

ASSESSING MERCURY EXPOSURE AND SPATIAL
PATTERNS IN ADULT AND NESTLING BALD EAGLES IN
NEW YORK STATE, WITH AN EMPHASIS ON THE
CATSKILL REGION.

(Report BRI 2008-06)



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ADULT AND NESTLING BALD EAGLES IN NEW YORK STATE, WITH
AN EMPHASIS ON THE CATSKILL REGION.**

(BRI Report 2008-06)

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EXECUTIVE SUMMARY

Background and methods: We investigated mercury (Hg) exposure in nestling and adult bald eagles at nesting territories throughout New York State (NYS) in response to growing concerns about Hg contamination and effects on wildlife in the northeastern US. This study emphasized the Delaware / Catskill region of New York because this area is subject to notably high rates of Hg deposition, and is the focus of other ongoing Hg investigations. We collected breast feathers and/or blood from nestling bald eagles and shed feathers from adults at nest sites and analyzed these tissues for Hg (n = 102 tissues). Sampling in this study represented 53% of all occupied nesting territories and 69% of all territories fledging young statewide in 2006. We assessed statewide geographic patterns of bald eagle Hg concentrations among seven major watersheds and within the Catskill Park. In addition, we compared Hg concentrations found in this study to those reported elsewhere in North America and assessed the potential risk that Hg contamination poses to New York's eagle populations. We also compared Hg concentrations in eagle tissues to those found in local fish at a subset of lakes and reservoirs.

Assessment of Hg exposure in bald eagles from regions throughout New York: Findings of this study support assumptions that Hg concentrations may be higher in eagles in the Delaware / Catskill region compared to other regions in the state.

- The mean eaglet blood Hg concentration (which reflects Hg in recent diet) for the Delaware / Catskill region was 0.52 ± 0.25 ppm (n = 16 territories), significantly higher than the mean for all other regions (0.26 ± 0.16 ppm, n = 25).
- The mean eaglet blood Hg concentration was higher within or near the Catskill Park boundary (0.64 ± 0.24 ppm) than it was on the Delaware River along the NY/PA border (0.28 ± 0.11 ppm). Limited sampling indicated generally low (background, < 0.40 ppm) blood Hg concentrations in the Southeast Lake Ontario, Susquehanna, and Southeast / Croton regions. One or more eaglet blood samples fell within the moderate (0.40 – 0.69 ppm) range in the Delaware / Catskill, Western, Adirondacks, and Upper Hudson regions.
- Mean territorial adult feather Hg concentrations (which reflect chronic lifetime Hg burdens) were not significantly different between the Delaware / Catskill region (34.0 ± 20 ppm) and all other regions of New York (29.2 ± 19 ppm).

Population comparisons: Sampling indicates Hg in bald eagles in NYS varies by region. For most of the State, bald eagle Hg concentrations were similar to levels in populations that were considered to have low/background Hg exposure; however, mean concentrations from the Delaware / Catskill region and

from the Catskill Park in particular were similar to levels in other populations that were considered elevated.

- *Eaglets:* The mean eaglet blood Hg concentration in the Delaware / Catskill region was comparable (within 0.05 ppm) to levels found in eaglets from Maine lakes or from Pinchi Lake, B.C., areas considered to have high risks to eagles from Hg exposure. Pinchi Lake is associated with a Hg mine, while sources and exposure vary at Maine lakes. Reproductive impacts due to Hg have been suggested for Maine's lake-dwelling eagle population and other fish-eating wildlife such as common loons. The mean eaglet blood Hg concentration from within or near the Catskill Park approached the level considered elevated in this study (0.70 ppm) and was higher than levels reported in most comparable (i.e., similarly-aged eaglets) studies conducted in North America.
- *Adults:* Mean territorial adult feather Hg concentrations in New York were higher (statewide mean) than mean levels from Alaska, Florida (both locations <20 ppm; considered background levels) and the Great Lakes (considered moderate levels) but lower than levels found in Maine lakes, Pinchi Lake, and New Hampshire (all locations ≥ 40 ppm, the level considered elevated in this study).

Assessment of risks to populations: Findings based on analyses of both eaglet blood and adult feathers indicate a portion of NY bald eagle breeding territories had Hg levels exceeding those considered elevated and those associated with concern. In general, a higher proportion of territories were considered elevated in the Delaware / Catskill region compared to other regions of New York.

- *Eaglets:* Twenty-five percent of the territories sampled in the Delaware / Catskill region, and 43% of territories falling within or near the Catskill Park had mean blood Hg concentrations above the level designated as elevated in this study (≥ 0.70 ppm). The only territory considered highly elevated (≥ 1.0 ppm) was in the Catskill Park. No New York territories exceeded 0.70 ppm outside the Delaware / Catskill region.
- *Adults:* Twenty-six percent of the territories sampled statewide and 33% of territories sampled in the Delaware / Catskill region had mean feather Hg concentrations above the level designated as elevated in this study (40 ppm).

Hg concentrations in eagles and fish: Bald eagles are one of the most common species used to monitor contaminants in aquatic ecosystems; however, this study is the first to evaluate the relationship between fish and bald eagle Hg concentrations in the northeastern U.S.

- Several sites with elevated Hg levels in fish also had high eaglet blood Hg concentrations; however, overall patterns were inconsistent and varied by fish species and study site. Additional sampling is required to further understand the relationship between fish Hg levels and those found in eagles.
- Eaglet blood Hg concentrations were correlated with those measured in standard size smallmouth bass. Eaglet blood Hg was also positively related to concentrations found in both standard size walleye and brown trout; however, samples sizes were small and thus the relationships were uncertain. No relationships were detected between eaglet blood Hg and levels in standard size yellow perch or several other fish species.
- A variety of factors, including differential dietary habits of bald eagles, the use of foraging areas outside the fish-sampling waterbody, and the selection of fish species not represented in our dataset are likely causes for the variation in fish and eagle Hg relationships.

The results of this study constitute an initial baseline assessment of Hg in New York's bald eagle populations. Expanding on the knowledge gained through this study is critical to understanding the impact of Hg contamination on eagles and other biota in New York. We provide recommendations for further study at the end of this report.

INTRODUCTION

Concerns over mercury (Hg) contamination and subsequent impacts on humans and wildlife are increasing in northeastern states (Evers 2005). Hg in lakes and rivers can originate from both point and non-point sources. The primary source of Hg in the Northeastern U.S. is from atmospheric deposition related to local and regional municipal waste incinerators, coal burning power plants, and medical waste incinerators. Once Hg enters an ecosystem, factors such as quantity of shoreline wetland habitat, water level fluctuations, high acidity, and foodchain length have strong influences on the extent to which it biomagnifies up the foodweb and becomes available to wildlife (Driscoll et al. 2007, Evers et al. 2007, Munthe et al. 2007).

Hg is of concern throughout New York State; over 70 waterbodies are listed by the New York State Department of Health to have fish contaminant levels exceeding federal human health standards. Hg levels in fish and wildlife sampled by BioDiversity Research Institute (BRI), the New York State Department of Environmental Conservation (NYSDEC) and others commonly exceed concentrations associated with negative impacts on wildlife (Yates et al. 2005, BRI unpublished data, Loukmas and Skinner 2005, Loukmas et al. 2006, Simonin et al. 2008, Peter Nye, NYSDEC, unpublished data). Recent atmospheric Hg modeling has indicated that the Catskill Mountain region of New York is subject to some of the highest rates of Hg deposition in the northeast (Miller et al. 2005). In addition, other studies have suggested that the Catskill region is likely one of several designated “mercury hotspots” in the northeast (Evers et al. 2007).

Species such as the bald eagle (*Haliaeetus leucocephalus*) are at risk from Hg due to their long lifespan, piscivorous diet, and high trophic level. These characteristics also make eagles effective monitors of aquatic ecosystem health (Bowerman et al. 2002, Gill and Elliott 2003, DeSorbo and Evers 2007). Current studies on bald eagle populations in Maine suggest that Hg may be limiting the recovery of this species (DeSorbo and Evers 2007), raising further concern about similar impacts on eagle populations in New York.

OBJECTIVES

1. Evaluate Hg exposure in New York's resident adult and nestling bald eagles statewide, with emphasis on the Delaware / Catskill region (defined in "Spatial Hg evaluations" below; displayed in Fig. 1).
2. Compare Hg concentrations in New York's bald eagle population with other regions.
3. Analyze relationships between adult and nestling eagle Hg concentrations and those in local fish from the same locality
4. Assess the potential for negative impacts of Hg on New York's bald eagle population.

METHODS

In an effort to maximize statewide representation, sampling efforts were coordinated with annual eagle banding events conducted by NYSDEC. Sampling efforts emphasized successful nesting pairs (i.e., pairs that did not produce young are underrepresented). A summary of eagle nest occupancy and productivity in New York in 2006 can be found at:

<http://www.dec.ny.gov/animals/9381.html> (Nye et al. 2007).

Target Tissues

Bald eagle tissues collected were (1) nestling blood and feathers and, (2) shed adult feathers found in or near the nest tree. Nestling tissues reflect recent dietary uptake while adult feathers reflect cumulative Hg burdens in resident adults. The majority of samples in this study were collected in 2006. Additional blood and feather tissues collected during 1998-2005 by NYSDEC biologists were also incorporated into analyses to expand spatial representation of Hg patterns. Sample sizes by tissue type collected in different years are as follows: nestling blood (2004, n = 1; 2005, n = 1; 2006, n = 17), nestling breast feathers (2006, n = 46), adult shed feathers (2006, n = 31), and adult breast feathers (1998, n = 1; 1999, n = 1; 2000, n = 5; 2006, n = 2) (Table 1).

Eaglet Sampling

Aerial and ground surveys, coordinated by NYSDEC, were used to confirm nest occupancy and nesting age. Tree climbers used traditional rope and spike methods to access nest sites that contained nestlings 5-8 weeks of age. Samples were collected using two approaches: (1) nestlings were lowered to the ground for collection of blood, feathers, and morphometrics measurements or (2) breast feathers were sampled from nestlings in the nest, with limited morphometric measurements and no blood samples.

Eaglets taken from the nest were placed separately into a bag and lowered to the ground for processing and banding. Blood was taken from the cutaneous ulnar vein of each eaglet (7-10 mL) using 23 ³/₄" butterfly needles attached to heparinized evacuated test tubes or a syringe for Hg analyses and sample archives. Blood samples were labeled and placed into protective cases in a cooler, and were frozen within ten hours. A few nestling breast feathers were cut using stainless steel scissors and placed into an envelope. Morphometric measurements taken were weight, bill length, culmen, footpad length, tarsus width, and eighth primary length following methods described in Bortolotti (1984). All birds were banded using USFWS silver bands and approved color bands (Nye et al. 2007). Eaglet processing lasted approximately 15-30 minutes after which individuals were returned to the nest. Eaglets processed directly in the nest were banded and sampled for breast feathers.

Adult Sampling

Shed feathers were collected from within and below eagle nests during visits. Additionally, breast feathers taken from resident breeding adults that were captured during summer months by NYSDEC biologists using floating fish snare techniques (Cain and Hodges 1989) or rocket nets (Nye 1990) were also included in analyses. Feathers were air dried and stored in a labeled plastic bag or envelope until analysis.

Sample Preparation and Laboratory Analysis

Blood samples were thawed, dried, and ground using a cryomill prior to analysis and adjusted for percent moisture. All blood samples were analyzed for total Hg using Direct Mercury Analysis (DMA) at the Savannah River Ecology Lab, Aiken, SC, and University of

Georgia. We analyzed the distal portion (approximately 20 mm) of each breast feather for total Hg. Feather tips were lipid extracted to remove surface contaminants and ground in a cryomill prior to analysis for total Hg using DMA. Hg in this portion is highly correlated with the remaining portion of the feather ($r^2 = 0.92$, $n = 24$ BRI, unpublished data) and flight feathers ($r^2 = 0.98$, $n = 12$ BRI, unpublished data). Hg concentrations in feather tips were converted to reflect Hg in the larger portion of the feather to reflect a longer period of growth and exposure. Shed adult feathers, typically one collected per nesting territory, were also analyzed. All blood Hg levels are reported as wet weight (ww) and all feather Hg levels are as fresh weight (fw). All analyses used quality assurance and quality control (QA/QC) procedures including procedural blanks, duplicates, spike recoveries, and certified reference material (Natural Research Council of Canada; generally dogfish muscle tissue [DORM-2] and dogfish liver tissue [DOLT-2, DOLT-3]). Detection limits were approximately 0.0025 for both blood and feather analyses. All analytical results were within acceptable limits.

Eagle Tissue Hg Conversions

Blood and breast feathers are the most common tissues used to evaluate Hg exposure in nestling raptors. Blood sampling from eaglets is time intensive, as it is best accomplished by lowering birds to a ground crew for processing. Breast feathers, however, can be easily sampled from nestlings at the nest. In this study, we emphasized sampling of breast feathers from the majority of nestlings, while sampling blood at a subset of nests. At sites where only breast feathers were taken, feather Hg concentrations were then used to predict blood Hg concentrations based on data presented in Welch (1994) in which nestling blood and feathers were found to be significantly related ($r^2 = 0.71$, $n = 72$ $p < 0.0001$). The Equation used for this conversion was:

$$\text{Breast feather to blood}^1: y_b = -0.012 + 0.027(x_f)$$

Data summaries for this report prioritized conversions of nestling breast feathers to blood (versus the reverse) because a greater proportion of comparison studies solely report blood Hg and Hg patterns are generally similar in both tissue types in nestling eagles (Welch 1994). Territories in which blood samples were collected are depicted in Figure 1. All sibling eagle tissue Hg values were averaged in nesting territories for all analyses. Data from multiple eagle

¹ Where subscripts $_b$ and $_f$ represent total blood and feather Hg concentrations (ppm, ww), respectively. Blood to breast feather¹: $y_f = 3.349 + 26.09(x_b)$

territories from the same lake were averaged for comparisons to fish Hg concentrations from the same waterbody.

Spatial Hg Evaluations

To assess spatial Hg patterns within New York, nesting territories were assigned to 7 regions. These regions are based on HUC-4 watershed delineations (New York State GIS Clearinghouse, <http://www.nysgis.state.ny.us>). Watersheds were modified in some regions to combine adjacent watersheds where sample sizes were limited (Roe 2004). All samples collected in the Catskill Park boundary were included in the broader Delaware / Catskill Region watershed (see Fig. 1). This region is referred to as the “Delaware / Catskill Region” throughout this report. Samples collected within the Catskill Park boundary will be referred to as being within the “Catskill Park.”

Hg Exposure Categories

Adverse effect thresholds for have not been established for Hg in nestling bald eagle blood and feathers. For adult bald eagle feathers, we used an adverse effect threshold of 40 ppm based on the common loon (*Gavia immer*, Evers et al. 2008); this threshold may or may not be applicable to adult eagles. For context, spatial patterns of Hg exposure were evaluated by categorizing eaglet blood and adult feather Hg concentrations into exposure “risk” groups, an approach similar to studies by Evers et al. (2004) for common loons. Categories are designated based on the most recent data and literature pertaining to each age class and tissue type.

Eaglet Blood

Eaglet blood Hg concentrations provide a short-term measure of Hg exposure through diet among similarly aged eaglets. Investigations of Hg in eagles and loons in Maine provide justification for category delineations used in this study (Burgess and Meyer 2008, Evers et al. 2008). Hg concentration categories for eaglet blood were:

Background: < 0.40 ppm
Moderate: 0.40 – 0.69 ppm
Elevated: 0.70 – 0.99 ppm
Highly Elevated: ≥ 1.0 ppm

Background and moderate categories are delineated in this study to provide further distinction among territories below the blood Hg level considered elevated (i.e., 0.70, Wiemeyer et al. 1989, DeSorbo and Evers 2007). The delineation between background and moderate groups is relatively arbitrary. The elevated risk category of 0.70-0.99 ppm is based on eaglet blood Hg concentrations in Maine of >0.70 ppm that occurred in areas where Hg levels exceeded established adverse effect levels in loons (DeSorbo and Evers 2007, Evers et al. 2008). Furthermore, Kenow et al. (2007) measured 0.66 ppm in blood Hg in 5-week old common loon chicks dosed with 0.4 ppm Hg, reporting suppression of antibody-mediated immunity in this exposure group. Collectively, evidence from lab and field studies indicates a 0.70 ppm benchmark for adverse effects on piscivores is reasonable. The highly elevated risk category at ≥ 1.0 ppm Hg in blood is based on similar studies in Maine. Eaglets in Maine with blood Hg concentrations ≥ 1.0 ppm were often located at sites associated with point sources, highly sensitive habitats (i.e., fluctuating water levels, extensive wetland habitat), or both. This characterization is consistent with those indicated by similar Hg investigations of common loon populations in Maine, where reproductive impacts have been documented (Evers et al. 2008). The highly elevated risk category is used to better depict individuals at the greatest potential risk to Hg.

Adult Feathers

Adult feather Hg concentrations can be variable due to influences such as age, sex, molt (Braune 1987), and other factors (Wolfe et al. 1998). Feathers are, however, widely used in Hg monitoring efforts in order to assess cumulative body burdens in adults (Burger 1993). Hg concentration categories for adult feather tissues analyzed in this study were:

Background: <20 ppm
Moderate: 20 – 40 ppm
Elevated: 40 – 60 ppm
Highly elevated: >60 ppm

In this study eagle feathers <20 ppm Hg were considered background levels based on Scheuhammer (1991); he suggested that bird populations with feather Hg levels >20 ppm should be considered at risk for toxic effects. We use 40 ppm to delineate the elevated Hg category based primarily on lab (Spaulding et al. 2000) and field (Evers et al. 2008) studies. Spaulding et al. (2000) reported 40 ppm in feathers of egrets fed 0.5 ppm Hg, providing some indication of how dietary intake in eaglets. Evidence of negative impacts on behavior were detected in that study. Evers et al. (2008) found flight feathers of adult common loons with Hg burdens ≥ 40 ppm in had lower symmetry in bilateral flight feathers. The ability of birds to develop symmetric bilateral characters is considered an indirect measure of fitness (Clarke 1995). Increased wing asymmetry has been linked to increased energy expenditure (Swaddle 1997) and decreased survival during extreme climactic events (Brown and Brown 1998). Further evidence for using 40 ppm as a Hg level of adverse effects exists; (1) Weech et al. (2006) found that adult eagles from a contaminated Hg site on Pinchi Lake regularly had >40.0 ppm Hg in feathers, and (2) Berg et al. (1966) reported 45-65 ppm Hg in feathers of white-tailed eagles in Sweden where Hg compounds were applied directly to the landscape as a fungicide. Reproductive impacts were suggested in that study, however reproductive effects may have been attributable to organochlorine compounds, which were not tested. The highly elevated Hg category is delineated at 60 ppm to better categorize individuals at greatest risk of potential Hg impacts. Feather Hg concentrations >60 ppm are not commonly reported in literature except in situations where populations were exposed to notable anthropogenic Hg influences, such as in James Bay, Quebec (Osprey; DesGranges et al. 1998) or Sweden (Berg et al. 1966, Westermark et al. 1975). Reproductive effects were not detected in the DesGranges et al. (1998) study. Reproductive impacts due to Hg were not evaluated in the Westermark et al. (1975) study.

Fish Sampling and Analysis

Fish Hg data from several recent NYSDEC contaminant monitoring projects on New York lakes, ponds, and reservoirs were used to assess the relationship between eagle tissue and local prey based concentrations (Loukmas and Skinner 2005, Loukmas et al. 2006, Simonin et al. 2008).

NYSDEC and New York City Department of Environmental Protection biologists collected fish from 1998 - 2005 using a variety of methods including electrofishing, gill netting, and

angling. Fish were handled according to standard NYSDEC fish collection and handling procedures (Loukmas and Skinner 2005). This required recording the date of collection, a unique identification number, the location including GPS coordinates, species, length in millimeters, weight in grams, and method of collection on standard specimen collection forms. Chain-of-custody forms were maintained and samples were kept cool and frozen immediately after handling on the same day of collection.

Fish samples were processed according to standard NYSDEC methods (Loukmas and Skinner 2005), which included partially thawing fish, removing scales, and then removing a skin-on and rib bone-in fillet that extended from the gill cover to the caudal fin (i.e., standard fillet). The fillet was then homogenized in a food processor before being placed in a clean sample jar. Hg analysis was performed by staff at the NYSDEC Hale Creek Field Station for samples collected from 1998 - 2000. Cebam Analytical (Seattle WA) analyzed all subsequent samples (2001 - 2005). All fish data are presented on a ww basis. QA/QC results for fish samples were previously reported in Loukmas and Skinner (2005), Loukmas et al. (2006), and Simonin et al. (2008). These results were all within acceptable limits.

Standardization of Fish Data

Fish length is positively correlated with Hg concentrations (Loukmas and Skinner 2005), but intraspecific mean fish length varied substantially among project waters. In order to standardize fish Hg levels for individual species among waters, linear regressions were performed using Hg concentrations and fish length as the dependent and independent variables, respectively, with subsequent regression-based predictions made for average-sized (i.e., standard size) fish of selected species. These standardizations allowed for comparisons of individual species of fish and eagle Hg concentrations among waters. Data were excluded for fish species from several lakes if sample sizes were too small, or if the data were considered too unusual for reliable Hg predictions.

Statistical Analysis

Normality of datasets were evaluated using visual inspection of normal quantile plots, distributions, and a Shapiro-Wilk W test. Group means were evaluated using a Student's t test or ANOVA as appropriate for normal datasets, and a Wilcoxon test when data were not normally

distributed. Linear regression was used in tissue conversions. Pearson or Spearman rank correlation tests were used to compare relationships between variables depending on normality of datasets.

RESULTS AND DISCUSSION

One hundred and two tissues from nestling and adult bald eagles from New York State were analyzed for Hg (Table 1). Samples were collected from 58 breeding territories, comprising 69% of all territories fledging young statewide, and 53% of all occupied nesting territories in 2006 (Nye et al. 2007). Eaglet breast feathers and blood were analyzed in 16 territories in the Delaware / Catskill region while adult feathers were analyzed from 12 territories in this region. Forty-six percent (47/102) of all tissues analyzed in this study were collected in the Delaware / Catskill region.

Table 1. Number and type of tissues collected from nestling and adult bald eagles in New York State overall (and within the Delaware / Catskill region) analyzed for Hg, 1998-2006^a.

Tissue	Eaglets		Adult	
	no. samples	no. territories	no. samples	no. territories
Blood	19 (12)	16 (10)	0	-
Breast feather	46 (20)	39 (16)	7 (1)	6 (1)
Shed feather	-	-	31 (14)	30 (12)
TOTAL:	65 (32)	41 (16)	37 (15)	35 (12)
Breast feather converted to blood	35 (13)	34 (12)	-	-

^a Sample sizes reflect the total number of individual samples analyzed statewide. Numbers in parentheses indicate the number of samples / territories in the Delaware / Catskill region as defined in methods and delineated in Fig. 1. Sample sizes in Table 1 will vary from those presented in analyses due to averaging multiple samples in nesting territories. All samples represent those associated with nesting territories. Totals in the territory columns do not match tissue subtotals in rows due to cases where multiple tissue types were collected in a territory (and only counted once). Last row indicates the number of samples / territories in which nestling breast feather Hg values were used to predict blood Hg values (see methods).

Evaluating Spatial Hg Patterns in New York's Eagle Population: Preliminary Findings

The Delaware / Catskill region in southeastern New York was the focal area of emphasis for this study (Fig. 1), and therefore is best represented in sampling efforts. Samples collected by NYSDEC in other areas of the state allowed for additional assessments of Hg in New York bald eagles elsewhere in New York State. Samples sizes were, however, limited in these other

regions, and therefore provide only preliminary results. Because eaglet blood samples are less influenced by bird age and chronic Hg body burdens compared to other tissues such as adult feathers, eaglet blood is emphasized in the following discussion of spatial Hg patterns.

Findings of this study support assumptions that Hg concentrations may be higher in eagles in the Delaware / Catskill region compared to most other regions in the state (Figs. 1, 2). Eaglet sampling elsewhere in the state, although limited, indicates generally low (background) blood Hg concentrations of < 0.40 ppm in (1) Southeast Lake Ontario, (2) Susquehanna, and (3) Southeast / Croton regions. One or more eaglet blood samples fell within the moderate ($0.40 - 0.69$ ppm) range in the Delaware / Catskill, Western, Adirondacks, and Upper Hudson regions. Only the Delaware / Catskill region contained a territory (Neversink Reservoir, nest #15) that fell into the highly elevated category based on mean eaglet blood Hg concentrations. Eaglets from the Adirondack mountains region had higher blood Hg levels than those from the St. Lawrence River area (Fig. 1). Factors including increased atmospheric deposition (Miller et al. 2005) and lower pH of lakes in the Adirondack Mountains (Driscoll et al. 2007) likely contribute to this finding. The sample size of adult feathers was insufficient to evaluate such geographic patterns.

Hg Exposure in Eaglets: Delaware / Catskill Region vs. Other Regions

The mean blood Hg concentration for eaglets in New York regions excluding the Delaware / Catskill region was 0.26 ± 0.16 ppm (Figs. 1 & 2). This mean was significantly lower than the mean eaglet blood Hg concentration for the Delaware / Catskill Region (0.52 ± 0.25 ppm; $n = 16$) ($p = 0.0002$, $t = 4.1$, $n = 41$; Figs. 1 & 2). Within the Catskill Park boundary, the mean eaglet blood Hg concentration was 0.64 ± 0.24 ppm ($n = 7$ territories on Ashokan, Rondout, Neversink, Mid-Pepacton, and Dunraven). These sites are responsible for increasing the mean Hg concentration for eaglets in the Delaware / Catskill region. Conversely, 4 sites on the Delaware River along the New York / Pennsylvania border (Hancock #38; Cole Flats #45, Tusten #20, and Cedar Rapids #109) lowered the mean blood Hg concentration for the overall Delaware / Catskill region; the mean for these territories was 0.28 ± 0.11 ppm. Three out of four of these Delaware River eagle territories had eaglet blood Hg concentrations < 0.40 ppm, and one site (#20 Tusten) was at the low end of the $0.40 - 0.69$ ppm range. The variability in Hg exposure within the Delaware / Catskill region demonstrates the influence of other factors, such as habitat and geographic location on Hg exposure in bald eagles. Increased sample sizes are

needed to further assess differences among habitats and regions, both of which have significantly influenced Hg exposure in eaglets elsewhere (Welch 1994, DeSorbo and Evers 2007). For example, eaglets at lakes in Maine have higher Hg concentrations compared rivers, and Hg exposure also differed significantly among watersheds. Fish and birds sampled in reservoirs may exhibit elevated Hg compared to natural lakes and rivers (Kamman et al. 2005). All sites within the Catskill Park boundary were reservoirs. Habitat and spatial influences on Hg patterns are due to both anthropogenic (e.g., proximity to atmospheric and point sources, water level management, and dredging), and natural factors (e.g., Hg deposits and the ability of certain habitats to methylate inorganic Hg).

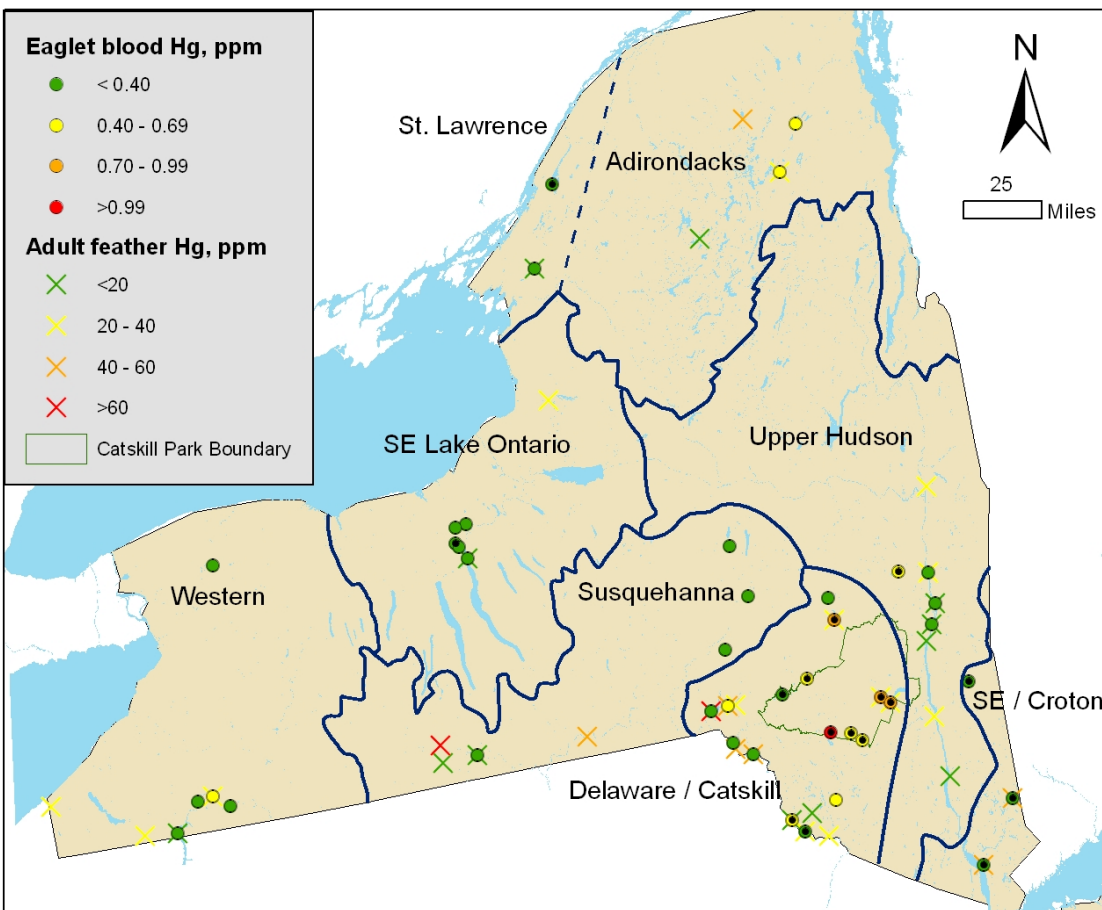


Figure 1. Mercury concentrations in eaglet blood and adult feathers in 7 regions of New York State.

Figure 1 Caption: Watershed boundaries delineated by solid blue lines. Dotted line delineates the St. Lawrence mentioned in discussion. Territories in which blood samples were collected from eaglets noted by black dots; eaglet blood Hg concentrations at all remaining territories predicted from Hg concentrations in breast feathers (see text).

Population Comparisons and Interpretations: Eaglets

Numerous studies have evaluated blood Hg concentrations in similarly aged eaglets in other regions of North America (Fig. 2). Although falling only in the middle of the “moderate” range, the mean blood Hg concentration in the Delaware / Catskill Region (0.52 ppm) was most similar to studies in which authors considered Hg levels to be elevated compared to background levels. The mean eaglet blood Hg concentration for the remainder of New York State (0.26 ppm) was generally comparable to other inland populations in which researchers characterized Hg exposure and risk as low.

Delaware / Catskill Region: The mean eaglet blood Hg concentration in the Delaware / Catskill region was notably higher than levels found in populations in South Carolina, Florida, and Washington State (Fig. 2). While some individuals approached or exceeded levels of concern in those regions, average Hg concentrations in eaglets from those states were generally considered to be lower than those associated with adverse effects in other species (see Fig. 2 for citations). Blood Hg concentrations for Delaware / Catskill region eaglets were 18% higher than those found on Maine rivers (0.44 ppm), and 11% higher than levels in the Columbia River Estuary (0.47 ppm).

Maine river sampling in particular reflects a wide range of Hg concentrations from a diverse selection of inland sites, including some highly contaminated areas identified as U.S. Environmental Protection Agency Superfund sites. Authors of a study in the Columbia River Estuary considered blood Hg concentrations in eaglets from that region to be elevated, likely due to the combined influences of point sources, dredging, and hydroelectric dam operations in the region. No evidence of negative reproductive impacts was detected in eagle populations from Maine rivers or the Columbia River Estuary; however, other studies (DeSorbo 2008, Evers et al. 2008) demonstrate negative impacts due to Hg may not be detected with small sample sizes such as those in these habitats and regions.

Mean blood Hg concentrations for eaglets in the Delaware / Catskill region were 8% lower than those found on Maine lakes (0.56 ppm), and 10% lower than those found on Pinchi Lake, B.C (0.57 ppm). Authors of studies in Maine (DeSorbo and Evers 2007, DeSorbo 2008) and in Pinchi Lake, B.C. (Weech et al. 2006) considered these means to be above background

levels. Significant adverse effects on reproduction have been demonstrated in lake-dwelling eagle and common loon populations in Maine (DeSorbo and Evers 2007, Evers et al. 2008). No evidence of reproductive impacts due to Hg were found in eaglets at the Pinchi Lake, B.C., although small territory sample sizes and use of short-term productivity measures (3 years) precluded robust statistical analyses).

Blood Hg concentrations in 7-11 week-old eaglets in southcentral Oregon (1.2 ppm) are highly elevated and are higher than levels reported from any other region (Fig. 2)². Two factors influenced eaglet Hg exposure in this population: (1) cinnabar deposits and increased bioavailability of Hg from mining activities create a “mercuriferous belt” spanning parts of the western U.S. and Canada (Jonasson and Boyle 1972, Wiemeyer et al. 1989) and, (2) the older age of eaglets sampled in this region. Slowing rates of feather growth provide fewer excretory routes for Hg compared to younger nestlings (Fournier et al. 2002, Kenow et al. 2003, BRI unpubl. data). Therefore fair comparisons between the Oregon study and others is challenging. The Hg level in Oregon eaglets, however, may best represent an upper level benchmark for comparison to other studies.

Other regions in New York excluding the Delaware / Catskill region: The mean eaglet blood Hg concentration from all regions in New York State excluding the Delaware / Catskill Region (0.26 ppm) falls within the background category delineated in this study; however, this level is still ≥ 2 times that found in populations in South Carolina and eutrophic lakes in Florida. These concentrations are also 13% higher than that found in Washington State, but considerably lower than levels in several other populations (Fig. 2). Authors of studies in South Carolina and Florida suggested that while some individuals may have approached Hg levels of concern, overall populations in those regions were not considered to be at significant risk to Hg impacts. Additional sampling will be necessary to more thoroughly characterize Hg exposure in eaglets outside of the Delaware / Catskill region in New York.

² Wiemeyer et al. (1989) also noted 1.50 ppm in post-fledged eaglets in Montana. Post-fledged eaglets are not used as comparisons in this study as they are not comparable to prefledged eaglets due to demonstrated influences of the feather molt on circulating blood Hg levels.

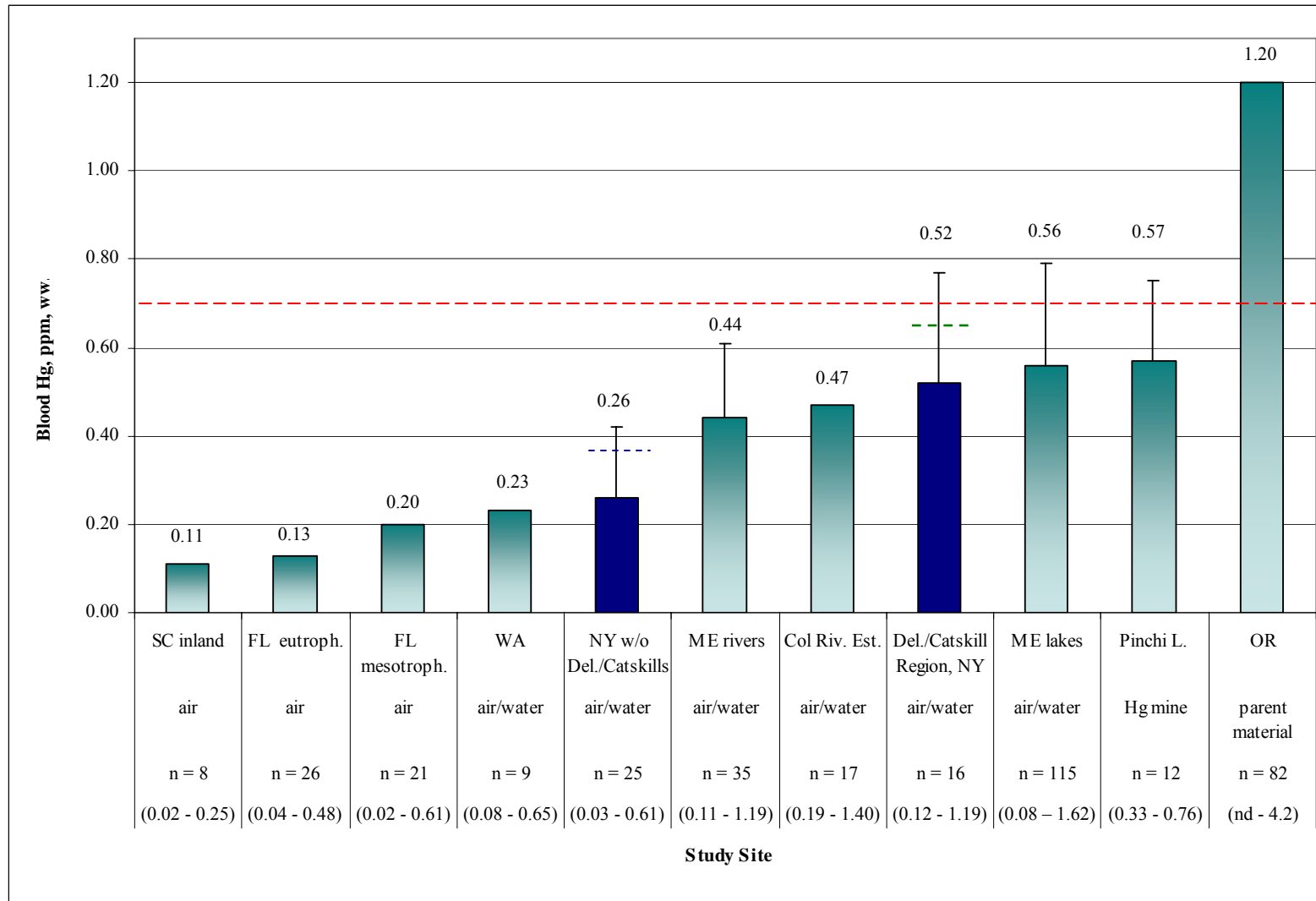


Figure 2. Blood mercury concentrations (ppm, ww) measured in inland nestling bald eagles in the United States and Canada.

Error bars represent standard deviations and were not available in six comparison populations. Sample sizes represent number of territories. Siblings and repeat sampling between years are averaged/nest. Red dashed line at 0.70 ppm reflects blood Hg level considered “elevated” in this report and other studies (see methods). Regions from left to right: South Carolina inland (Jagoe et al. 2002; range reflects inland and marine nests), Florida eutrophic and mesotrophic lakes (Wood et al. 1996); Washington State (Wiemeyer et al. 1989); NY w/o Catskills = nests sampled throughout NY state, excluding those in the Catskills Region. Dotted blue line on NY w/o Del./Catskills (0.36 ± 0.23 ppm; range: 0.05 – 1.0 ppm) represents pooled mean of ALL sampled NY territories. “Maine rivers”; freshwater sites only (DeSorbo and Evers 2007); “Col. Riv. Est.” = Columbia River Estuary (Anthony et al. 1993) a site associated with extensive Hg point source pollution inputs likely exacerbated by numerous anthropogenic activities (e.g., dredging, hydroelectric dams); Delaware / Catskill region, NY (this study), dashed green line on this bar represents mean for territories within/near the Catskill park boundary (0.64 ± 0.24 ppm, n = 7); Pinchi L. (Pinchi Lake, BC, Canada, Weech et al. 2006; a site associated w/ a Hg mine. Oregon (Wiemeyer et al. 1989; represents unusually elevated eaglet blood Hg exposure (see text).

When considering all sampled territories excluding those within the Delaware / Catskill region, none exceeded our adverse effect level (≥ 0.70 ppm) (Fig. 3). Of all the territories sampled statewide, 10% had mean blood Hg concentrations above the adverse effects level³. Twenty-five percent of the sampled territories in the Delaware / Catskill region had mean Hg concentrations above the effects level. Lastly, 43% of territories falling within or near the Catskill Park boundary had mean Hg concentrations above the effects level.

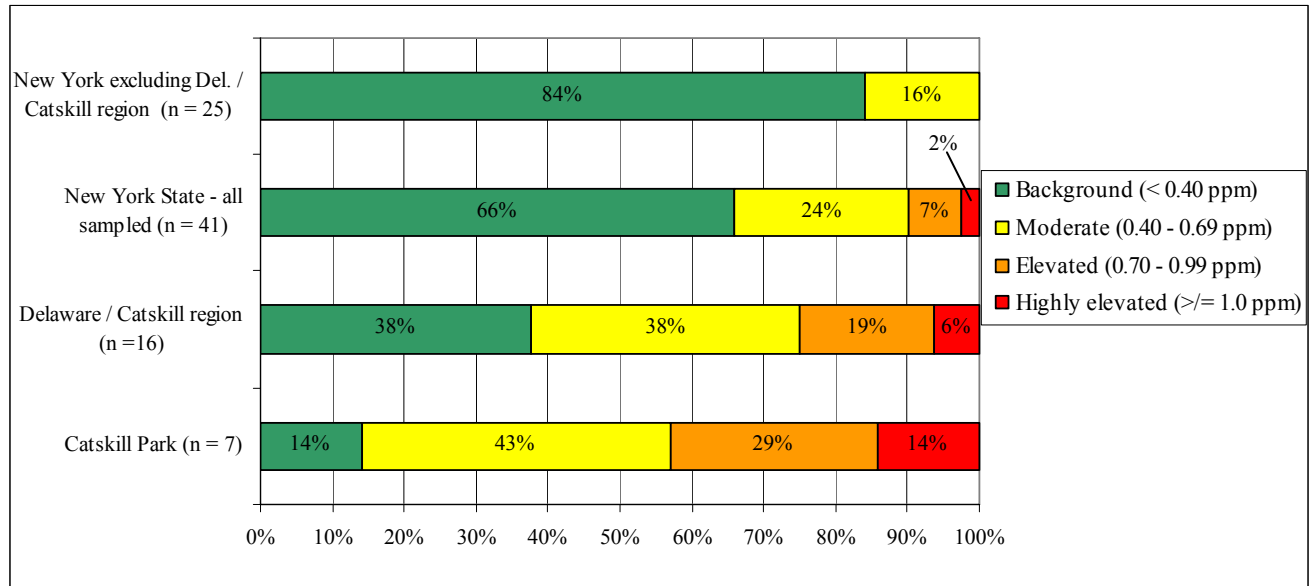


Figure 3. Proportions of New York bald eagle territories in which mean eaglet blood Hg concentrations fell within 4 ranges of Hg concentrations.

See Fig. 1 and text for delineation of Delaware / Catskill and other regions. Catskill Park represents territories falling inside or near the Catskill Park boundary. Territory sample sizes in parentheses.

Population Comparisons and Interpretations: Adult Eagles

Hg concentrations in adult feathers provide a coarse measure of chronic accumulated body burdens. Analysis of shed and sampled breast feathers at breeding sites throughout New York State indicate that Hg is bioaccumulating to elevated (≥ 40 ppm) concentrations in some individuals. The overall mean adult feather Hg concentration from all regions was 30.9 ± 19 ppm (Fig. 4). The mean Hg concentration in resident adult bald eagle feathers was 34.0 ± 20 ppm in the Delaware / Catskill region (range: 5.7 – 77.9 ppm), and 29.2 ± 19 ppm (range: 8.9 –

³ The number of territories in this group adds to 10% (despite the appearance from the figure that it = 9%) after considering decimal places not shown in the figure for presentation.

75.6 ppm) in other regions in New York. These means were not significantly different ($p > 0.05$). Other studies have demonstrated adult bald eagle feathers are less likely to reflect geographic differences often detected in blood (DeSorbo and Evers 2007, DeSorbo 2008). Hg concentrations in eagle feathers have high variability due to factors such as, age, sex, location, and food predilection. Because of the similarity in mean Hg concentrations between the Delaware / Catskill region and other New York sites, the statewide mean (30.9 ppm) will be used for comparisons to other studies.

Similar to measures in eaglet blood, Hg concentrations in New York's adult eagle population fell in the middle of the "moderate" range, but were higher than several populations in the southeastern and midwestern U.S. The statewide mean was most comparable to populations found on Maine rivers, although several New York samples contained higher concentrations than those found on Maine lakes. The mean feather Hg concentration for adult bald eagle feathers in New York State fell between 20 ppm and 40 ppm levels, which have some references in literature. Scheuhammer (1991) suggested bird populations should be considered for toxic Hg effects from when Hg levels exceeded 20 ppm. Evers et al. (2008) considered 40 ppm an adverse impact threshold (see also review in Wolfe et al. 1998).

Sixty-six percent of territories sampled in New York had adult feather Hg concentrations ≥ 20 ppm; a level considered moderate in this study (Fig. 5). Twenty-six percent of territories sampled had Hg concentrations in feathers considered above Evers et al.'s (2008) adverse effect level (≥ 40 ppm).

In the Delaware / Catskill region, 83% of the adult eagle feathers exceeded the moderate level (≥ 20 ppm), while over one-third exceeded adverse effect level at > 40 ppm. Sample sizes limited further delineations of adult feather Hg concentrations within the Catskill Park as was conducted for eaglet blood.

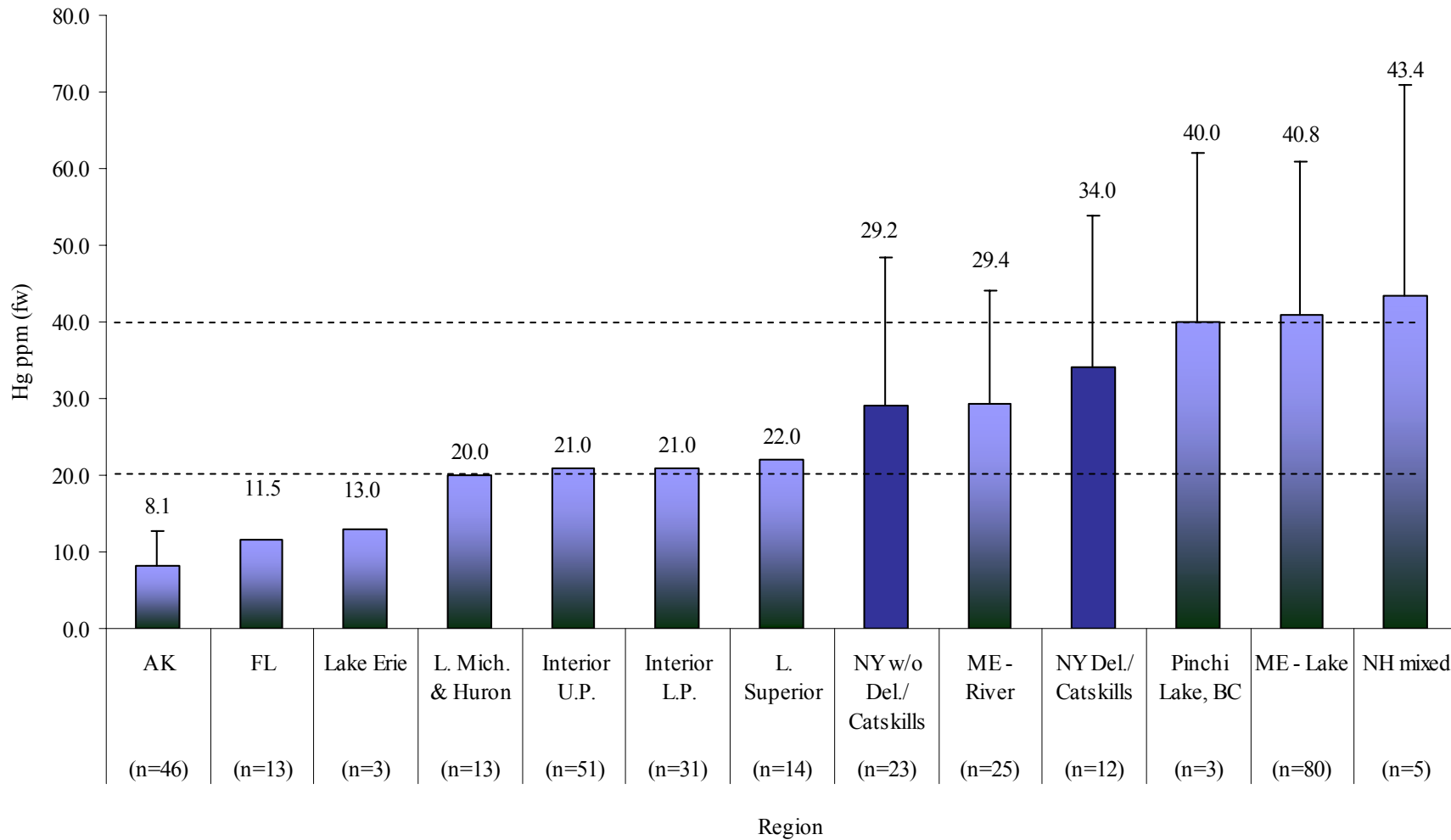


Figure 4. Mercury concentrations in shed and breast feathers from breeding adult eagles in New York and comparison regions throughout the U.S.

Error bars (SD) given when available. All feathers analyzed averaged per territory; sample sizes in parentheses. Lower dotted line at level at which Scheuhammer (1991) suggests toxic investigations on bird populations should be investigated. Upper dotted line represents level at which: (1) Evers et al. (2008) found evidence of links between Hg and flight feather symmetry in adult common loons, in population (ME and NH) shown to display reproductive impacts from Hg, and (2) Spaulding et al. (2000) detected negative effects in egrets dosed with 0.5 ppm Hg. Comparison populations include: AK = Alaska (Evans 1993), range: 1 - 20; FL = Florida (Wood et al. 1996), range: 2.01-34.7. All Midwest comparisons from Bowerman et al. (1994): Lake Erie, range: 9-19; Lake Michigan/Huron: range: 7.2 - 40; Interior Upper Penninsula, Michigan, range: 0.2 - 66; Interior Lower Penninsula, Michigan, range 6.1-62; Lake Superior, Wisconsin, range, 5.9 - 38. Red line represents NY statewide mean (30.9 ± 19 ppm) Maine and New Hampshire samples from DeSorbo and Evers (2007); Pinchi Lake, BC, range 24 - 65 ppm; ME river, range, 1.4 - 46.7, ME lake, range, 7.5 - 93.5; New Hampshire mean includes one feather collected from a winter perch and feathers from Umbagog Lake, Squam Lake, and the Connecticut River. One NH sample from the Connecticut River (91.54 ppm), introduces significant variability into the NH mean.

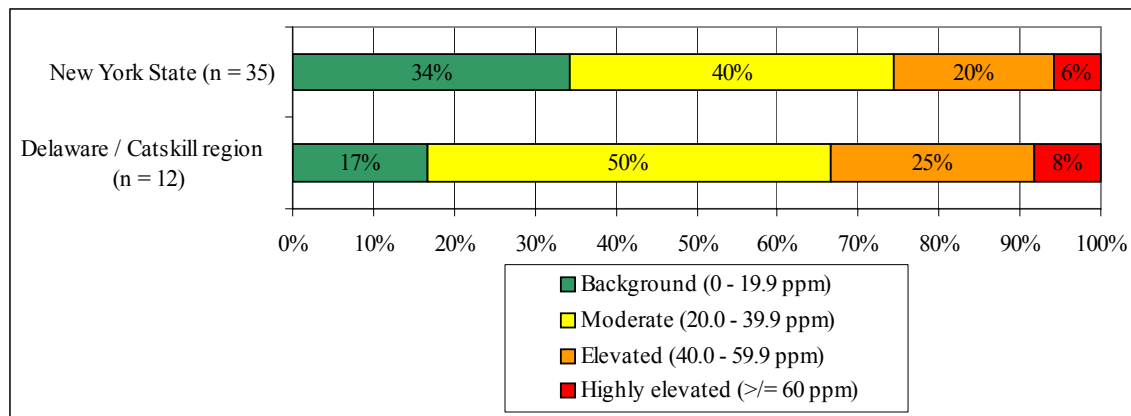


Figure 5. Proportion of New York bald eagle territories in which adult feathers fall within 4 ranges of Hg exposure.

Evaluating Relationships Between Hg Concentrations in Eagles and Fish

Data from both fish and eaglet Hg sampling were analyzed for 10 waterbodies in New York State (Fig. 6). Eaglet blood Hg concentrations were correlated with those in standard size (381 mm) smallmouth bass ($r^2 = 0.75$, $p = 0.02$, $n = 9$). However, smallmouth bass Hg concentrations were consistently higher compared to those found in eaglet blood from the same waterbodies (Fig. 6). Results, although limited, also suggest a possible relationship between Hg concentrations in eaglet blood and standard size walleye (508 mm, $r^2 = 0.95$, $p = 0.05$, $n = 4$), and brown trout (483 mm, $r^2 = 0.48$, $p = 0.19$, $n = 5$; Fig. 6). Smallmouth bass Hg concentrations were highly correlated with those in brown trout ($r^2 = 0.91$, $p = 0.03$, $n = 5$) and walleye ($r^2 = 0.99$, $p = 0.0001$, $n = 4$). Hg concentrations in brown trout were generally within 0.3 – 0.5 ppm to those found in eaglet blood at the 5 sites in which both species were represented. No relationship was evident between Hg concentrations in eaglet blood and standard size (254 mm) yellow perch. Mean predicted yellow perch Hg concentrations were lower in four (57%), and higher in three (43%) than eaglet blood Hg concentrations in reservoirs where both were represented. No relationships were evident between eaglet or adult feather Hg concentrations vs. those measured in fish (not presented). Eaglet breast feathers had higher Hg concentrations than all fish and eaglet blood samples by an order of magnitude, a commonly reported pattern (Welch 1993, DesGranges et al. 1998)⁴.

⁴ Note that eaglet breast feather Hg concentrations in ppm were divided by a factor of 10 (parts per 100,000) to evaluate relationships and for figure scaling purposes. Eaglet breast feathers ranged from 9.7 to 25 ppm (fw) at

Bald eagles are one of the most common species used to monitor contaminants in aquatic ecosystems (Anthony et al. 1993, Bowerman et al. 2002, DeSorbo and Evers 2007); however, this study is the first to evaluate the relationship between fish and bald eagle Hg concentrations in the northeastern U.S. Other studies have related Hg levels in foodweb components to piscivorous raptors. DesGranges et al. (1998) found a strong relationship ($r^2 = 0.67$, $p < 0.01$) between Hg in nestling osprey blood and concentrations predicted in fish. Wood et al. (1996) developed a trophic state index based on eagle prey remains in Florida, and reported a significant correlation between the index and eaglet blood Hg. Similar to our study, neither DesGranges et al. (1998) nor Wood et al. (1996) detected relationships between concentrations of Hg in prey and those found in feathers. Higher Hg concentrations in both nestling and adult eagle feathers compared to eagle blood and fish exemplifies the major excretory route for Hg provided by growing feathers in developing or molting birds (Fournier et al 2002). At many sites, eaglet blood Hg concentrations will increase dramatically after the development of body and flight feathers has been completed (approximately 13 weeks of age, post fledging; Bortolotti 1984, Buehler 2000). Blood, which reflects recent exposure to Hg through the diet, appears to be the most appropriate tissue for use in comparing Hg concentrations in eagles and fish.

Eagles are known for their opportunistic dietary habits, and will often respond to seasonal changes in food abundance, such as spawning white sucker in the spring and early summer, or availability of carrion (Buehler 2000). Such habits might result in poor or unexpected relationships between Hg concentrations in eagle tissues and fish at some sites as some food items (i.e., low trophic level fish, terrestrial based prey items) may be consumed which are poor indicators of Hg in freshwater systems. Variation in eagle and fish Hg concentration relationships among locations is likely a reflection of a variety of factors, including: (1) differential dietary habits of bald eagles, including the opportunistic use of terrestrial food sources, (2) the use of foraging areas outside the fish-sampling waterbody, and (3) the selection of fish species not represented in our dataset.

these sites, and were higher than any fish sampled. Higher Hg concentrations in blood (which closely reflects prey) compared to feathers is commonly reported (e.g., Welch 1994, DesGranges et al. 1998).

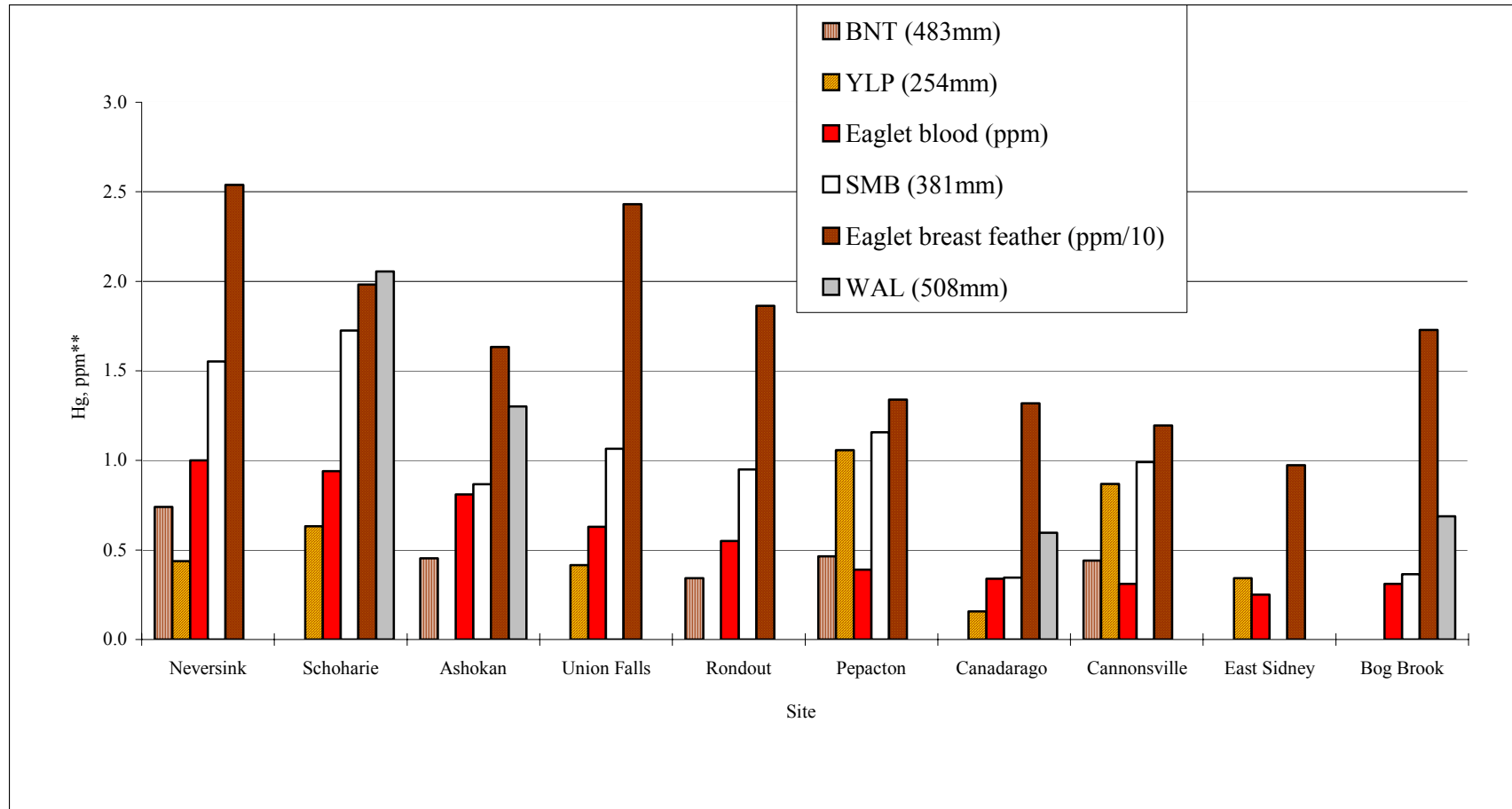


Figure 6. Mercury concentrations in bald eagles and fish sampled at 10 New York Waterbodies.

** Note eaglet breast feather Hg concentrations are presented for this figure in parts per 100,000 for scaling purposes. Length (mm) in parentheses indicates mean fish length used (mean fish length for individual species over the entire dataset) to standardize fish length and Hg concentrations across lakes to allow for interlake comparisons. All sites considered reservoirs with the exception of Canadarago Lake. BNT = brown trout, YLP = yellow perch, SMB = smallmouth bass, and WAL = Walleye

CONCLUSIONS AND RECCOMENDATIONS

Findings from this study indicate that a portion of the adult and nestling bald eagle population in New York State is accumulating Hg to levels associated with concerns, particularly within the Delaware / Catskill region. Elevated Hg concentrations in eagle populations in the Delaware / Catskill region are likely influenced by higher rates of atmospheric deposition within this area, exacerbated by reservoir effects (methylation), such as fluctuating water levels some sites. Estimated Hg deposition (wet and dry) has been found to be particularly elevated in the Delaware / Catskill region (Miller et al. 2005). Once atmospheric Hg is deposited on the landscape, the extent of biomagnification depends on such factors as water chemistry, food chain length, and habitat characteristics associated with Hg methylation. This study also documented a relationship between Hg concentrations in eaglet blood and smallmouth bass; however, relationships were weak or not evident for other eagle tissue types and fish species.

Recommendations for further study include:

1. Further evaluation of potential negative Hg impacts on New York's eagle population by comparing tissue Hg concentrations (especially blood) to productivity at statewide scales. Reproductive impacts due to Hg have been demonstrated in Maine warrant similar investigations in New York State. Some sites in New York State such as Schoharie Reservoir exhibiting generally low productivity have contained elevated Hg concentrations in inviable eggs (P. Nye, NYSDEC, unpubl. data).
2. The effects of Hg are often confounded by other toxic compounds, such as DDE and PCBs (Wiemeyer et al. 1984, 1993, Bowerman et al. 2002). Eagles in New York State are exposed to multiple contaminants, including several organic compounds (P. Nye, unpubl. data). Increased concern is being raised recently about the concentrations and effects of many flame retardants (i.e., PBDEs) in the environment, particularly in high trophic level wildlife. Impact thresholds for these compounds are poorly understood. PBDEs have been measured in bald eagle eggs in Maine (Goodale 2007, USFWS unpublished data) and eagle nestling blood plasma in Wisconsin (Dykstra et al. 2005). Recent sampling of eagle nestlings in Wisconsin suggest total PBDE levels in nestling plasma have doubled since Dykstra et al's (2005) study (B. Route, NPS, pers. com.). Further investigations to document baseline exposure levels of PDBDE to and establish

impact thresholds for many such compounds are recommended. Evaluations of these compounds may be necessary in order to fully decipher the impacts of Hg on bald eagle populations in New York.

3. Additional eaglet and adult sampling to increase the number of territories represented in differing habitat types and regions. This will allow for greater interpretation of preliminary Hg patterns observed in this study.
4. Continued collection of samples from adults in both breeding and winter seasons. While eaglets and shed feathers are reliable indicators of Hg exposure in territorial eagles, samples gathered directly from captured adults would provide the best insight into Hg exposure.
5. Further evaluation of fish/eagle Hg relationships by: (i) increasing the sample size of sites in which both eagles and fish are sampled, (ii) expanding the number of fish species represented at lakes, and (iii) investigation of cases in which Hg concentrations do not correspond with fish Hg concentrations by identifying foraging areas, prey selected and quantifying eagle diet at sites using a combination of techniques (direct or video observation (i.e., Gill and Elliott 2003), stable isotope analysis, analysis of prey remains.
6. Findings from this study should be merged with larger more comprehensive Hg datasets (i.e., songbirds, invertebrates, other raptors; Evers and Clair 2005, Evers and Duron 2006) being collected within the state to improve abilities to monitor spatial and temporal Hg patterns from local to national scales. Data from this study should be incorporated into broader programs such as the National Mercury Monitoring Network. (Wolfe et al. 2007).

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