Results — Long-Term Monitoring and Assessment of Mercury Based on Integrated Sampling Efforts Using the Common Loon, Prey Fish, Water, and Sediment

Results

Mercury in the foodweb
Mean Hg concentrations within the foodweb 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 (0.017 μg/g) to fish (large fish = 0.09 μg/g, extra-large fish = 0.167 μg/g) to loons (0.72 μg/g adult female, 2.16 μg/g adult male). There was a strong correlation between large and extra-large fish Hg and loon blood Hg (large fish vs. FLU: R²=0.2878, F=16.17, p<0.001; vs. MLUs R²=0.3196, F=15.97, p<0.001; extra-large fish vs. FLU R²=0.2088, F=12.11, p=0.002; vs. MLUs R²=0.4533, 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 adult, averaging 0.24 μg/g (s=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. 1% of male and female loons were at high risk of a behavioral and reproductive impacts based on blood Hg exposure (Fig. 1), and 17% of male and 7% of female loons were at high risk of impacts based on feather Hg exposure. 13% of loon eggs were at high risk for Hg exposure. It is alarming that, if the chicks hatched, their behaviors would be abnormal, and they would have a reduced likelihood of surviving to fledging.

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: R²=0.2878, F=16.17, p<0.001; vs. extra-large fish: R²=0.2894, F=15.07, p<0.001) and loon tissues (pH vs. FLU: R²=0.1786, F=4.20, p<0.05; vs. MLUs R²=0.3129, F=5.55, p=0.024). Although no significant spatial trends in Hg availability within the Adirondacks were observed (Fig. 3), a kriging model estimated the southward Hekateans concentrated the southwest Adirondacks tended to have lakes with higher loon Hg levels, corresponding to increased acid deposition for that area.

Correlation between mercury and loon productivity
For the meadows 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.

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 loons and females, the slope of the regression line increased at the 80th and 90th percentiles, indicating that Hg likely exerts more pressure on the upper limits of the Adirondack loon population.

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 (λ=0.1003), compared to that of birds that had low Hg loads (λ=1.026; Fig. 4).

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 strongly regulate mercury and acid 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

Introduction
High levels of environmental mercury (Hg) have been documented in five biological “hotspots” of contamination, north of the North America, including New York’s Adirondack Park. In aquatic 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), sediment (n=43 lakes), and lake basin characteristics. 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. Looon Hg concentrations were converted to a single common unit (female loon (FLU) or male loon (MLU)) to evaluate and utilize existing data from various biotic compartments, and facilitate comparison between locations and years.

Study Objectives
1. Characterize aquatic-based Hg exposure in the Adirondack Park by:
   a. Individual lake Hg profiles by determining Hg levels in both abiotic (water and sediment) and biotic (zooplankton, crayfish, fish, and loons) compartments.
   b. Evaluating the spatial distribution of Hg across the Adirondack Parks.
   c. Developing a bioconcentration factor for the Adirondacks.
   d. Determining relationships between Hg in various aquatic compartments of the food chain.
   e. Relationship between lake acidity and Hg contamination.
   f. Determine the % of the Adirondack loon population at risk of reduced productivity.
   g. Assess the effect of Hg on the Adirondack common loon population via:
      1. Evaluating relationships between Hg and lake acidity on productivity.
      2. Modeling the long-term effect of Hg on the Adirondack loon population using the US EPA common loon population model (Greer et al. 1999).
      3. 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.

Wetland criterion value
We used variables specific to the Adirondack to develop a New York Based Wetland Criterion Value to provide an estimate of wildlife productivity within the collection of contaminant stressors. We determined that an unfiltered water sample ≤ 2.00 mg Hg/L is protective of male loons, while a water sample ≤ 1.69 mg Hg/L is protective of females.