



RESULTS – LONG-TERM MONITORING AND ASSESSMENT OF MERCURY BASED ON INTEGRATED SAMPLING EFFORTS USING THE COMMON LOON, PREY FISH, WATER, AND SEDIMENT



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Introduction

- High levels of environmental mercury (Hg) have been documented in five biological "hotspots" of contamination in northeastern North America, including New York's Adirondack Park. In acidic environments, as in many northeastern lakes, elemental Hg is converted at a higher rate to methylmercury (MeHg), a neurotoxic form that magnifies up the food web. The current availability of MeHg in aquatic ecosystems of this region potentially affects wildlife and people.
- The common loon (*Gavia immer*), a piscivorous predator, breeds on waterbodies throughout the Park and is at the top of the aquatic food web. The species has high potential to be detrimentally affected by toxins, such as Hg, that bioaccumulate and biomagnify through the environment. In this study, we use loons as an indicator species to assess Hg exposure and risk in aquatic ecosystems in the Adirondack Park.

Study Site and Methods

- Biotic and abiotic samples were collected within New York's Adirondack Park over a two-year period (2003 to 2004). Samples included water (n=44 lakes), fish (n=44 lakes), zooplankton (n=43 lakes), crayfish (n=26 lakes), and sediment core samples (n=32 lakes). All samples were analyzed for total Hg. MeHg was analyzed in water, sediment, and zooplankton.
- Loon blood samples were collected from birds captured on 44 lakes from 1998-2007, feather samples from 40 lakes; nonviable eggs were collected from 29 lakes. Blood, feather, and egg samples were analyzed for total Hg concentrations. All biotic Hg and MeHg concentrations are expressed in µg/g on a wet weight (ww) basis. Loon Hg concentrations were converted to a single common unit (female loon unit (FLU) or male loon unit (MLU) to evaluate and utilize existing data from various biotic compartments, and facilitate comparisons between locations and years.

Study Objectives

- Characterize aquatic-based Hg exposure in the Adirondack Park via:
 - Individual lake Hg profiles by determining Hg levels in both abiotic (water and sediment) and biotic (zooplankton, crayfish, fish, and loons) compartments.
 - Evaluating the spatial distribution of Hg across the Adirondacks.
 - Developing a bioconcentration factor for the Adirondacks.
 - Determining relationships between Hg in various aquatic compartments of the food web.
 - Relationship between lake acidity and Hg contamination.
- Determine the % of the Adirondack loon population at risk of reduced productivity.
- Assess the effect of Hg on the Adirondack common loon population via:
 - Evaluating relationships between Hg and lake acidity on loon productivity.
 - Modeling the long-term effect of Hg on the Adirondack loon population using the US EPA common loon population model (Grear et al. 1999).
 - Assessing ecological risk using a wildlife criterion value (WCV; Nichols et al. 1999), to determine a recommended water Hg level to protect the Adirondack loon population.

Results

Mercury in the food web

Mean Hg concentrations within the food web followed the predicted pattern, with an increase in Hg by many orders of magnitude from water (0.0000017 µg/g) to zooplankton (0.006 µg/g) to crayfish (0.047 µg/g) to fish (large fish = 0.096 µg/g, extra-large fish = 0.167 µg/g) to loons (1.72 µg/g = adult female blood, 2.16 µg/g = adult male blood). There was a strong correlation between large and extra-large fish Hg and loon blood Hg (large fish vs. FLU: $R^2=0.2878$, $F=16.17$, $p<0.001$; vs. MLU: $R^2=0.3196$, $F=15.97$, $p<0.001$; extra-large fish vs. FLU: $R^2=0.2808$, $F=12.11$, $p<0.002$; vs. MLU: $R^2=0.4535$, $F=24.07$, $p<0.001$).

Common loon blood mercury

The mean adult blood Hg level on each lake was 1.97 µg/g (± 0.17 SE), with a wide range of variation (0.58 – 5.62 µg/g). Females averaged lower blood and feather Hg loads than males. Juvenile blood Hg level was lower than adults, averaging 0.24 µg/g (±0.03 SE; range: 0.01 – 0.76 µg/g). The mean Hg concentration of nonviable eggs was 0.80 µg/g (± 0.09 SE; range: 0.35 – 2.15 µg/g).

Common loon exposure risk

Loons were placed into four risk categories of mercury concentrations in their tissues, based on previous research for effects levels conducted by BRI and others. 21% of male loons and 8% of females were at a high risk of behavioral and reproductive impacts based on blood Hg exposure (Fig. 1), and 37% of male and 7% of female study birds were at high risk of impacts based on feather Hg exposure. 13% of loon eggs were at high risk for Hg exposure, indicating that, if the chicks hatched, their behaviors would be abnormal, and they would have a reduced likelihood of surviving to fledging.

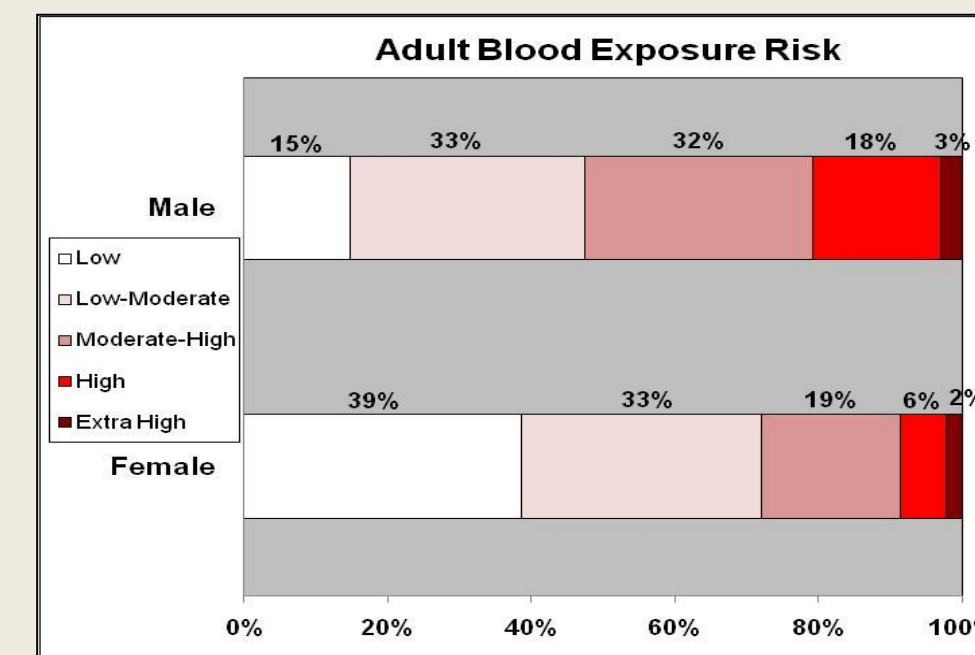


Figure 1. Risk ratios for Hg exposure based on adult blood Hg exposure groups: low (0–1 µg/g), low-moderate (1–2 µg/g), moderate-high (2–3 µg/g), high (3–4 µg/g) and extra-high (>4 µg/g).

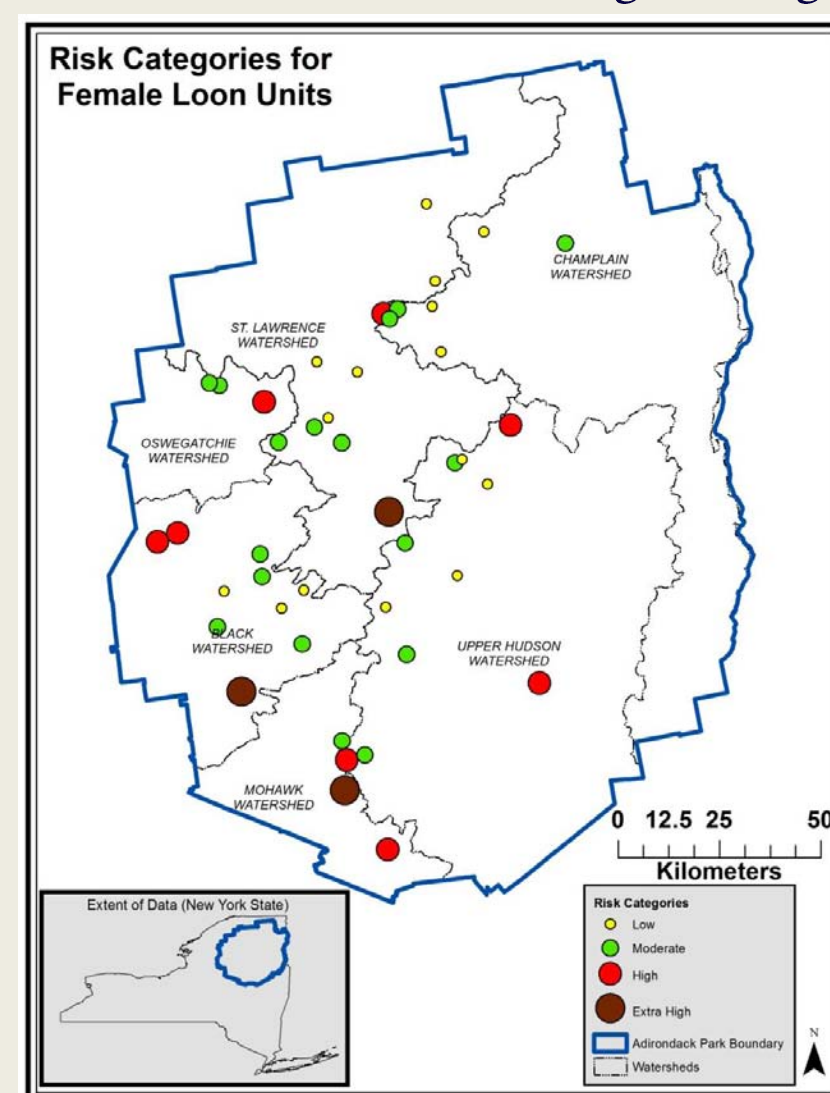


Figure 2. Study lakes (2003–2004) located within the Adirondack Park and spatial distribution of lakes with low, moderate, high and extra high FLUs. Low (0–1 µg/g), moderate (1–2 µg/g), high (2–3 µg/g), and extra-high (>3 µg/g).

Relationship between mercury and lake acidity

Lake acidity correlated with Hg levels, with more acidic lakes exhibiting higher Hg concentrations in both fish (pH vs. large fish: $R^2=0.2878$, $F=16.17$, $p<0.001$; vs. extra-large fish: $R^2=0.2894$, $F=15.07$, $p<0.001$) and loon tissues (pH vs. FLU: $R^2=0.1796$, $F=9.20$, $p<0.004$; vs. MLU: $R^2=0.1219$, $F=5.55$, $p<0.024$). Although no significant spatial trends in Hg availability within the Adirondacks were observed (Fig. 2), kriging analysis indicated the southwestern Adirondacks tended to have lakes with higher loon Hg levels, corresponding to increased acid deposition for that area.



Wildlife criterion value

We used variables specific to the Adirondacks to develop a New York-based Wildlife Criterion Value to provide an estimate of wildlife population viability through measurement of contaminant stressors. We determined that an unfiltered water sample ≤ 2.00 ng Hg/L is protective of male loons, while a water sample ≤ 1.69 ng Hg/L is protective of females.

Correlation between mercury and loon productivity

For the 54 territories where we obtained three or more consecutive years of productivity data, female loons in the highest Hg exposure risk category showed a 32% reduction in the number of chicks fledged per year compared to those in the lowest exposure risk category (Fig. 3). Males in the highest Hg exposure group showed a 54% reduction in productivity compared to those in the lower exposure group.

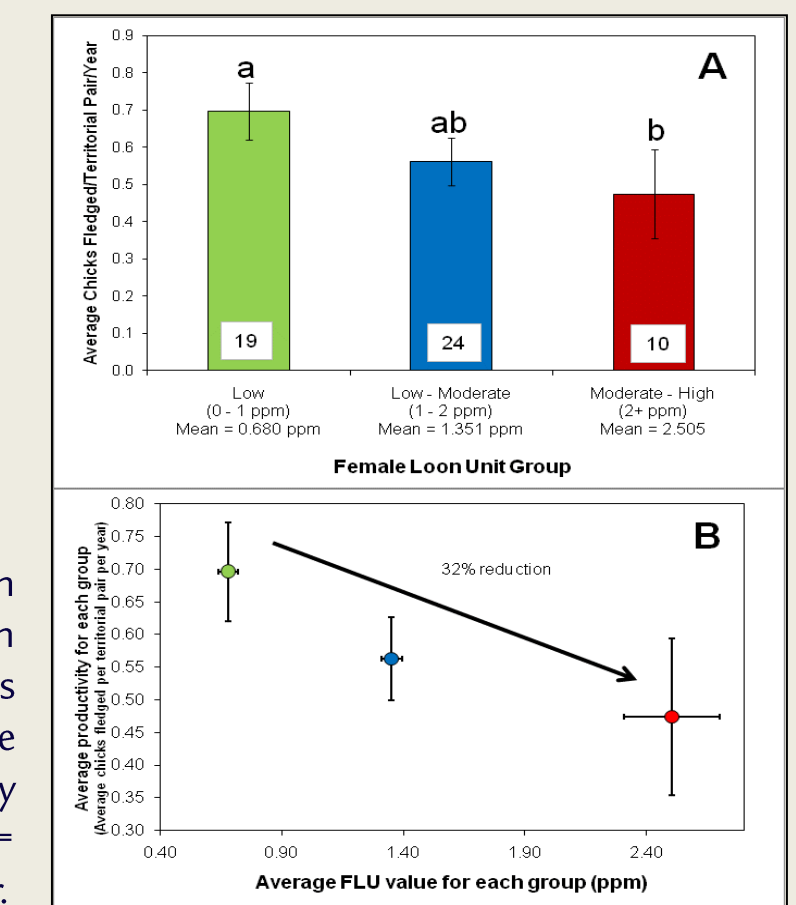


Figure 3. Comparison of annual productivity by female loon unit groups for A) three mercury risk groups and B) based on average mercury value within each group. Numbers within bars indicate number of territories where productivity and female loon unit were both measured, letters indicate marginally significant differences between groups (Kruskal-Wallis $\chi^2 = 5.136$, $df = 2$, $p = 0.077$) and error bars indicate standard error.

Quantile regression

We found a negative correlation between productivity and Hg levels for both FLUs ([Productivity] = -0.128 [FLU] + 0.764) and MLUs ([Productivity] = -0.0992 [MLU] + 0.806). For both males and females, the slope of the regression line increased at the 80th and 90th quantiles, indicating that Hg likely exerts more pressure on the upper limits of the Adirondack loon population.

Quantile regression indicated that the maximum Adirondack loon productivity with negligible female or male loon Hg exposure was ~1.0 CF/TP, and that productivity would be reduced by 50% when female blood Hg levels were 3.3 µg/g or male blood Hg levels were 4.5 µg/g. We predict that productivity would fail entirely when female blood Hg levels exceed 6.8 µg/g or male blood Hg levels are higher than 8.96 µg/g.

Population model

An EPA loon population model indicated that the portion of the Adirondack loon population exposed to high Hg levels has a much reduced growth rate ($\lambda = 1.0005$), compared to that of birds that had low Hg loads ($\lambda = 1.026$; Fig. 4).

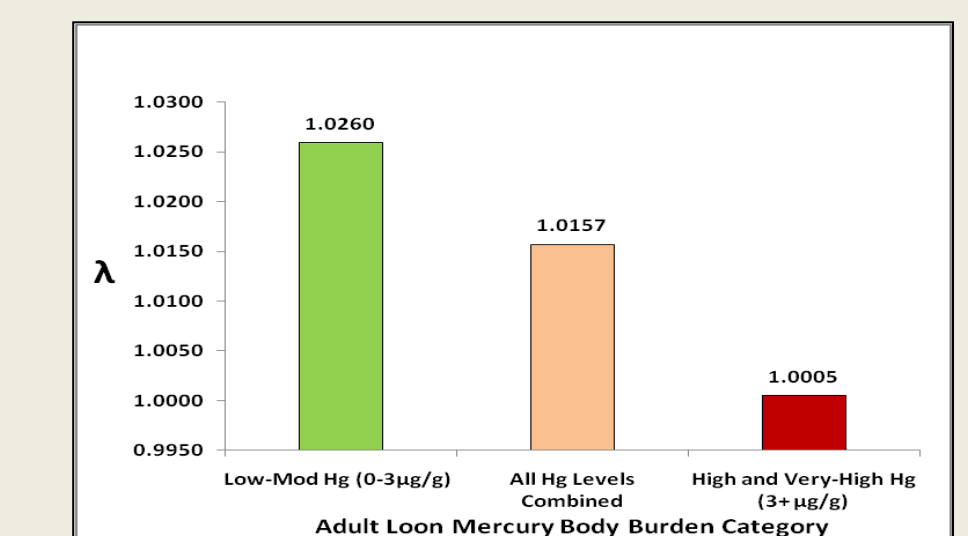


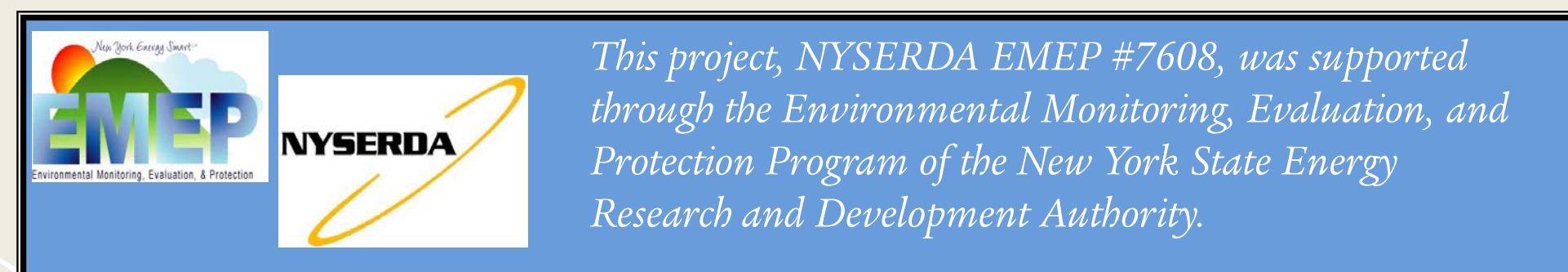
Figure 4. Adirondack adult loon population growth rate by Hg body burden category, based on Grear et al. (2009) loon population model.

Discussion

Our study provides additional support for the critical need to protect aquatic ecosystems from the impacts of environmental mercury contamination. In particular, our results 1) documented the extent of mercury contamination and its impacts to New York's aquatic ecosystems; 2) provided evidence for ecological damage to public resources; 3) provided science-based justification for policy-makers to stringently regulate mercury and acidic emissions on local, regional, and national scales; and 4) established a baseline for detecting future changes in biotic impacts from atmospheric mercury deposition.

Literature Cited

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