000. Unpubl. Rept. BRI00-01 submitted to the Maine Dept. of Environmental Protection, Surface Water Ambient Toxic Monitoring Program, SHS 17. 55pp.

Evers, D.C., K.M. Taylor, A. Major, R. J. Taylor, R.H. Poppenga, and A.M. Scheuhammer. In review. Common Loon eggs as indicators of methylmercury availability in North America. Submitted to Ecotoxicology.

Evers, D.C., J.D. Kaplan, M.W. Meyer, P.S. Reaman, W.E. Braselton, A. Major, N. Burgess, and A. M. Schuehammer. 1998. A geographic trend in mercury measured in Common Loon feathers and blood. Environmental Toxicology and Chemistry 17(2): 173-183.

Lewis, S.A., Becker, P.H. and Furness, R.W. 1993. Mercury levels in eggs, tissues, and feathers of Herring Gulls *Larus argentatus* from the German Wadden Sea Coast. Envrion. Pollut. 51, 293-299.

Major, A. R., K. Karwowski, F. Pinkney, K. Trust, D.C. Evers, and C. Franson., 1998. ME, NH, VT, MA, NY, VA, AK – Regional comparison of heavy metal exposure in fish-eating birds. Project proposal of the U.S. FWS Region 5 Environmental Contaminants Program, Off-Refuge Investigations Sub-Activity.

McIntyre, J.W. 1988. The Common Loon: Spirit of the northern lakes. Univ. Minn., Minneapolis, MN.

McIntyre, J.W., J.T. Hickey, K. Karwowski, C.L. Holmquist, and K. Carr. 1992. "Toxic Chemicals and Common Loons in New York and New Hampshire, 1978-1986". Pp 73-91 in L. Morse, S. Stockwell, and M. Pokras (eds.). The loon and its ecosystem: status, management, and environmental concerns. 1992 American Loon Conference Proceedings. North American Loon Fund. U.S. Fish & Wildlife Service. Concord, NH.

Meyer, M.W., D.C. Evers, J.J. Hartigan, and P.S. Reaman. 1998. Patterns of Common Loon (*Gavia immer*) mercury exposure, reproduction, and survival in Wisconsin, USA. Environmental Toxicology and Chemistry 17(2): 184-190.

New York State Dept. of Health, Div. of Environmental Health Assessment. 2000. 2000-2001 Health advisories: Chemicals in sportfish and game. 19pp. http://www.health.state.ny.us/nysdoh/environ/fish.htm.

Nocera, J.J. and P.D. Taylor. 1998. In situ behavioral response of Common Loons associated with elevated mercury (Hg) exposure. Conservation Ecology [online] 2(2):10.

Parker, K.E. 1988. Common Loon reproduction and chick feeding on acidified lakes in the Adirondack Park, New York. Can. J. Zool. 66:804-810.

Scheuhammer, A.M. and P.J. Blancher. 1994. Potential risk to common loons (*Gavia immer*) from methylmercury exposure in acidified lakes. In Kerekes, J.J., and J. B. Pollard (eds.). Proc. Symp. Aquatic Birds in the Trophic Web of Lakes. Sackville, New Brunswick. Canada. Hydrobiologia 279/280: 445-455.

Simonin, H.A., S.P. Gloss, C.T. Driscoll, C.R. Schofield, W.A. Kretser, R.W. Karcher, and J. Symula. 1994. Mercury in yellow perch from Adirondack drainage lakes (New York, U.S.). Pp 457-469 in Trace Substances in the Environment. Lewis Publishers. Chelsea, MI.

Thompson, D.R. 1996. Mercury in birds and terrestrial animals. Pp 341-355 in Beyer, W.N., G.H. Heinz, and A.W. Redmon-Norwood (eds.). Pp341-355 in Environmental Contaminants in Wildlife: Interpreting Tissue Concentrations. Lewis Publishers. Clemson, SC.

U.S. EPA. 1997. Mercury study report to Congress. Volume VII: Characterization of human health and wildlife risks from mercury exposure in the United States. EPA-452/R-97-009.

ACKNOWLEDGMENTS

We would especially like to thank all the New York State Department of Environmental Conservation (DEC) personnel and volunteers, and the U.S. Fish and Wildlife Service personnel that assisted us in the many aspects of the field work for this project. In addition, we are extremely grateful for the extensive cooperation and assistance we received from private landowners, members of the public, and DEC personnel in acquiring access to lakes, information about the presence or absence of breeding loons, publicizing this study, and in obtaining housing for the field crew. DEC staff at several offices also assisted greatly with numerous details so that the field work was conducted smoothly.

The views expressed in this report are those of the authors and do not necessarily reflect the views of all agencies and organizations involved in this study.

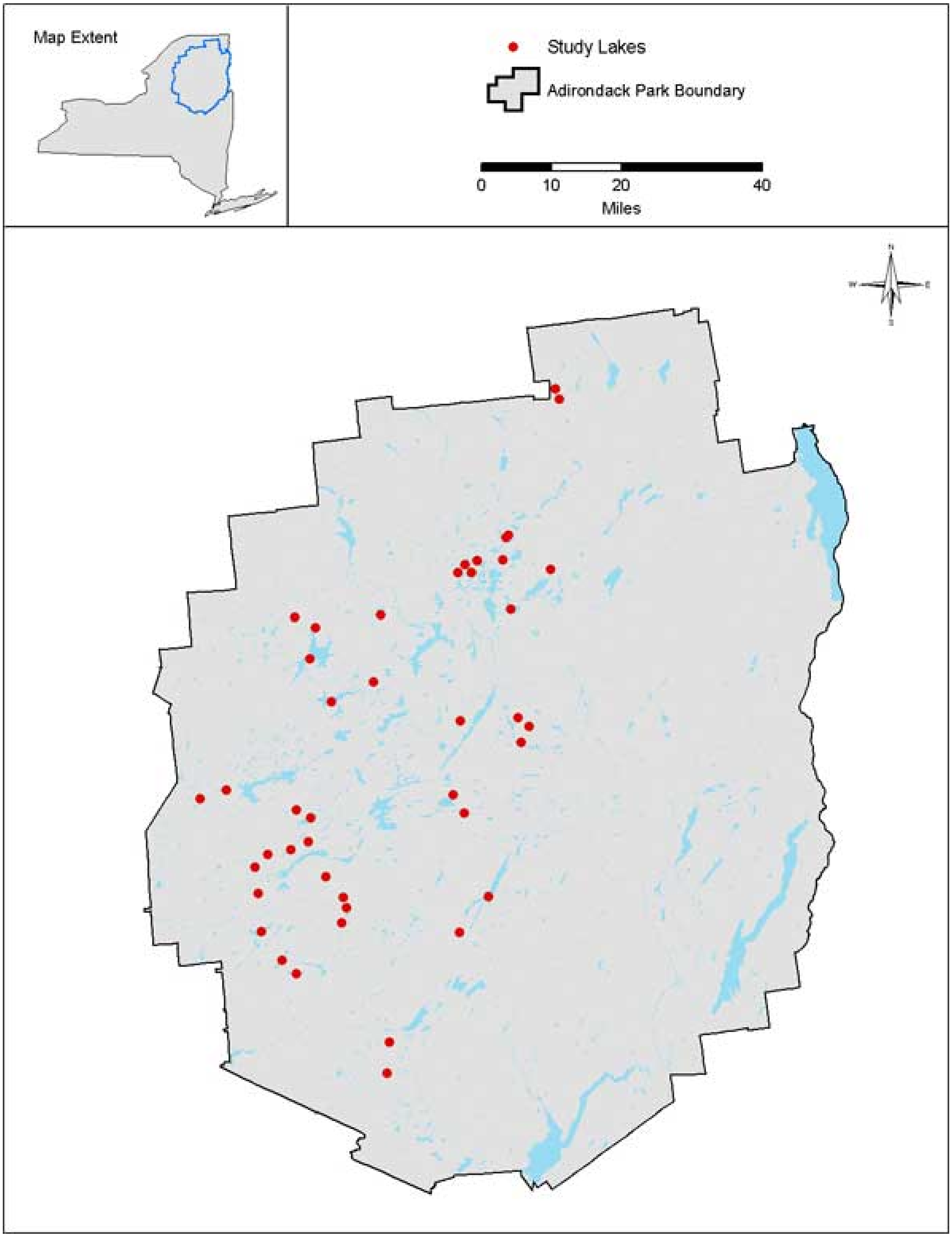
Appendix 1: *New York lakes sampled for water quality: Mean air equilibrated pH, dissolved organic carbon, and acid neutralizing capacity*[1]

POND NAME	AIR EQ pH	DOC (mg/L-C)	ANC (μeq/L)
Arbutus Lake	6.89	3.90	62.80
Beaver Lake – Hamilton Cty	6.35	6.90	36.10
Beaver Lake – Lewis Cty	5.96	3.50	11.70
Cooks Pond[2]	na	na	na
Cranberry Lake	6.33	na	28.00
Deer Pond	7.16	na	135.00
East Pine Pond	7.19	5.90	145.10
Ferris Lake	5.72	4.00	9.50
Gibbs Lake	6.50	7.30	56.40
Hitchins Pond	6.41	11.40	81.00
Indian Lake - Franklin Cty	7.37	5.10	214.10
Indian Lake -Ham. Cty #1	6.75	3.20	58.80
Indian Lake -Ham. Cty #2	4.89	4.30	-6.00
Lake Colby	7.46	4.60	482.20
Lake Durant	6.36	7.00	71.10
Lake Rondaxe	6.00	3.30	23.80
Limekiln Lake	6.01	2.70	8.90
Little Clear Pond	7.52	2.60	263.30
Little Safford Lake	6.58	6.10	86.50
Long Pond - Franklin Cty	7.05	4.10	102.80
Long Pond - St. Lawr. Cty	5.38	14.40	15.40
Lower Mitchell Pond	7.03	2.80	107.50
Low's Lake	6.59	5.10	40.30
Mason Lake	7.29	3.70	213.50
Mcrorie (Rock) Pond	7.06	4.50	133.10
Middle Pond	7.11	5.30	99.50
Middle Saranac (+ Weller Pond)	6.64	4.10	161.20
Moshier Reservoir	5.74	4.40	19.40
Moss Lake	6.68	4.60	72.50
Mountain View Lake	7.57	6.70	406.90
Nicks Lake	7.17	4.40	107.00
North Lake	5.06	5.00	-1.90
Private #1 - Ham. Cty	5.78	na	20.6
Private #2 - Ham. Cty	6.90	5.10	79.00
Silver Lake	7.27	3.80	195.00
South Lake	5.21	na	-4.90
Spitfire Lake	7.28	4.10	166.10
Turtle Pond	6.83	4.00	60.10
Twitchell Lake	5.64	2.60	2.90
Upper St Regis Lake	7.38	na	166.70
Wolf Pond	6.99	na	59.30
Woodhull Lake	5.76	1.80	10.00

[1] Water quality information was provided by the Adirondack Lake Survey Corporation. These data were from ALSC's 1984-1987 comprehensive survey of Adirondack lakes.

[2] No water quality information was available for Cooks Pond.

Appendix 2: *Loon sampling sites in the Adirondack Park, New York, 1998-2000*



Appendix 3: *List of lakes sampled in New York and their associated loon blood mercury risk levels.*

	Low Blood Mercury Risk Category			Moderate Blood Mercury Risk Category			High Blood Mercury Risk Category			Extra High Blood Mercury Risk Category			
POND NAME	**Total # Loons**	**# Adults**	**#Chicks**	**Total # Loons**	**# Adults**	**#Chicks**	**Total # Loons**	**# Adults**	**#Chicks**	**Total # Loons**	**# Adults**	**#Chicks**	**Total # Loons by Lake**
Arbutus Lake	0			0			2	1	1	0			2
Beaver - Hamilton Cty	2	1	1	0			0			0			2
Beaver - Lewis Cty	0			0			1	1		1	1		2
Cooks Pond	1		1	1	1		0			0			2
Cranberry Lake	0			4	4		2	2		0			6
Deer - Huntington Forest	1		1	0			1	1		0			2
East Pine Pond	0			1	1		0			0			1
Ferris Lake	0			0			0			2	1	1	2
Gibbs Lake	1		1	0			0			0			1
Hitchins Pond	0			2	2		0			0			2
Indian Lake - Franklin Cty	2	1	1	1	1		0			0			3
Indian Lake - Hamilton Cty #1	0			1	1		0			0			1
Indian Lake - Hamilton Cty #2	2	1	1	0			0			0			2
Lake Colby	1		1	0			0			0			1
Lake Durant	0			3	2	1	0			0			3
Limekiln Lake	0			1	1		0			0			1
Little Clear	7	4	3	0			0			0			7
Little Safford	3	1	2	0			0			0			3
Long Pond - St. Lawr. Cty: Massawepie	1		1	0			0			0			1
Long Pond - Franklin Cty: St. Regis Canoe Area	2	1	1	1	1		1	1		0			4
Lower Mitchell	2	1	1	0			0			0			2
Low's Lake	1		1	3	3		0			0			4
Mason Lake	0			1	1		0			0			1
McRorie Lake	0			1	1		0			0			1
Middle Saranac	2	1	1	0			0			0			2
Moshier Reservoir	0			0			0			1		1	1
Moss Lake	0			2	1	1	0			0			2
Mountain View Lake	0			0			0			0			0
Nicks	1		1	0			1	1		0			2
North Lake - Herkimer Cty	0			1	1		0			0			1
Private #1 - Hamilton Cty	0			0			0			1		1	1
Private #2 - Hamilton Cty	0			0			1		1	0			1
Rondaxe	1	1		0			0			0			1
Silver	1	1		1	1		0			0			2
South Lake - Herkimer Cty	3	2	1	0			0			0			3
Spitfire	3	1	2	0			0			0			3
Turtle Pond	1		1	1	1		0			0			2
Twitchell	0			0			0			2	1	1	2
Upper St. Regis	3	3		1		1	0			0			4
Wolf Pond - Essex Cty	2	1	1	1	1		0			0			3
Woodhull Lake	1	1		4	1	3	0			0			5

Appendix 4: *List of lakes sampled in New York and their associated loon feather mercury risk levels.*

POND NAME	Low Feather Mercury Risk Category # Adults	Medium Feather Mercury Risk Category # Adults	High Feather Mercury Risk Category # Adults	Extra High Feather Mercury Risk Category # Adults	Total # Adults
Arbutus Lake		1			1
Beaver - Hamilton Cty			1		1
Beaver - Lewis Cty	1	1			2
Cooks Pond		1			1
Cranberry Lake		6			6
Deer - Huntington Forest		1			1
East Pine Pond		1			1
Ferris Lake		1			1
Hitchins Pond		2			2
Indian Lake - Franklin Cty	2				2
Indian Lake - Hamilton Cty #1 - Campground	1				1
Indian Lake - Hamiton Cty #2	1				1
Lake Durant		2			2
Limekiln Lake		1			1
Little Clear	3	1			4
Little Safford		1			1
Long Pond - Franklin Cty: St. Regis Canoe Area		3			3
Lower Mitchell	1				1
Low's Lake		3			3
Mason Lake		1			1
McRorie Lake		1			1
Middle Saranac - Weller		1			1
Moss Lake	1				1
Mountain View Lake	1				1
Nicks		1			1
North Lake - Herkimer Cty		1			1
Rondaxe		1			1
Silver	1			1	2
South Lake - North - Herkimer Cty		2			2
Spitfire	1				1
Turtle Pond			1		1
Twitchell		1			1
Upper St. Regis	3				3
Wolf Pond - Essex Cty		1	1		2
Woodhull Lake - East End	1	1			2

Appendix 5: *Loon blood mercury risk categories for New York lakes, 1998-2000*