2009-2010

Onondaga Lake Migratory and Winter Waterfowl Pilot Contaminant Assessment

Biodiversity Research Institute

ONONDAGA LAKE MIGRATORY AND WINTER WATERFOWL PILOT CONTAMINANT ASSESSMENT

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FRONT PHOTO CAPTION*: Male Common Merganser captured on Onondaga Lake, April 2010*

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EXECUTIVE SUMMARY

Onondaga Lake serves as an important winter staging area for a number of species of migratory waterfowl. As part of a pilot assessment to determine exposure of waterfowl to mercury (Hg) at Onondaga Lake and assess the potential for adverse effects, we conducted capture and sampling efforts to determine total Hg concentrations in waterfowl species and compare these values with other published and unpublished literature available on similar species. Throughout the winter of 2009 and early 2010, 74 individuals were captured representing four different species[1]. Blood and feather samples were collected from all individuals, while muscle biopsies were taken from 14 individuals. These selected tissues were used to demonstrate Hg concentrations over the course of the winter sampling period. Prey samples representing major waterfowl food sources were also collected and analyzed for Hg concentrations to determine possible predator/prey Hg level correlations.

Blood samples, representing recent dietary uptake, demonstrated a visible trend of increased Hg burden from low to high trophic level foraging guilds. Feather samples, representing longer-term Hg exposure, but not necessarily Hg concentration at the site of capture, showed a somewhat different scenario. While common merganser feathers contained higher Hg concentrations than other feather samples, black duck and mallard feather samples contained greater concentrations of total Hg than did the samples collected from bufflehead. Muscle samples, representing a more mid-term level of Hg exposure, demonstrated a similar trend in Hg to blood results, with higher concentrations reported for the higher trophic-level guilds, higher in total Hg than those of mallards or black ducks. Fish samples contained higher concentrations of Hg than mollusks and other invertebrates.

Adverse effect thresholds are not well understood in many waterfowl species. Common loons are long-lived piscivorous species that fill an ecological niche similar to that of the common merganser. Evers et al. (2008) reported an adverse effect threshold in common loons at 3.0 µg/g (ww) Hg in blood. A conservative Hg effects level for tree swallows was estimated to be 0.63 µg/g (ww) in blood (Jackson 2011). Also, Jackson et al. (2011) found that a blood Hg

[1] Throughout this report, species will be referred to using American Ornithologists' Union (AOU) alpha codes: ABDU = American Black Duck, BUFF = Bufflehead, COGO = Common Goldeneye, COME = Common Merganser, MALL = Mallard

concentration of 0.70 µg/g was associated with 10% reduced reproductive success in Carolina wrens. Blood Hg data from all species from this study fell below the common loon blood Hg effect level, whereas mean blood Hg data from bufflehead and the single common merganser sampled exceeded the tree swallow and Carolina wren blood Hg effect levels discussed above. The mean concentration of Hg in blood of mallards and black ducks were below blood Hg effect thresholds for the tree swallow, Carolina wren, or common loon.

Although feather Hg concentrations are presented in this report, these data do not represent Hg exposure at Onondaga Lake, as discussed later in the report.

Muscle biopsy samples from this study showed higher Hg levels in common mergansers and bufflehead when compared to lower-level foraging guilds (e.g., mallards and black ducks). These values fell within the range of muscle Hg concentrations reported in the same species in other studies. These findings, however, do suggest that wintering waterfowl species on Onondaga Lake have the potential to accumulate Hg concentrations in internal body tissues that may have implications for other wildlife species in the area that utilize similar prey items or use Onondaga waterfowl as a direct food source. Our data suggest that most waterfowl present on Onondaga Lake during the winter months spend less than a month on the Lake, limiting their exposure to Hg.

To better understand how waterfowl species wintering on Onondaga Lake are accumulating Hg, stable isotopes including carbon, nitrogen, and deuterium were measured in the blood of captured individuals to determine likely geographic origins and trophic level position. Prey samples were also analyzed to determine specific isotope signatures that would represent which foraging guilds our target species were utilizing. The $\delta^{13}C$ and $\delta^{15}N$ analyses among species confirmed common mergansers are occupying the highest trophic level among species sampled. Likewise, bufflehead occupied a higher trophic level than mallards and black ducks, but lower than that of common mergansers. As expected, $\delta^{13}C$ analysis among species suggests that in addition to trophic level differences, our sampled species were also feeding on prey items of differing origin.

INTRODUCTION

The anthropogenic input of inorganic Hg into the environment is of broad socioeconomic concern because of the potential long-term impacts on ecological and human health. Bacterial methylation of the inorganic form into a biologically toxic form called methylmercury (MeHg) varies according to environmental, hydrological, and biochemical properties of Hg (Driscoll et al. 2007). Geographic sensitivities related to these properties of Hg create biological Hg hotspots that are related to both atmospheric deposition and waterborne point sources (Evers et al. 2005). Much is known about Hg distribution and availability of MeHg in the northeast United States. This large body of knowledge provides a basis for efforts to disentangle the relationship between Hg loading and biotic uptake. In an effort to assess Hg availability to wildlife at Onondaga Lake, New York, we used migratory waterfowl species as indicators of Hg bioaccumulation. Waterfowl species were chosen for their ability to accumulate Hg body burdens by feeding on fish and other aquatic prey items.

Ecologically, Onondaga Lake has been classified as a lacustrine, eutrophic, dimictic lake. This means the Lake: 1) contains an aquatic community consistent with nutrient-rich waters, 2) occurs in a broad, shallow basin that has two periods of mixing or turnover of the water (spring and fall), and 3) is thermally stratified in the summer (warm upper layer and cold bottom layer), then freezes over and becomes inversely stratified (colder upper layer and warmer bottom layer) in the winter.

Onondaga Lake has a long history of various uses. The Lake lies within the indigenous territory of the Onondaga Nation. For centuries, Onondaga villages were located on the shores of the Lake and the Onondaga Nation relied heavily on the Lake and its tributaries for fishing, gathering of plants for medicinal and nutritional needs, recreation, and ceremonial uses.

Later, in the late 1800s and early 1900s, Onondaga Lake supported a thriving resort industry based upon the recreational utilization of the Lake, including swimming and recreational fishing. The Lake also had a cold-water fishery, which supported a commercial fishing industry until the late 1800s. However, from the late 1800s to the present, Onondaga Lake has been a discharge point for both industrial and municipal wastes.

Starting in the 1970s, a wide variety of County, State, and Federal programs have targeted Onondaga Lake for various levels of cleanup and monitoring. Numerous efforts have focused on eliminating contaminant releases to the Lake, assessing the impacts of contaminated water and sediment, and implementing recreational restrictions and fish consumption advisories in the Lake.

On December 16, 1994, Onondaga Lake and upland areas of the Lake that contribute or have contributed contamination to the Lake system were added to the U.S. Environmental Protection Agency's (USEPA) National Priorities List (NPL), thereby designating the Lake as a Superfund site. On June 23, 1998, Onondaga Lake was added to the New York State Registry of Inactive Hazardous Waste Disposal Sites.

Onondaga Lake serves as an important winter staging area for several species of migratory waterfowl. While much of the Lake freezes during the coldest months (December and January), small pockets of open water are known to persist throughout these periods, providing waterfowl species areas to congregate and feed during their migration and staging. The focus of this study was to sample and analyze tissues from birds representing different foraging guilds present on the Lake. Target species included the piscivorous common merganser (*Mergus merganser*), as well as the common goldeneye (*Buchephala clangula*) and bufflehead (*Bucephala albeola*) that eat fish as well as mollusks. We also sampled the omnivorous mallard (*Anas platyrhynchos*) and black duck (*A. rubripes*). Prey items for each of these foraging groups were also collected for analysis.

Based on Evers et al. (2005), species of waterfowl in the Northeast at highest risk to Hg availability include piscivores and molluscivores. Obligate piscivores, such as the common merganser, have elevated levels of Hg (Scheuhammer et al. 1998). Mollusk-eating diving ducks, such as bufflehead and common goldeneye, have also been shown to accumulate environmental contaminants (Gerstenberger 2004; Custer and Custer 2000; Rothschild and Duffy 2005). In areas where the exotic zebra mussel (*Dreissena polymorpha*) has been introduced, molluscivores are more susceptible to contaminant exposure because of the zebra mussel's ability to bioaccumulate greater concentrations of contaminants than other prey items such as native gastropods (de Kock and Bowmer 1993; Petrie et al. 2007).

Zebra mussels successfully invaded Onondaga Lake in the early 1990s but near-shore densities remained low until 1998. An abrupt shift to high densities occurred in 1999 and 2000, coincident with increased treatment at the wastewater treatment plant at the south end of the Lake (Spada et al. 2002).

A study by Custer and Custer (1996) documented diet shifts in waterfowl on Lake Erie after a zebra mussel invasion. In the analysis, 83% of common goldeneye and 60% of bufflehead contained one or more zebra mussels in their upper gastrointestinal tract. Zebra mussels comprised nearly 80% of common goldeneye diets and 25% of bufflehead diets. Prior to the invasion, goldeneye diets in a nearby river contained only trace amounts of mollusks.

Recent studies have also indicated elevated Hg exposure and impacts in bird species that feed on invertebrates (Edmonds et al. 2010; Cristol et al. 2008; Custer et al. 2007).

OBJECTIVES

(a) Determine the fall and winter foraging patterns of waterfowl on Onondaga Lake.

(b) Determine the length of time migrating and overwintering waterfowl are present on Onondaga Lake.

(c) Non-lethally collect samples of blood, feathers, and muscle from waterfowl on Onondaga Lake and determine Hg concentrations during three discrete time periods.

(d) Collect samples of preferred prey items on Onondaga Lake and analyze for Hg.

STUDY AREA

Onondaga Lake is located in Syracuse, NY (Onondaga County). Capture sites were primarily located along the western shore of the Lake, as these proved to be the preferred foraging and rafting areas for waterfowl present on the Lake. During the February sampling period, ice cover on the Lake prevented any capture efforts from taking place outside the small open-water areas of Ninemile Creek and the Seneca River outlet (Figure 1).

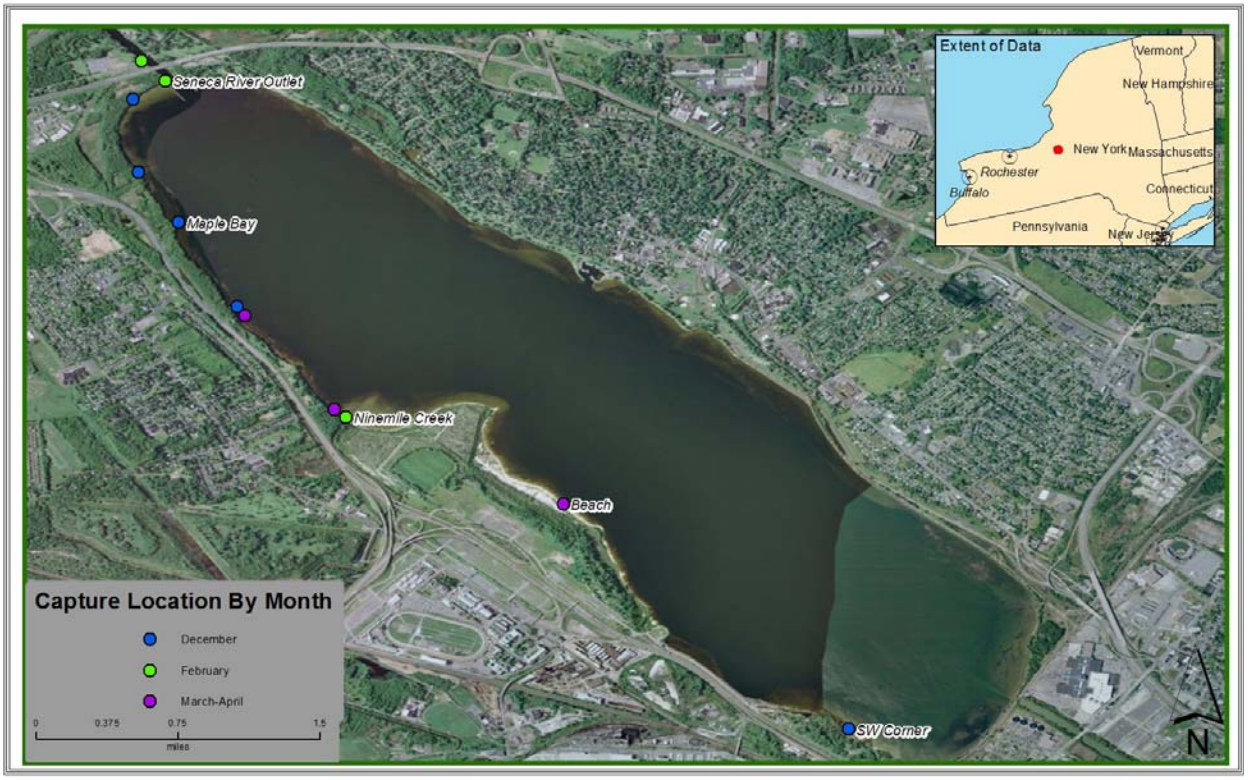

Figure 1. Map of waterfowl sampling locations on Onondaga Lake, 2009-2010.

METHODS

Capture Methods

Bird sampling efforts occurred from December 4, 2009, to April 5, 2010. Two- to three-week capture efforts were spread throughout the winter season and early spring migration – December, January-February, and March-April. Our primary capture method varied depending on each particular target species. Common mergansers and buffleheads were captured using a floating mist net apparatus (Figure 2). This consisted of 3-5 floating metal platforms anchored to shore and extending perpendicular to the shoreline. Between these platforms, appropriately sized mist nets were strung. Depending on target species, appropriate decoys were laid out in a formation surrounding the mist nets to attract birds in flight (Brodeur et al. 2008).

To capture dabblers such as mallards and black ducks, baited walk-in traps were used. These traps were constructed with metal fencing materials and baited with whole corn

available at most feed stores. Traps were placed along the shoreline in areas observed to have a high abundance of foraging ducks.

Attempts were made to capture waterfowl at night via spotlights and dip nets. These attempts were unsuccessful due to unpredictable flock locations and unfavorable responses to the spotlight. Due to the observed abundance of target species in these areas, all captures took place along the western shore of the Lake from the mouth of the Seneca River to the southern end of the Lake (Figure 1).

While mist netting led to the capture of all buffleheads and a single merganser, this technique was relatively unsuccessful in producing target sample sizes. Common mergansers in particular did not respond well to decoys and rarely flew low enough or close enough to the shoreline for this technique to be effective. Baited walk-in traps were very effective in capturing mallards and black ducks, providing a sample size for these species above our target.

Figure 2. Floating mist arrangement set up in the Maple Bay area of Onondaga Lake.

Sample Collection and Handling

Non-lethal capture methods were used for sampling of all birds. Blood and feather samples were collected using published BRI protocols (Evers 2009). Blood was drawn using a

small gauge needle to puncture either the cutaneous ulnar vein in the wing or the tarsal vein in the leg. Heparinized capillary tubes collected blood, and no more than 1% of the bird's body weight in blood was collected. The tubes were sealed on both ends with Critocaps® and placed in a labeled 10cc plastic vacutainer. Additional blood samples were stored in heparinized and/or no-additive microtainers, placed on ice in a cooler, and frozen within six hours of collection. The second secondary flight feather from each wing and two tail feathers were clipped from each bird. Collected feathers were then placed in a clean, labeled envelope and stored in a refrigerator. All samples were labeled with the date of collection, age and sex of the bird, U.S. Geological Survey (USGS) band number, and capture location. Muscle biopsies were collected from the breast muscle of 14 individuals using standard veterinary practices and stored in eppendorf tubes. Ducks were anesthetized using a subcutaneous injection of lidocaine at the incision site and muscle biopsies were taken with a disposable 3mm biopsy punch. Incisions were closed using tissue glue and individuals were held for at least an hour post-biopsy surgery to allow local anesthesia to wear off. Chain-of-custody procedures were observed at all times for all samples, from initial sample collection until samples were transferred to the contract laboratory. All samples were transferred with appropriate chain of custody forms.

Tissue Selection

Blood is best used to indicate short-term Hg exposure and recent dietary uptake (Evers et al. 2008; Monteiro and Furness 2001). Feathers are used to provide longer-term Hg exposure, reflecting blood Hg levels at the time of last molt (Bearhop et al. 2000). Feathers can also be representative of total body burden by serving as a terminal endpoint for remobilized Hg stored in muscle tissue. Since any non-resident, wintering bird caught on Onondaga Lake will not have grown feathers on the Lake during that time, feather Hg concentrations will likely not be representative of Hg accumulated on the Lake. However, since Hg stored in muscle tissue can be remobilized and deposited in newly-grown feathers, Hg accumulated in the muscle tissue of ducks wintering on Onondaga Lake will likely be represented in the feathers grown during future molts. Therefore, muscle Hg concentrations reported in this study will be representative of Hg bioaccumulation since the time of the previous feather molt. Piscivorous

waterfowl species, particularly common mergansers, have been shown to have significantly higher muscle Hg concentrations than other waterfowl foraging guilds (Evers et al. 2005).

Laboratory Analysis

Total Hg concentrations were analyzed in sample tissues. All avian tissue Hg analyses were conducted at the Wildlife Research Mercury Lab at BRI Headquarters in Gorham, Maine. All avian tissue samples were analyzed for total Hg using thermal decomposition technique with a direct Hg analyzer (DMA 80, Milestone Incorporated) using the USEPA Method 7473 (USEPA 2007). Fish and other prey items were analyzed for Hg at the University of Connecticut Center for Environmental Sciences and Engineering. A sample of whole corn used for baiting walk-in traps was also analyzed to be sure that baiting methods did not affect Hg levels. Hg results in tissues are reported as wet weight (ww) in blood, muscle, and prey items and fresh weight (fw) in feathers. Blood samples from captured individuals along with whole-body prey items were analyzed for stable isotopes (carbon, nitrogen, and deuterium) at Colorado Plateau Stable Isotope Laboratory at Northern Arizona State University.

Statistical Analysis

Kruskal-Wallis, Steel-Dwass, Tukey-Kramer HSD, and summary statistics were performed using the JMP 9.0 statistical program and Microsoft Excel after results were tested for normality. Results of statistical tests were considered significant if the probability of a greater P-value was <0.05.

Waterfowl Abundance Surveys

Throughout the course of the study, surveys were conducted on Onondaga Lake and adjacent waterways to estimate population sizes and foraging areas for each target species. Surveys were regularly conducted, beginning in early December 2009 and lasting through April 2010. Surveys were conducted three times during each study period by doing a complete boat survey of all accessible areas of the Lake, by surveying from shore those areas not accessible by boat, and by driving roads adjacent to the Seneca River north to the town of Phoenix. Flocks observed during capture efforts and not during designated survey efforts were noted and

included in the overall survey data. Data collected during the three survey periods included number of species, number of individuals per species, date and time, regularly taken digital photographs of Onondaga Lake and areas of open water occupied by waterfowl, weather at the time of survey, and human activities proximate to the sites.

Estimating Length of Time Spent on Onondaga Lake

To develop an initial understanding of the residence time of migratory and wintering waterfowl, all individuals captured were uniquely marked with USGS leg bands. Each captured individual was also marked with fluorescent oil-based paint to facilitate the re-sighting of individuals after release (Figure 3). Birds were painted a different color determined by the month in which they were captured (December = Orange, February = Pink, March-April = Green) so that any re-sighted individual could be traced back to an approximate capture period. In this way, the approximate amount of time spent on Onondaga Lake could be recorded for any marked and re-sighted individuals. Individuals that underwent muscle biopsy surgery were painted with a double stripe instead of a single to distinguish them from other captures. This allowed us to confirm post-surgery survival.

Figure 3. Male bufflehead captured in December 2009 marked with fluorescent orange paint prior to release.

Prey Item Collection

Prey species and collection locations were selected based on observations of foraging behaviors during surveys and a literature review of foraging behavior for each target waterfowl species. For piscivorous waterfowl, prey-sized fish were collected using minnow traps. These minnow traps were deployed both at the mouth of Ninemile Creek and underneath the bridge at the outlet of the Seneca River. Mollusks were hand-collected, sorted, identified, and stored. Mollusk samples consisted of quagga and zebra mussels collected from shallow water areas at the outlet of the Seneca River and along the shore of Maple Bay. To represent the diet of other non-piscivorous waterfowl (e.g., mallards and black ducks), appropriate aquatic invertebrates (e.g., scud, snails, and insect larvae) were opportunistically collected when present inside minnow traps. Morphometric measurements (e.g., length, width, weight) were recorded for all fish and mussels. Samples of prey items were collected and stored in I-CHEM jars or 10cc vacutainers.

RESULTS

Waterfowl Abundance Surveys

Surveys were conducted three times per sampling period throughout the duration of the study. Focal survey areas were the Seneca River outlet north to the town of Phoenix, Ninemile Creek to Maple Bay, and the south end of the Lake. Opportunistic surveys were also conducted in any area where large congregations of birds were observed. Maple Bay, Ninemile Creek, and the south end of the Lake were the areas most consistently used by large groups of birds and flocks were rarely ever seen utilizing the eastern shoreline where the majority of human activity takes place. In order to minimize double-counting in our abundance surveys, we always had at least two, but usually three people conducting counts at the same time. If individual counts differed, an average was taken. The results of these surveys showed that waterfowl were most abundant on the Lake during the January survey period. This is consistent with waterfowl survey data collected by the U.S. Fish and Wildlife Service in the winter of

2007-2008, with January supporting the highest number of birds (Secord 2011). During January 2010, the majority of the Lake was covered with ice and birds that were present were heavily congregated at the south end of the Lake and at the mouth of Ninemile Creek. These were the two primary open water areas that remained. While it was still possible to access the Lake via Ninemile Creek, the south end of the Lake was inaccessible by boat during this period and, therefore, was only surveyed from shore. Areas along the Seneca River remained open during this period, but were less heavily used by the birds.

Species composition remained fairly static during the survey periods, with common merganser, mallard, bufflehead, and goldeneye being the most consistently abundant. Other species such as lesser scaup (*Aythya affinis*), redhead (*A. americana*), and hooded merganser (*Lophodytes cucullatus*) were also occasionally observed. These species, however, were less abundant and less consistently present on the Lake (Figure 4). While environmental factors, such as temperature and wind speed, were recorded during each survey effort, these factors did not significantly correlate with the abundance of birds observed. Aside from occasional construction ongoing at the marina on the eastern shore of the Lake, very little human activity and disturbance were recorded during the survey periods (see Appendix 2).

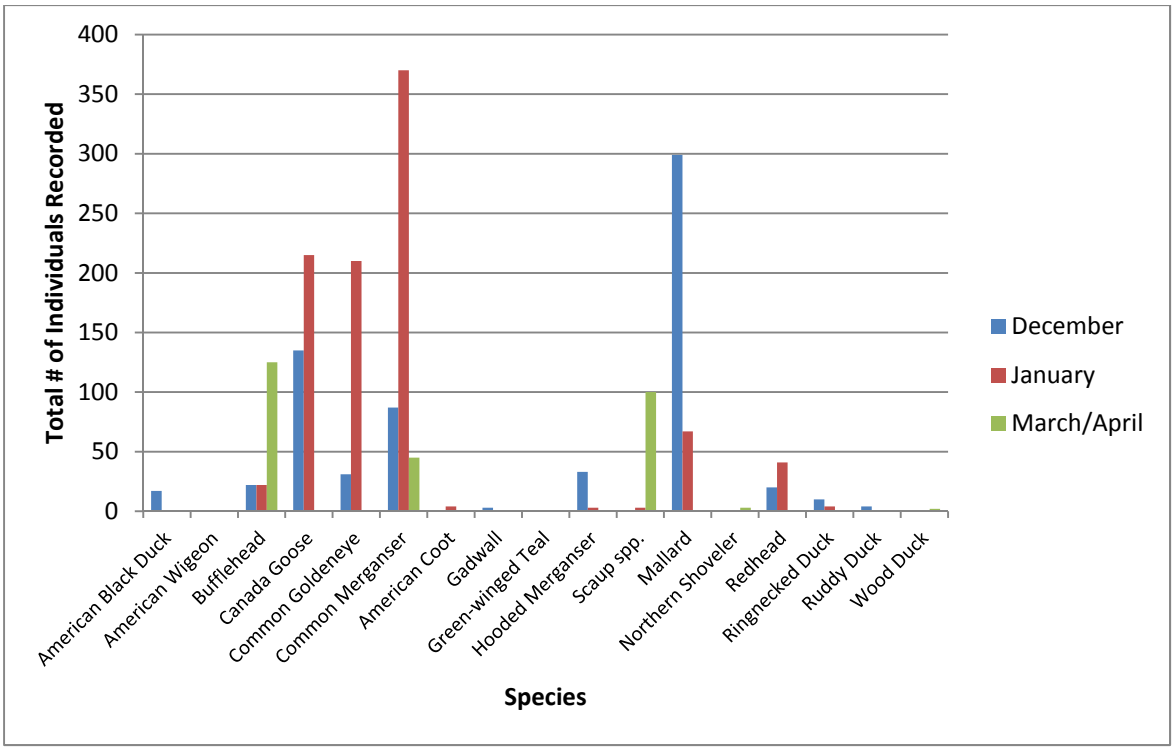

Figure 4. Species recorded on Onondaga Lake and Seneca River during abundance surveys, per capture effort time period.

Estimating Time Spent on Onondaga Lake

Following the release of captured birds on the Lake, efforts were made during our abundance surveys, and opportunistically throughout our daily capture efforts, to re-sight these individuals. During the December capture period, two male and one female paint-marked bufflehead were frequently seen among a small flock of the same species. Although this marking method only allowed us to identify the broad capture period for these birds, rather than the capture date of the individual, it was estimated that these three birds were re-sighted on the Lake up to two weeks after their capture date. Also during the December session, two male and one female mallard were re-sighted. The female was painted with a double stripe, indicating she had undergone muscle biopsy surgery. This female had been captured and released earlier this same day. The two males could have been captured anywhere between one and twelve days prior to being re-sighted.

During the following two capture attempts (February & March/April) no birds from previous capture efforts were re-sighted anywhere on the Lake or the Seneca River. Likewise,

no birds captured within either of these time frames were re-sighted during the same period. While it is possible that marking paint could have worn off during the elapsed time between site visits, our re-sighting data and subsequent band recoveries suggest that it is more likely that most individuals present on Onondaga Lake during the winter months spend less than a month on the Lake.

Band recoveries

To date, there have been three reported band recoveries from birds banded on Onondaga Lake during this study:

1. Adult, female mallard. Banded December 14, 2009. Recovered January 1, 2010, in Baldwinsville, New York. Recovered approximately 6 miles from capture site, 18 days after release.
2. Adult, male bufflehead. Banded December 4, 2009. Recovered January 2, 2010, in Jacksonville, North Carolina. Recovered approximately 580 miles from capture site, 29 days after release.
3. Adult, male mallard. Banded December 11, 2009. Recovered January 8, 2010, on Owasco Lake, New York. Recovered approximately 20 miles from capture site, 28 days after release.

These recoveries were made via hunter harvest. The distance traveled and time elapsed between capture and recovery date further suggests a relatively short period of time spent on Onondaga Lake during winter months.

Mercury Analysis

Blood

Blood Hg concentrations are used to represent recent dietary Hg uptake (primarily during the past 1-2 weeks) in a given individual. Over 95% of blood Hg is in the form of MeHg (Wolfe et al. 2007). Mercury values were analyzed for a total of 74 individuals representing four different species (Table 1). Kruskal-Wallis and Steel-Dwass tests were performed across all pairs (except COME due to small sample size) to determine significant statistical differences

among these species. We found that bufflehead mean[2] blood Hg levels were significantly higher than Hg levels in mallards and black ducks (p=0.0015 and 0.0058, respectively). This is to be expected given the tendency of buffleheads to consume prey at a higher trophic level than dabbling ducks. No significant difference in mean blood Hg concentrations was identified between mallards and black ducks (p=0.4552). Although our common merganser sample size (n=1) did not allow us to statistically compare common merganser data to data from other species, the blood Hg concentration for the one individual caught was higher than the mean blood Hg concentrations for the other species across all sampling locations on the Lake (Figure 5). Due to relatively low sample sizes for all species except mallards, these statistical analyses may not be indicative of the populations as a whole. However, our data does suggest visible trends in Hg bioaccumulation consistent with trophic level.

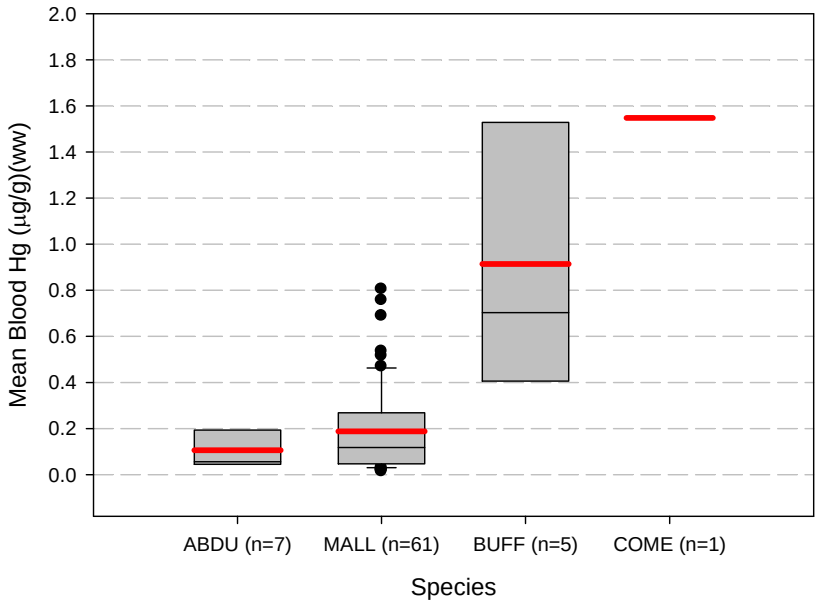

Figure 5. Mean blood Hg concentrations for all species captured on Onondaga Lake. Box represents 25th and 75th percentiles with median (black) and mean (red) shown. Error bars represent 10th and 90th percentiles. *ABDU = American black duck, BUFF = Bufflehead, COME = Common merganser, MALL = Mallard.*

[2] Arithmetic mean is used in all cases as all summary statistics are back-transformed for tables and figures.

Table 1. Summary statistics for blood Hg in species captured on Onondaga Lake.

Species	n	Mean Blood Hg	Min	Max	sd +/-
ABDU	7	***0.1060***	0.0416	0.2619	0.0871
BUFF	5	***0.9140***	0.2964	1.8032	0.6105
COME	1	***1.5480***	1.5480	1.5480	~
MALL	61	***0.1880***	0.0139	0.8047	0.1902

ABDU=American black duck; BUFF=Bufflehead; COME=Common merganser; MALL=Mallard

Feather

Feather Hg concentrations are used to determine long-term dietary uptake and exposure (for the past year or longer). Although Hg feather data are presented here, these data are not likely to reflect Hg exposure during the winter at Onondaga Lake, rather Hg exposure during feather growth (generally during the breeding season). Mercury values were analyzed for a total of 75 individuals representing four different species (Table 2). Kruskal-Wallis and Steel-Dwass tests were performed across all pairs (except common merganser due to small sample size) to determine significant statistical differences among these species. We found no significant difference in feather Hg concentrations between mallards, black ducks, and buffleheads (p=0.0620). Low sample sizes make statistical analysis for these species difficult. However, the visible trend does show the common merganser with a higher feather Hg concentration than the mean feather Hg concentrations of the other species (Figure 6).

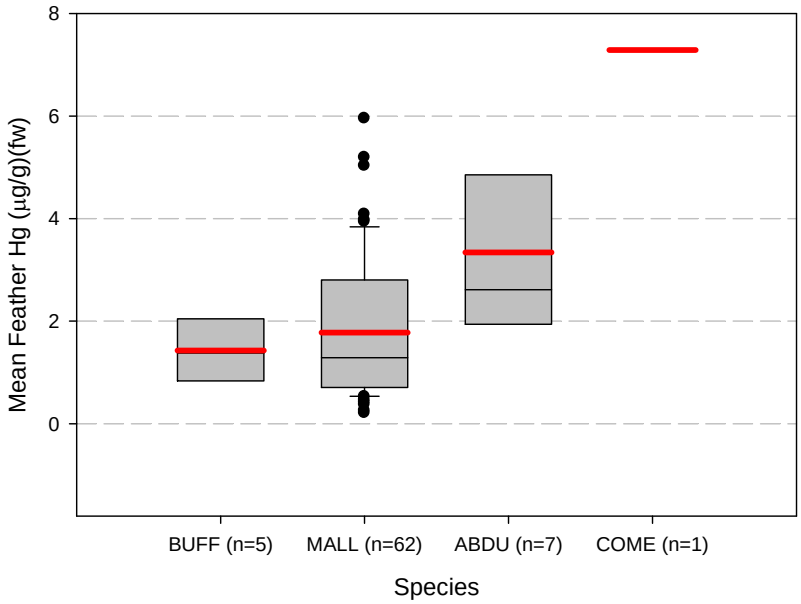

Figure 6. Mean feather Hg concentrations for all species captured on Onondaga Lake. Box represents 25th and 75th percentiles with median (black) and mean (red) shown. Error bars represent 10th and 90th percentiles. *ABDU = American black duck, BUFF = Bufflehead, COME = Common merganser, MALL = Mallard.*

Table 2. Summary statistics for feather Hg in species captured on Onondaga Lake.

Species	n	Mean Feather Hg	Min	Max	sd +/-
ABDU	7	***3.3382***	1.1944	7.0246	1.9888
BUFF	5	***1.4282***	0.3416	2.6456	0.8179
COME	1	***7.2885***	7.2885	7.2885	~
MALL	62	***1.7764***	0.2075	5.9479	1.3445

ABDU=American black duck; BUFF=Bufflehead; COME=Common merganser; MALL=Mallard

Muscle

Muscle tissue Hg concentrations are used to determine mid-range dietary exposure and uptake. Mercury concentrations were determined for a total of 14 individuals representing four different species and two different capture periods (Table 3). Given small sample sizes among the species sampled, statistical analysis for these values was not relevant. While these limited sample sizes may not be representative of an entire population, simple visual analysis shows a trend of increased muscle Hg concentrations in higher trophic level species (Figure 7). It should be noted that a small number of biopsies contained extremely low Hg concentrations.

When compared to corresponding blood values from the same bird, it suggests that these samples might not have been ideal (i.e. may have been primarily fatty tissue or skin instead of muscle) and may not have been representative of the true muscle tissue Hg concentration.

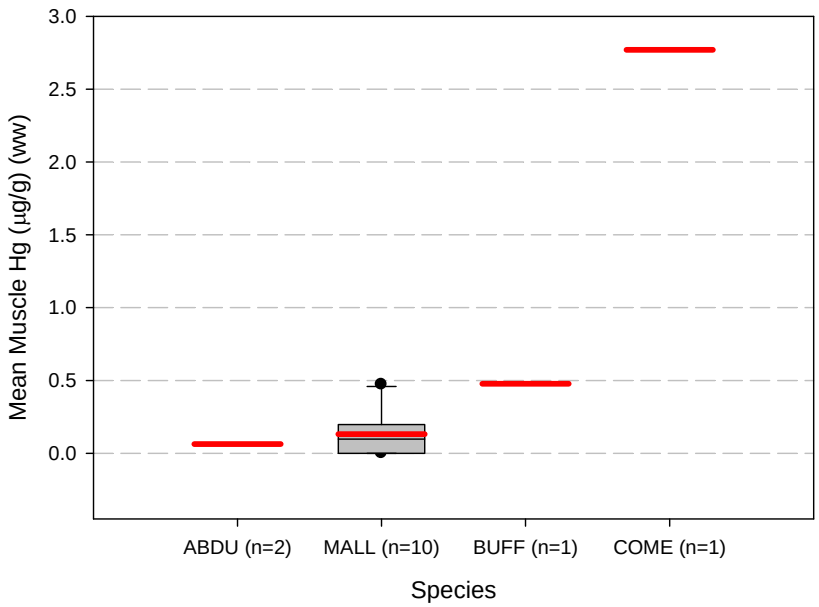

Figure 7. Mean muscle Hg concentrations for species captured on Onondaga Lake. Box represents 25th and 75th percentiles with median (black) and mean (red) shown. Error bars represent 10th and 90th percentiles. *ABDU = American black duck, BUFF = Bufflehead, COME = Common merganser, MALL = Mallard.*

Table 3. Summary statistics for muscle tissue Hg in species captured on Onondaga Lake.

Species	n	Mean Muscle Hg	Min	Max	sd +/-
ABDU	2	***0.0632***	0.0000	0.1263	0.0893
BUFF	1	***0.4767***	~	~	~
COME	1	***2.7700***	~	~	~
MALL	10	***0.1306***	0.0000	0.4716	0.1611

ABDU=American black duck; BUFF=Bufflehead; COME=Common merganser; MALL=Mallard

Prey

Prey items representative of each target waterfowl foraging guild were analyzed for total body Hg concentrations (Figure 8). Total Hg data from these prey items were tested for statistical significance. We found no significant difference between mollusks and other

invertebrates (e.g., insect nymphs, scud, etc.) collected (p=0.5377). Fish species analyzed were shown to have higher mean Hg concentrations than both mollusks and other invertebrates (p<0.001 and p=0.0021, respectively). In order of abundance, fish species collected included banded killifish (*Fundulus diaphanus*), pumpkinseed sunfish *(Lepomis gibbosus),* logperch (*Percina caprodes*), black crappie (*Pomoxis nigromaculatus*), brook silverside (*Labidesthes sicculus*), and bluegill (*Lepomis macrochirus*).

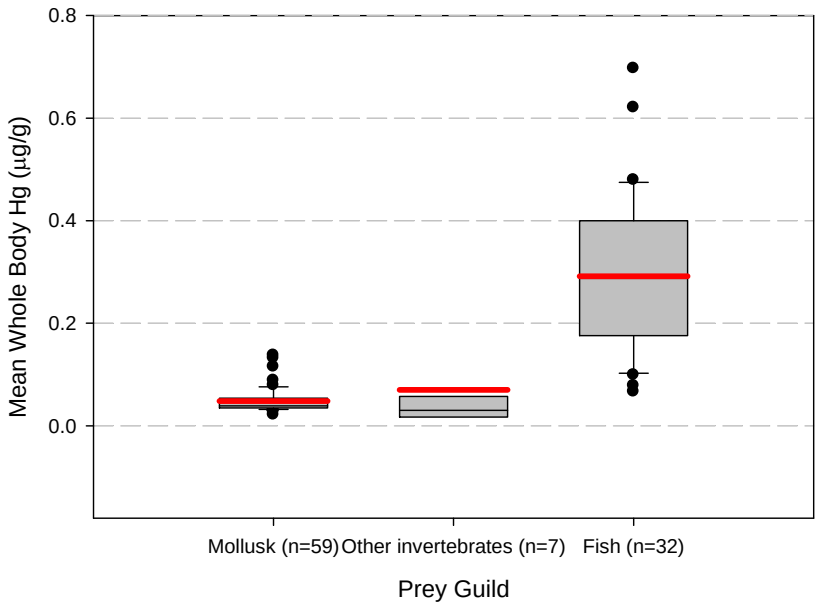

Figure 8. Mean whole body Hg concentrations for all prey species captured on Onondaga Lake. Box represents 25th and 75th percentiles with median (black) and mean (red) shown. Error bars represent 10th and 90th percentiles.

Foraging guild

Blood Hg concentrations within each waterfowl foraging guild were compared to the mean Hg concentrations of their respective prey items (Figure 9). A visual analysis shows the expected trend that Hg bioaccumulation increases as one moves further up in trophic level. With a sample size of one, no statistical analysis was possible to compare piscivores to other foraging guilds. Analyses did show that mean Hg concentrations in diving ducks were significantly higher than those in dabblers (p=0.0012).

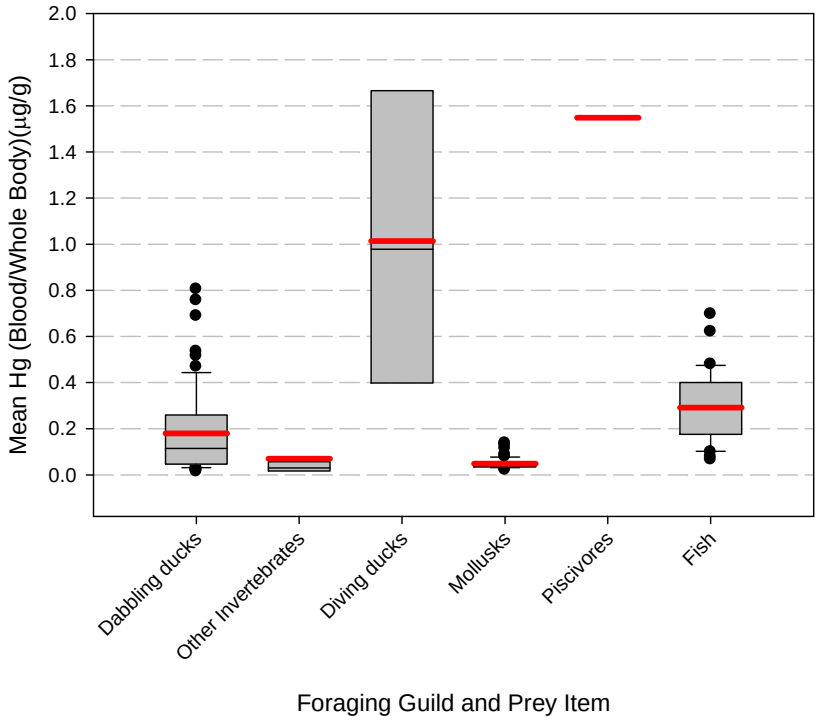

Figure 9. Mean Hg concentrations for all ducks and prey items captured on Onondaga Lake. Prey items were analyzed as whole body samples. *Dabbling ducks = mallards/black ducks; Diving ducks = buffleheads; Piscivores = common merganser.* Box represents 25th and 75th percentiles with median (black) and mean (red) shown. Error bars represent 10th and 90th percentiles.

Mercury exposure by site

Given their similar blood Hg concentrations, mallard and black duck blood Hg results were pooled to determine if blood Hg levels differed between sites. This would indicate whether Hg bioavailability was greater in certain areas of the Lake. Using a Kruskal-Wallis test to compare mean blood Hg levels, we found no significant difference in mean Hg concentrations between capture sites (p=0.5202) (Figure 10).

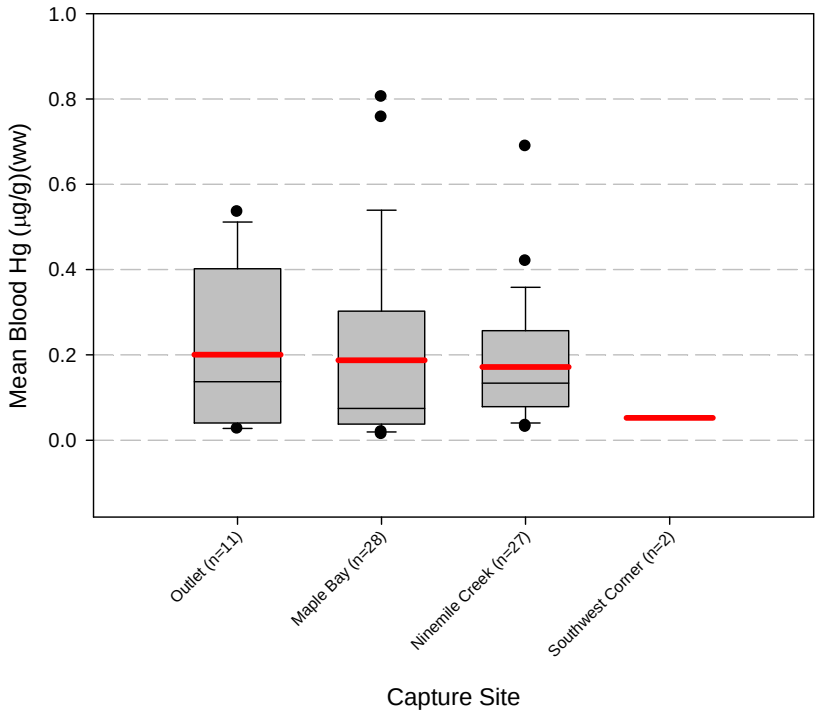

Figure 10. Mean blood Hg levels for pooled mallards and black ducks by capture site. Box represents 25th and 75th percentiles with median (black) and mean (red) shown. Error bars represent 10th and 90th percentiles.

Mercury exposure by month

To determine if Hg levels varied between months of sampling effort, we once again pooled mallard and black duck blood and feather Hg levels. Using a Kruskal-Wallis test to compare mean blood and feather Hg levels, we found no significant difference between capture periods (p=0.1905) (Figures 11 & 12). It should be noted that this analysis does not include the sampling period of March-April, as capture success during this period was low and did not provide large enough sample sizes for proper analysis.

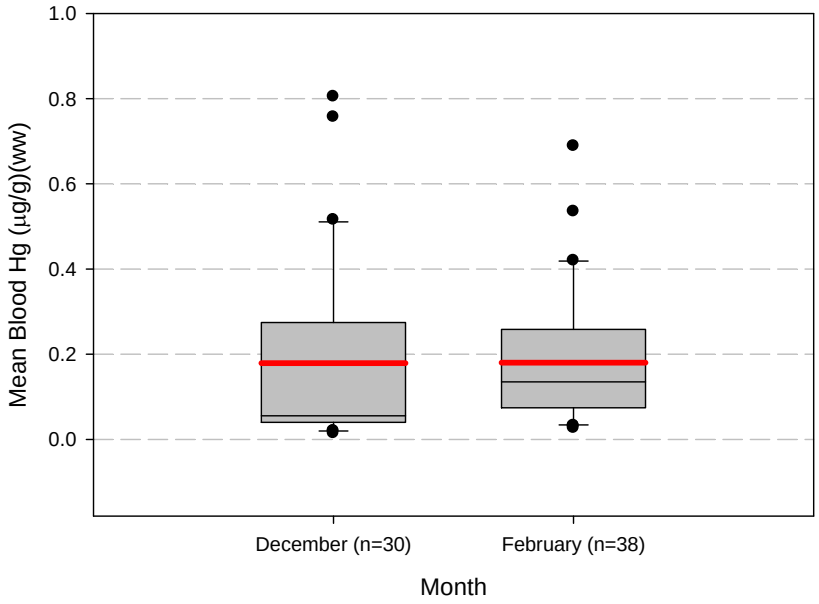

Figure 11. Mean blood Hg levels for pooled mallards and black ducks by month. Box represents 25th and 75th percentiles with median (black) and mean (red) shown. Error bars represent 10th and 90th percentiles.

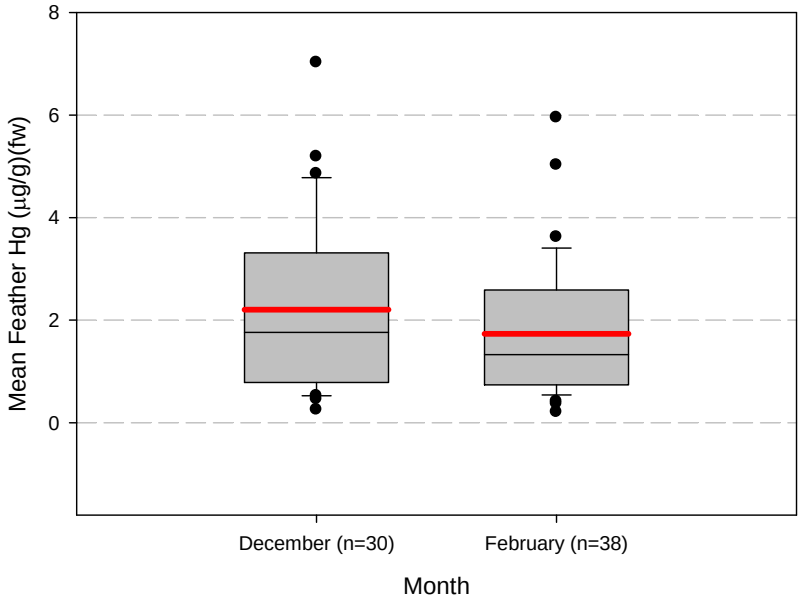

Figure 12. Mean feather Hg levels for pooled mallards and black ducks by month. Box represents 25th and 75th percentiles with median (black) and mean (red) shown. Error bars represent 10th and 90th percentiles.

Stable Isotope Analysis

Stable isotopes of carbon, nitrogen, and deuterium were measured in the blood of captured individuals to determine likely geographic origins and trophic level position within the Lake ecosystem. Prey samples were also analyzed to determine specific isotope signatures that would represent which foraging guilds our target species were utilizing. Previous studies have shown that whole blood collected from birds provides carbon and nitrogen signatures of recently consumed food items (Hobson and Clark 1992). Stable isotopes of nitrogen ($\delta^{15}N$) are often used to determine relative trophic level position of an individual or species, as each trophic level typically experiences enrichment factors between 2 and 4% (Post 2002). Generally, higher $\delta^{15}N$ values are present in individuals feeding higher in the food chain. Carbon ($\delta^{13}C$) values are more useful in representing differences in the actual prey items being consumed, as it generally does not increase between trophic levels (Inger and Bearhop 2008). Deuterium stable isotope analyses of blood reflect current dietary uptake and can be compared with deuterium stable isotopes in food items to characterize dietary habits and contaminant pathways (Hobson et al. 1999; Doucett et al. 2007).

Blood

Blood samples from 73 individuals were analyzed for carbon ($\delta^{13}C$), nitrogen ($\delta^{15}N$), and hydrogen (δD) stable isotopes to determine trophic position and its relationship to blood Hg concentrations.

Analysis of $\delta^{13}C$ and $\delta^{15}N$ isotopes confirmed our earlier assumptions that our target species feed at different trophic levels (Figure 13). Mallards and black ducks had similar $\delta^{15}N$ levels, suggesting that they are feeding on prey items within the same trophic level in the food chain. As expected, buffleheads had higher levels than the dabblers and the common merganser had the highest level, placing it as the highest trophic-level feeder among our target species. $\delta^{13}C$ values suggest that mallards and black ducks are feeding on similar prey items, while buffleheads and mergansers are foraging on very different prey items. Stomach content analysis would be necessary to quantify actual diet compositions for these species on Onondaga Lake.

To further identify the trophic structure of Onondaga Lake, future studies should also include stable isotope analysis at all levels of the food chain (i.e. sediment, aquatic vegetation, etc.) during the winter months. This would provide a more complete representation of the Lake ecosystem and increase confidence in determining precise trophic level positions for wintering waterfowl species on the Lake.

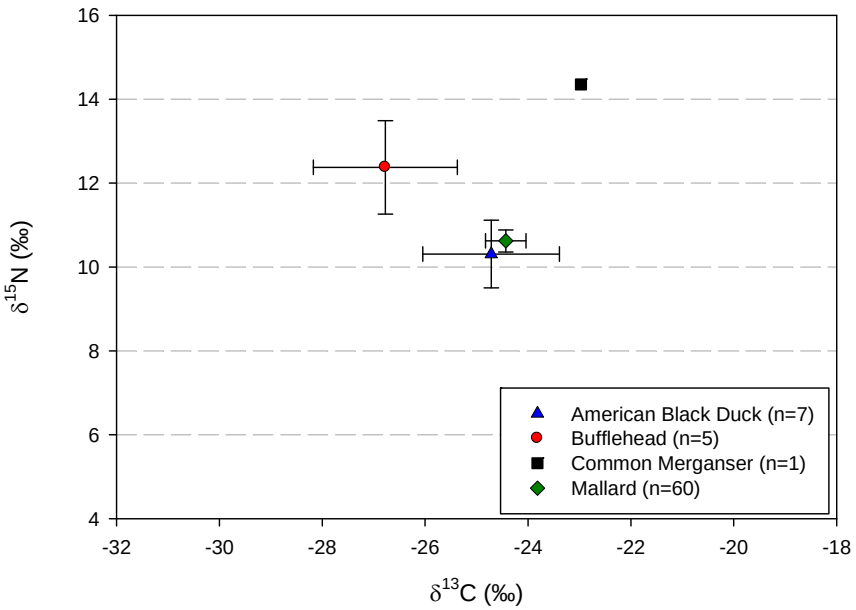

Figure 13. Carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotope levels in blood. Error bars represent standard error of the mean.

When plotted against one another, there was a strong positive correlation ($r^2 = 0.99$) between mean $\delta^{15}N$ and mean blood Hg levels in all four species sampled (Figure 14). This confirms the assumption that higher trophic level foragers accumulate higher concentrations of Hg through dietary uptake.

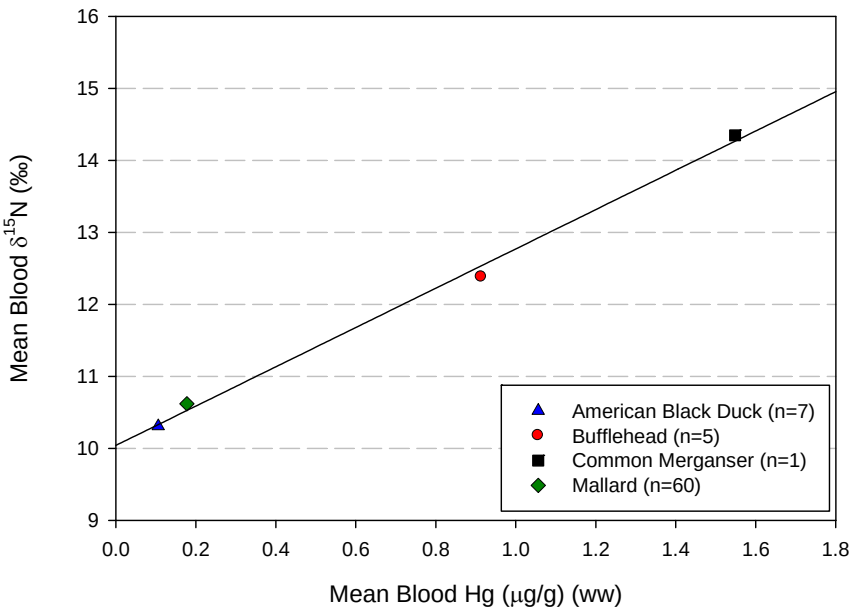

Figure 14. Mean nitrogen ($\delta^{15}N$) stable isotope levels plotted against mean blood Hg concentrations in four waterfowl species on Onondaga Lake.

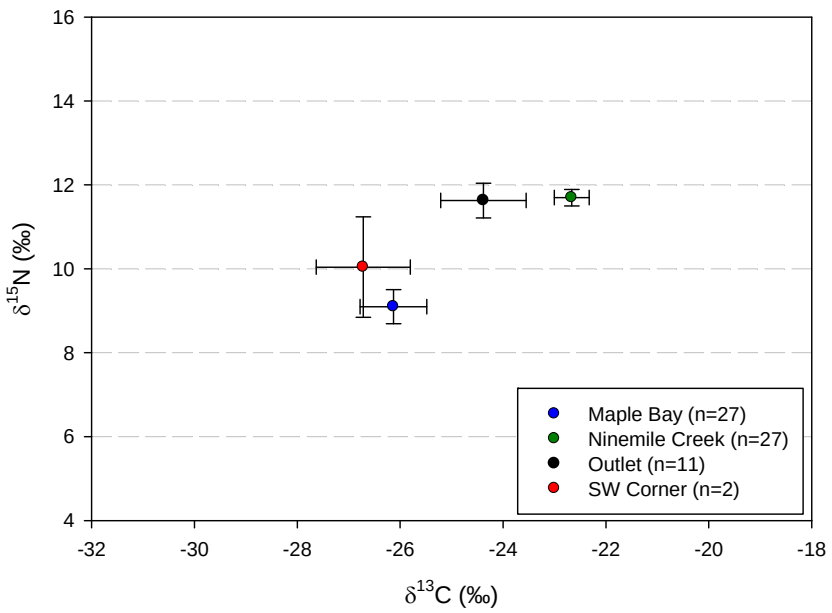

Figure 15. Carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotope levels in blood of mallards and black ducks among all sampling locations. Error bars represent standard error of the mean.

$\delta^{13}C$ and $\delta^{15}N$ stable isotopes were also compared between capture sites of mallards and black ducks. These species, while representing a large sample size, were also shown to be very similar in both stable isotope values and were, therefore, pooled together for this

comparison. We found a significant difference (p=0.0010) in $\delta^{13}C$ values between dabblers caught in Maple Bay and those caught at Ninemile Creek. This suggests that mallards and black ducks in these two sites may be utilizing different prey items. Significant differences in $\delta^{15}N$ were also determined between dabblers caught in Maple Bay and those caught in both Ninemile Creek and the Seneca River outlet (p<0.0001 and p=0.0087, respectively). This suggests that mallards and black ducks in these areas are likely occupying different trophic levels based on the availability of certain prey items.

Prey Items

$\delta^{13}C$ and $\delta^{15}N$ stable isotope analysis of fish and scud collected from the Lake showed distinct isotopic signatures between the two prey items (Figure 16). However, the analysis did little to determine the exact prey items consumed by our target species. We deduce from the data that the fish samples we collected were not representative of the diet of the single common merganser we sampled.

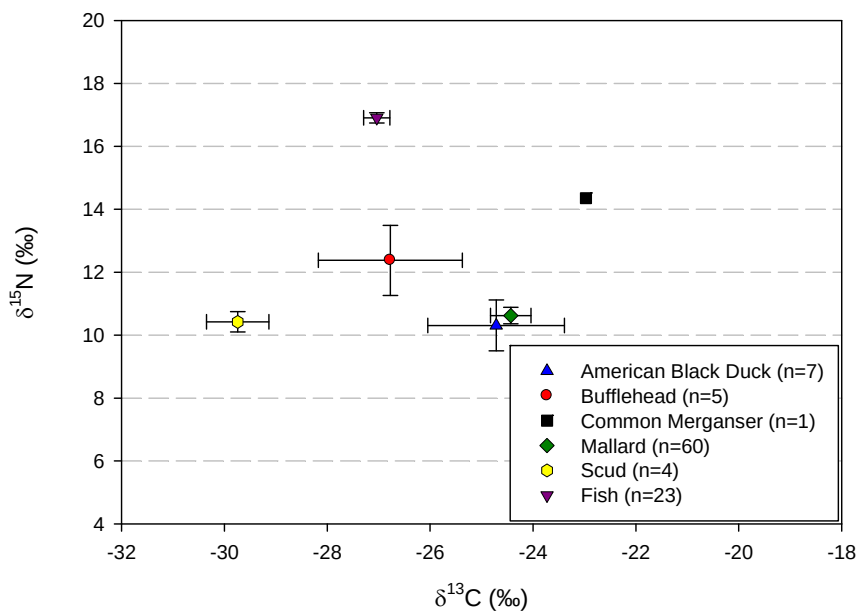

Figure 16. Carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotope values in blood of all ducks sampled along with whole-body prey items. Error bars represent standard error of the mean.

Deuterium

Deuterium (δD) values were analyzed in the blood of all ducks captured, along with the whole bodies of fish and scud samples. Since stable isotope analysis in blood will only represent recent dietary uptake, this analysis does little to identify potential origins of duck species migrating through or staging on Onondaga Lake. Waterfowl species and their food items would not be expected to have identical values given the dynamics by which deuterium is processed through the food web. However, the relative similarity between deuterium values in duck blood and analyzed prey items (Figure 17) does suggest that the individual ducks we sampled may have spent time feeding on or near the Lake prior to capture. The small sample sizes (particularly for the COME) limit our ability to be more definitive. Future stable isotope analysis of feathers collected during this study may be able to provide possible geographic origins of birds captured.

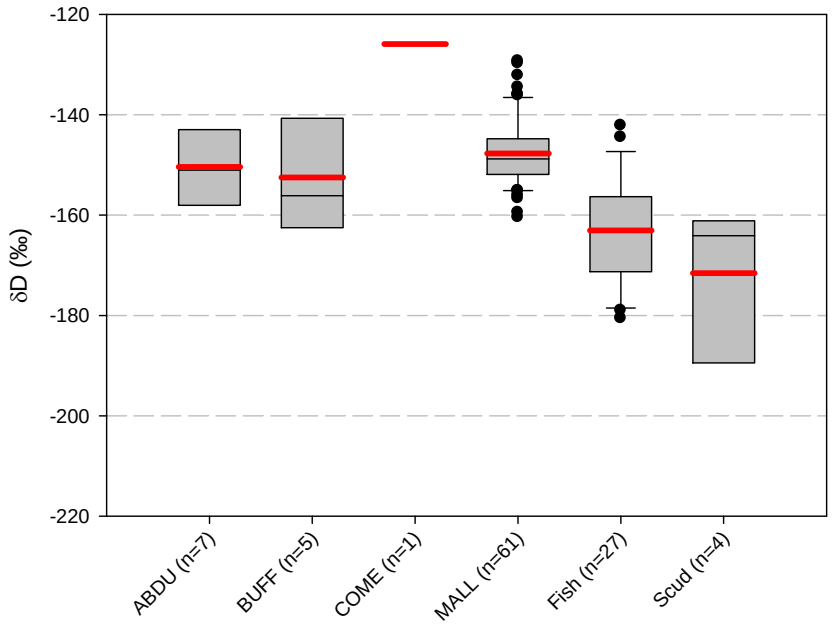

Figure 17. Deuterium (δD) stable isotope values in duck blood and whole-body prey items.

DISCUSSION

Wintering waterfowl exposure to mercury on Onondaga Lake

Comparison to other avian mercury levels

To gain a more comprehensive understanding of the level of Hg exposure on Onondaga Lake and its potential effects on difference species of waterfowl, data were evaluated from previous published and unpublished studies and compared to those found in this study. While adverse effect levels for most waterfowl species have not yet been established, we can use known thresholds for other species to evaluate waterfowl Hg data from Onondaga Lake.

Adverse effect thresholds for adult common loons have been determined to be 3.0 µg/g (ww) in blood and 40.0 µg/g (fw) in feathers. These effect levels were related to reproductive failure (blood) and flight feather asymmetry (feather) (Evers et al. 2008).

Adverse effect thresholds in mallards have been extensively studied and are well understood. Captive dosing studies (Heinz 1974, 1979) determined adverse effects in mallards starting at total feather Hg levels of 9.0 µg/g (fw).

The tree swallow (*Tachycineta bicolor*) may also be a relevant species for comparison. Particularly during the breeding season, tree swallows forage primarily over open water areas, consuming mostly flying insects, beetles, and ants (Robertson et al. 1992). Many of these flying insects have an aquatic life-stage and are, therefore, a direct link between aquatic Hg contamination and upper level consumers. Blood-egg pairings, using the known egg Hg LOAEL (Lowest Observed Adverse Effects Level), were used to determine a conservative LOAEL for tree swallows to be 0.63 µg/g (ww) in blood (Jackson 2011).

Finally, Jackson et al. (2011) found that a blood Hg concentration of 0.70 µg/g was associated with 10% reduced reproductive success in Carolina wrens (*Thryothorus ludovicianus*).

Although few other blood or feather Hg effects thresholds exist for birds, a study conducted by Heinz et al. (2009) highlights the variability in avian species sensitivity to Hg. These authors injected Hg into the eggs of 26 bird species and documented egg mortality.

Species categorized as having low sensitivity to Hg were the mallard, hooded merganser, lesser scaup, double-crested cormorant, and laughing gull. Species categorized with a medium sensitivity to mercury were clapper rail, sandhill crane, ring-necked pheasant, chicken, common grackle, tree swallow, herring gull, common tern, royal tern, Caspian tern, great egret, brown pelican,+ and anhinga. Species categorized as highly sensitive to Hg were American kestrel, osprey, white ibis, snowy egret, and tri-colored heron.

Common Merganser

When compared with mean blood and feather Hg concentrations of common mergansers sampled in other studies, the Hg concentration in the single individual in this study does not stand out as a noticeably high outlier (Table 4).

Table 4. Comparison of blood and feather Hg summary statistics for common mergansers sampled during this study along with those from similar published and unpublished studies.

Species	Location	Period	Tissue	n	Hg (µg/g)	SD +/-	Min	Max	Study
COME	*Onondaga Lake, NY*	*Wintering*	*Blood*	*1*	***1.5480***	~	~	~	
			Feather	*1*	***7.2885***	~	~	~	*This study*
COME	ME, NH, NY, VT, NB, NL, NS, PQ		Blood	11	1.57	0.59	0.74	2.35	
			Feather	24	8.0	4.1	3.3	17.7	Evers et al. 2005
COME	Rangeley Lakes Region, ME	Breeding	Blood	11	1.5742	0.5848	0.7390	2.3500	
			Feather	2	17.4000	0.4243	17.1000	17.7000	BRI unpublished data
COME	Kabetogama Lake, MN	Breeding	Blood	10	0.5650	0.1587	0.2800	0.8700	
			Feather	9	5.4978	1.5119	3.2300	7.4900	BRI unpublished data
COME	Clark River Delta	Breeding	Blood	1	1.1300	~	~	~	
			Feather	1	21.4000	~	~	~	BRI unpublished data
COME	Howard A. Hanson, WA	Breeding	Blood	1	0.1360	~	~	~	
			Feather	1	12.3000	~	~	~	BRI unpublished data
COME	West Branch Delaware River, NY	Wintering	Blood	16	1.1934	0.6969	0.2802	3.0725	BRI unpublished data

As very little data are available on blood and feather Hg levels in common mergansers and how they may relate to negative physiological impacts, we compared our data to the adverse effect thresholds for other species.

The common merganser captured during this study had blood and feather Hg concentrations well below the common loon LOAELs of 3.0 ug/g (blood) and 40 ug/g (feathers) (Figures 13 & 14). The 1.5 µg/g blood Hg concentration in the common merganser exceeded effect thresholds we propose earlier in this report for tree swallows (0.63 µg/g Hg) and Carolina wrens (0.70 µg/g Hg). Any comparisons between Hg levels in this common merganser and LOAELs from the literature are limited due to the very small sample size.

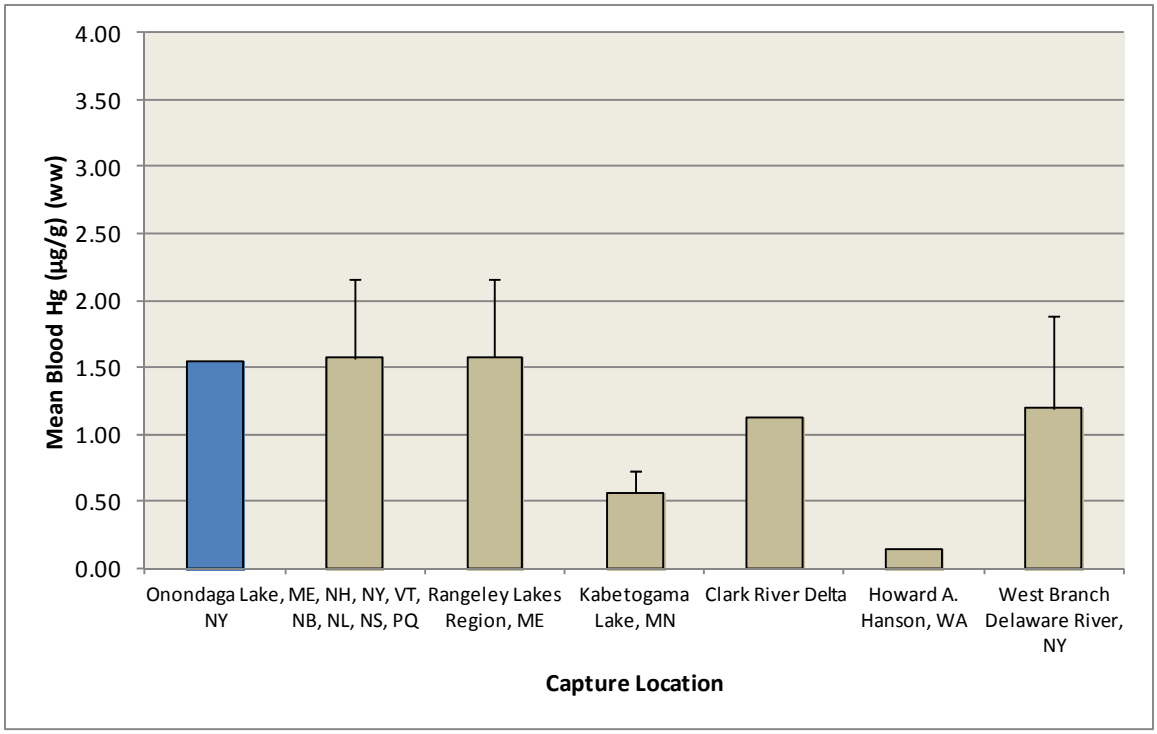

Figure 18. Common merganser mean blood Hg concentrations (±SD when available) from this and other studies.

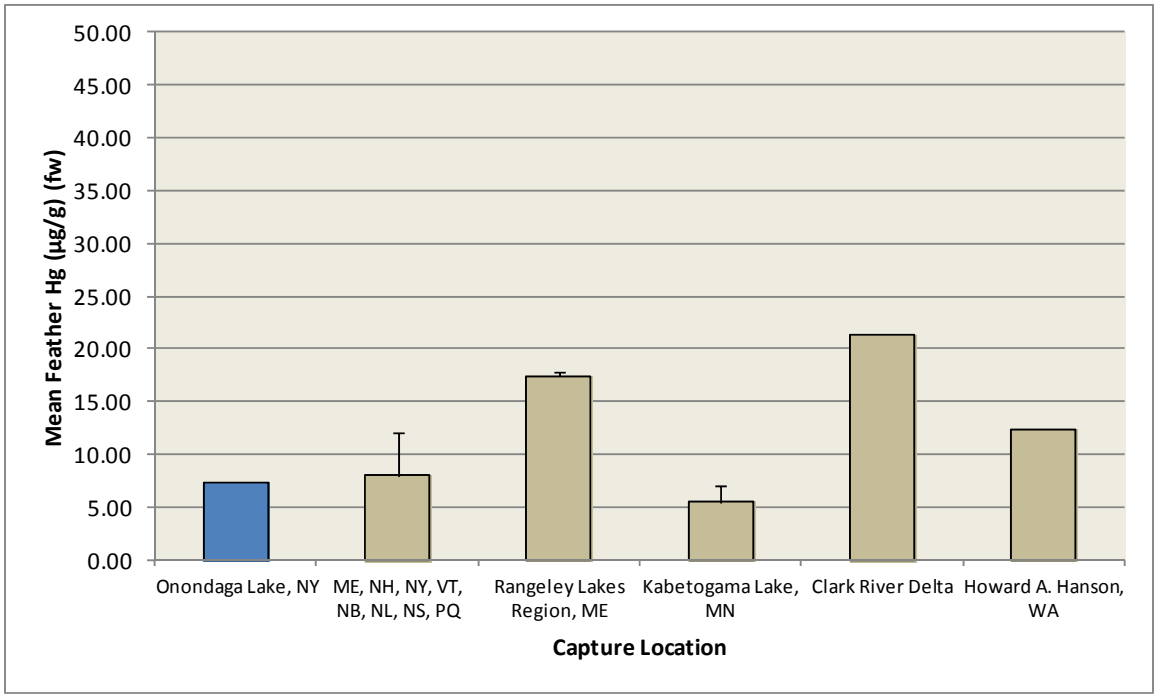

Figure 19. Common merganser mean feather Hg concentrations (±SD when available) from this and other studies.

Bufflehead

Mercury concentrations in bufflehead captured during this study were compared to existing BRI data. As very little literature exists on blood and feather Hg levels in bufflehead, our data were also compared with existing data on Hg concentrations in common goldeneye. The common goldeneye is a diving duck that occupies a similar foraging guild to bufflehead and serves as a reliable comparison species. We found that mean blood Hg levels for bufflehead captured on Onondaga Lake were substantially higher than blood Hg for buffleheads and common goldeneye captured in previous studies. These comparison studies took place primarily in the northeastern United States and areas of eastern Canada while one dataset exists from Minnesota (Table 5). This suggests that buffleheads on Onondaga Lake are subject to higher levels of Hg than similar species sampled for other studies. Published literature describing the zebra mussel as a staple food item for buffleheads on the Great Lakes (Hamilton et al. 1994) suggests that it may be part of the diet of buffleheads foraging on Onondaga Lake. Given the zebra mussel's ability to accumulate high concentrations of Hg (Petrie et al. 2007), it would be expected that buffleheads on Onondaga Lake would demonstrate elevated levels of total blood Hg. Zebra mussels sampled in this study contained a mean Hg concentration of 0.0486 µg/g (ww). This mean Hg concentration was slightly higher than that reported in a study by Roper et al. (1996) in which zebra mussels were placed at the Times Beach Confined Disposal Facility in Buffalo, New York, to assess bioaccumulation potential. After a 34-day sample period, zebra mussels at the contaminated site in that study averaged 0.03 µg/g Hg (ww). Mussels sampled in that study were similar in size to those in our study (avg. 16mm and 17.3mm, respectively).

The mean Hg concentration in blood of buffleheads 0.9 µg/g did not exceed the 3 µg/g blood LOAEL for the common loon, but did exceed the 0.63 µg/g blood effect level for the tree swallow and 0.70 µg/g blood effect level for the Carolina wren. Feather Hg concentrations reported in bufflehead during this study were lower than those in common goldeneye and bufflehead from our comparison data. This may suggest that bufflehead migrating to and staging on Onondaga Lake are doing so from areas of lower Hg contamination.

Table 5. Comparison of blood and feather Hg summary statistics for buffleheads sampled during this study along with common goldeneye sampled in similar published and unpublished studies.

Species	Location	Period	Tissue	n	Hg (µg/g)	SD +/-	Min	Max	Study
BUFF	*Onondaga Lake, NY*	*Wintering*	*Blood*	*5*	***0.9140***	*0.6105*	*0.2964*	*1.8032*	
			Feather	*5*	***1.4282***	*0.8179*	*0.3416*	*2.6456*	*This study*
BUFF	Penobscot Bay, ME	Wintering	Feather	4	2.8682	1.2512	1.1610	3.9684	BRI unpublished data
COGO	ME, NB, NL, NS, PQ		Blood	6	0.21	0.06	0.15	0.31	
			Feather	32	2.80	1.3	0.8	7.0	Evers et al. 2005
COGO	Rangeley Lakes Region, ME	Breeding	Blood	6	0.2055	0.0570	0.1520	0.3130	BRI unpublished data
COGO	Kabetogama Lake, MN	Breeding	Blood	5	0.1360	0.0508	0.0700	0.2000	
			Feather	5	2.7100	2.5965	1.1200	7.2300	BRI unpublished data

Mallard and Black Duck

Larger sample sizes and greater capture efficiency for mallards and black ducks allowed for more thorough statistical analysis and comparison. Our results were compared to blood and feather Hg values from other studies, including a study on the South River in Virginia, a known point-source Hg contamination site (Table 6).

Table 6. Comparison of blood and feather summary statistics for mallards and black ducks sampled during this study along with those from similar published and unpublished studies.

Species	Location	Period	Tissue	n	Hg (µg/g)	SD +/-	Min	Max	Study
MALL	*Onondaga Lake, NY*	*Wintering*	*Blood*	*61*	***0.1880***	*0.1902*	*0.0139*	*0.8047*	
			Feather	*62*	***1.7764***	*1.3445*	*0.2075*	*5.9479*	*This study*
ABDU	*Onondaga Lake, NY*	*Wintering*	*Blood*	*7*	***0.1060***	*0.0871*	*0.0416*	*0.2619*	
			Feather	*7*	***3.3382***	*1.9888*	*1.1944*	*7.0246*	*This study*
ABDU	NB, NL, NS, PE, PQ		Feather	39	1.8	1.2	0.6	6.6	Evers et al. 2005
MALL	ME, NH, NY, NB, NL, NS, PQ		Feather	11	0.9	0.5	0.3	1.8	Evers et al. 2005
MALL	South River, VA	Breeding	Blood	152	0.9440	0.8664	0.0060	5.4050	
			Feather	62	2.4170	3.0498	0.0160	17.7650	Savoy and Evers 2007

The mean blood Hg concentration for mallards captured in our study fell below the mean concentration in those captured at the South River site. However, the birds captured on the South River were sampled during the breeding season and likely were present on site for a longer period of time prior to sampling. There is some evidence that blood Hg concentrations will increase with the length of exposure. For example, Ackerman et al. (2008) found that blood Hg in Forster's terns in San Francisco Bay increased over a 45 day sampling period. Heinz (1979) determined the adverse effect level threshold in mallard feathers to be 9.0 µg/g (fw). None of the mallards or black ducks sampled during this study exceeded this threshold (Figure 20). We reiterate that the Onondaga Lake winter mallard data are not likely to reflect Hg exposure during the winter at Onondaga Lake, rather Hg exposure during feather growth (generally the breeding season)[3].

[3] It should be noted that a sample of corn, which was used as bait for the walk-in traps, was analyzed for Hg and determined to have a concentration of 0.01 µg/g. Based on published mercury dosing studies, this concentration was low enough for us to feel confident that our baiting methods were not influencing blood Hg concentrations.

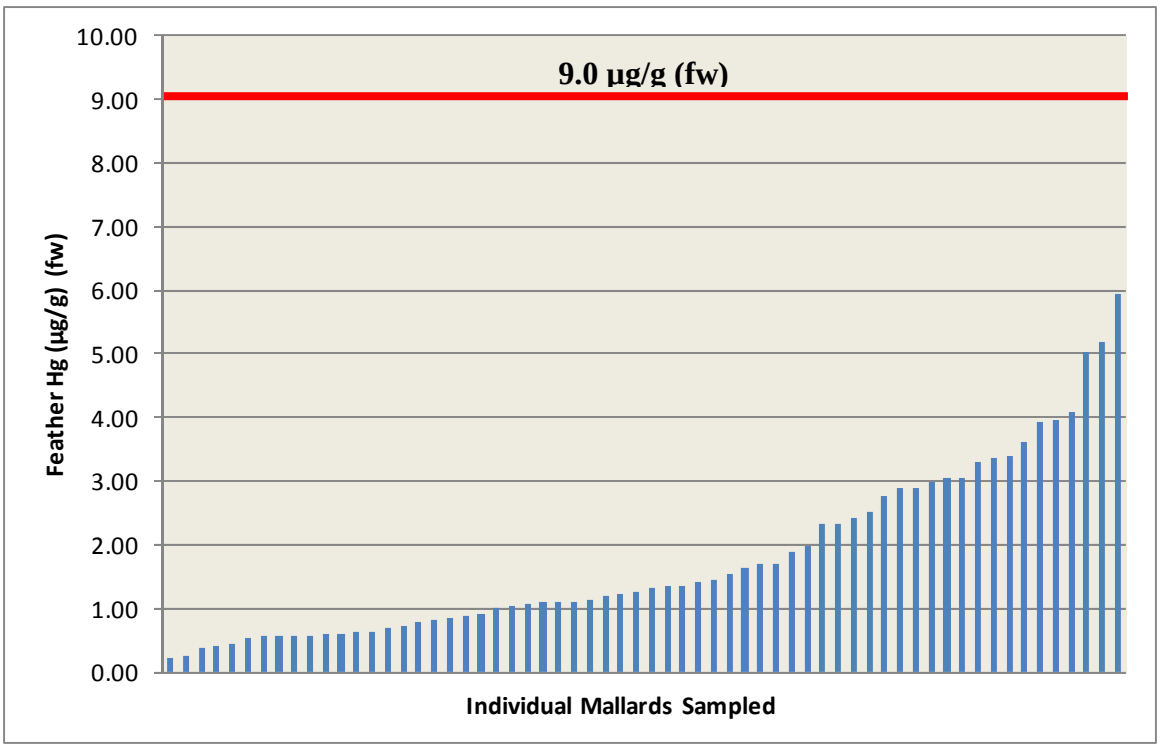

Figure 20. Mallard feather Hg concentrations from this study compared to the adverse effect level threshold (red) for mallards as suggested by Heinz 1979.

Mercury in prey items

Mercury levels in prey items have been shown to positively correlate with Hg levels in organisms that feed on them and have been directly linked to decreases in reproductive potential and success. Barr (1986) reported reproductive impairment in the form of reduced egg laying and territory fidelity in common loons feeding on fish with Hg concentrations of 0.3 µg/g. The aforementioned study also reported no reproduction occurring in loons feeding on fish with concentrations of 0.4 µg/g or higher. Mercury dosing studies performed on mallards and black ducks found that a steady diet of 3.0 µg/g (equivalent to ~0.6 µg/g in a natural succulent diet) led to decreased reproductive success in the form of increased duckling mortality, reduced egg laying, and increased embryonic mortality (Heinz 1974, 1976; Finley and Stendell 1978).

Several fish samples from Onondaga Lake equaled or exceeded these levels (Hg concentration range 0.01 – 0.7 µg/g) and could be limiting the reproductive potential of piscivorous bird species that breed on the Lake. Without performing stomach-content analysis,

it is difficult to determine the percentages of different food items in the diets of target birds. While common mergansers are recognized as primarily piscivores, their diets may differ between breeding and wintering seasons. When comparing Hg values, it is important to take fish size and trophic level into consideration. Positive correlations have been reported between Hg concentrations of fish muscle Hg and fish weight (Johnels et al. 1967). Our collection technique for prey fish was biased toward fish that could reasonably be caught with a narrow-gauge minnow trap. The weights of these fish fell within the range of 0.3 and 19.4 g. However in an unrelated study, we captured a common merganser that regurgitated a 395 g brown trout, indicating that they will often consume larger prey than our samples represent.

Muscle Hg concentrations and implications for other wildlife

As mentioned in the Results section, some muscle samples may not have been representative (i.e. may have contained fat and/or skin). However, Hg levels in muscle tissue of waterfowl species utilizing Onondaga Lake during the winter months could have potential implications for other higher trophic-level species in the area. They may also provide insight into how Hg levels in the Lake might be affecting other species with similar life history traits. Long-lived, piscivorous species are at highest risk for both biomagnification and bioaccumulation of environmental Hg in aquatic environments (Evers et al. 2005). Our study, complemented by other published and unpublished data, is consistent with the trend that piscivorous waterfowl species have significantly higher muscle Hg concentrations than other waterfowl species foraging guilds (Braune and Malone 2006; Evers et al. 2005; Gerstenberger 2004).

While muscle Hg levels reported in this study do not generally appear significantly elevated in comparison to data from other cited studies (with the exception of the common merganser – see Figure 21), the implications for other species foraging at higher trophic levels could still be important in determining overall ecosystem health in the Onondaga Lake system.

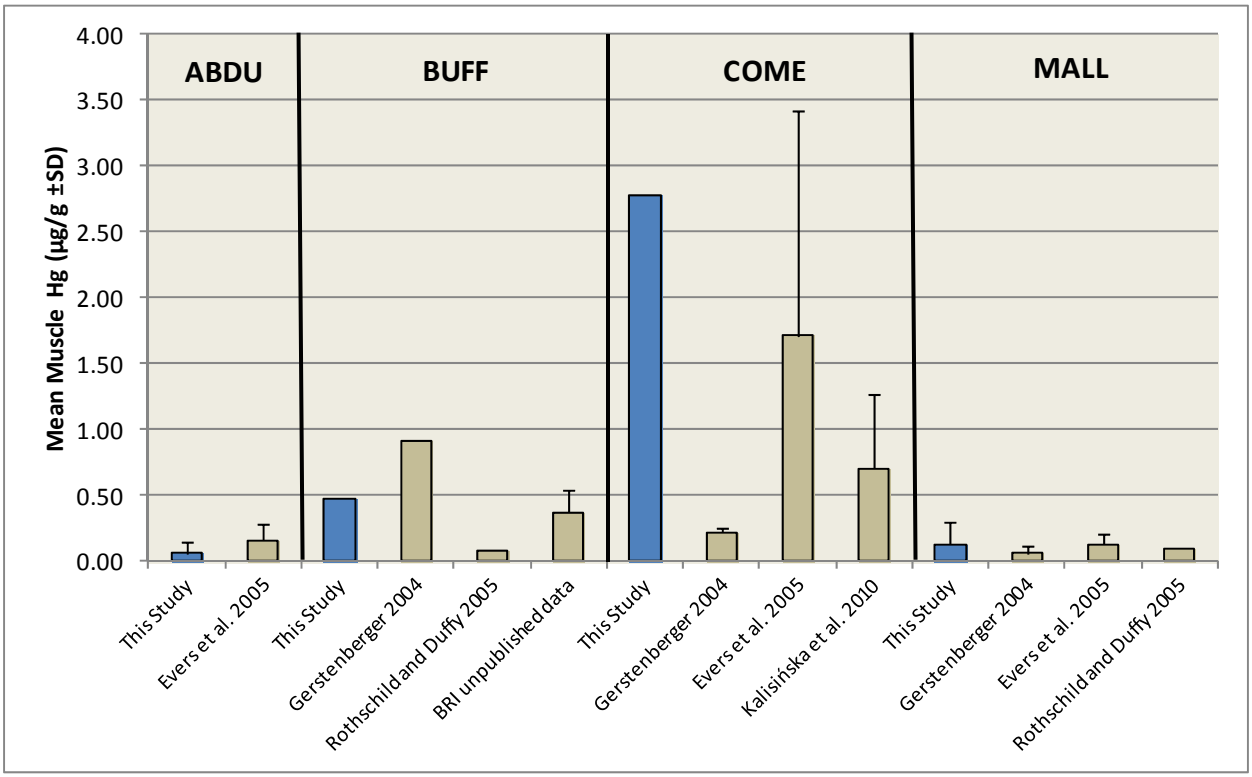

Figure 21. Mean muscle Hg concentrations from this study compared to concentrations reported in other published and unpublished studies. *ABDU = American black duck; BUFF = Bufflehead; COME = Common merganser; MALL = Mallard.*

Table 7. Mean muscle Hg concentrations from this study compared to concentrations reported in other published and unpublished studies.

Species	Location	Period	Tissue	n	Hg (µg/g)	SD +/-	Min	Max	Study
ABDU	*Onondaga Lake, NY*	*Wintering*	*Muscle*	*2*	***0.0632***	*0.0893*	*0.0000*	*0.1263*	*This study*
ABDU	NB, NL, NS, PE, PQ	Various	Muscle	62	0.1600	0.1200	0.0300	0.4500	Evers et al. 2005
BUFF	*Onondaga Lake, NY*	*Wintering*	*Muscle*	*1*	***0.4767***	~	~	~	*This Study*
BUFF	Nevada Wildlife Management Areas	Migration	Muscle	1	0.9100	~	~	~	Gerstenberger 2004
BUFF	Y-K Delta, Alaska	Various	Muscle	2	0.0781	~	~	~	Rothschild and Duffy 2005
BUFF	Penobscot Bay, ME	Wintering	Muscle	4	0.3734	0.1653	0.2280	0.5461	BRI unpubished data
COME	*Onondaga Lake, NY*	*Wintering*	*Muscle*	*1*	***2.7700***	~	~	~	*This Study*
COME	Nevada Wildlife Management Areas	Migration	Muscle	7	0.2200	0.0400	0.1300	2.4400	Gerstenberger 2004
COME	River Odra estuary, Poland	Wintering	Muscle	16	0.7041	0.5610	0.4227	1.0338	Kalisińska et al. 2010
COME	ME, NH, NY, VT, NB, NL, NS, PQ	Various	Muscle	31	1.7100	1.7100	0.0800	6.7700	Evers et al. 2005
MALL	*Onondaga Lake, NY*	*Wintering*	*Muscle*	*10*	***0.1306***	*0.1611*	*0.0000*	*0.4716*	*This Study*
MALL	Nevada Wildlife Management Areas	Migration	Muscle	12	0.0600	0.0600	0.0100	0.2200	Gerstenberger 2004
MALL	Y-K Delta, Alaska	Various	Muscle	3	0.0893	~	~	~	Rothschild and Duffy 2005
MALL	ME, NH, NY, NB, NL, NS, PQ	Various	Muscle	16	0.1300	0.0800	0.0200	0.2600	Evers et al. 2005

Stable Isotope Analysis

Stable isotope analysis of blood samples and prey items in this study served to begin the discussion of food web dynamics within the Onondaga Lake ecosystem and how Hg accumulation in wintering waterfowl species is related to diet composition and trophic level. The strong positive correlation between nitrogen stable isotopes and Hg concentrations among all waterfowl species in this study further solidifies our understanding of increased Hg bioaccumulation in higher trophic level species.

Analysis of carbon and nitrogen stable isotopes in prey items, when compared to those reported in duck blood, suggests that the prey items sampled may not have been representative of the diet of our target duck species. One major information gap within the stable isotope data is the lack of zebra and quagga mussels in the analysis. After Hg analysis was complete, there was not enough mussel tissue left to analyze for stable isotopes. Based on our assumptions that bufflehead and other such diving ducks on the Lake were feeding heavily on these mussels, stable isotope values of these mussels are needed to provide a thorough analysis of this food web structure.

Deuterium values reported in duck blood and prey items in this study begin to shed light on the isotopic signature of the Lake, but there are data gaps that exist within this context. While deuterium values in prey items are thought to have an isotopic signature of the aquatic system in which they live, the values we report here are much more depleted than what would be expected based on mean annual precipitation maps of the area. Based on the mean annual growing season rainfall in North America, expected deuterium values in the Onondaga Lake would range between -60 and -70 0/00 (Hobson et al. 1999). Prey samples collected on Onondaga Lake ranged between -140 and -200 0/00. This depletion can be explained by the discrimination against 2H during photosynthesis. Due to photosynthetic fractionation in the δD cycle, submerged aquatic plants will possess δD values that are far more depleted than that of the water source in which they live (Doucett et al. 2007). Further studies should include submerged aquatic vegetation and Lake-water samples in stable isotope analyses to provide a much more comprehensive view of food web dynamics and isotopic interactions within the Lake system.

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LITERATURE CITED

Ackerman, J.T., C.A. Eagles-Smith, J.Y. Takekawa, J.D. Bluso and T.L. Adelsbach. 2008. Mercury concentrations in blood and feathers of prebreeding Forster's terns in relation to space use of San Francisco Bay, California, USA, habitats. Environmental Toxicology Chemistry 27 (4): 897-908.

Barr, J.F. 1986. Population dynamics of the common loon (*Gavia immer*) associated with mercury-contaminated waters in north-western Ontario. Occasional paper 56. Canadian Wildlife Service. Ottawa, Ontario, Canada.

Bearhop, S., S. Waldon, D. Thompson, and R. Furness. 2000. Bioamplification of mercury in great skua *Catharacta skua* chicks: The influence of trophic status as determined by stable isotope signatures of blood and feathers. Marine Pollution Bulletin 40:181-185.

Braune, B.M. and B.J. Malone. 2006. Organochlorides and mercury in waterfowl harvested in Canada. Environmental Monitoring and Assessment 114:331-359.

Brodeur, S., G. H. Mittelhauser, J.P.L. Savard, P.W. Thomas, R.D. Titman, and D. Comeau. 2008. Capture Methods for Migrating, Wintering and Molting Sea Ducks. Waterbirds 31:133-137.

Cristol, D.A., R.L. Brasso, A.M. Condon, R.E. Fovargue, S.L. Friedman, K.K. Hallinger, A.P. Monroe, and A.E. White. 2008. The movement of aquatic mercury through terrestrial food webs. Science 320:335.

Custer, C.M., T.W. Custer, and E.F. Hill. 2007. Mercury exposure and effects on cavity-nesting birds from the Carson River, Nevada. Archives of Environmental Contamination and Toxicology 52:129-136.

Custer, C.M. and T.W. Custer. 1996. Food habits of diving ducks in the Great Lakes after the zebra mussel invasion. Journal of Field Ornithology 67(1):86-99.

Custer, C.M. and T.W. Custer. 2000. Organochloride and trace element contamination in wintering and migrating diving ducks in the Southern Great Lakes, USA, since the zebra mussel invasion. Environmental Toxicology and Chemistry 19(11):2821-2829.

de Kock, W.C. and C.T. Bowmer. 1993. Bioaccumulation, biological effects, and food chain transfer of contaminants in the zebra mussel (*Dreissena polymorpha*). Pages 503-533 *in* Zebra Mussels: Biology, Impacts, and Control (T.F. Nalepa and D. Schloesser, eds.). Lewis Publishers, Boca Raton, FL.

Doucett, R.R., J.C. Marks, D.W. Blinn, M. Caron, and B.A. Hungate. 2007. Measuring terrestrial subsidies to aquatic food webs using stable isotopes of hydrogen. Ecology 88(6):1587-1592.

Driscoll, C.T., Y.J. Han, C.Y. Chen, D.C. Evers, K.F. Lambert, T.M. Holsen, N.C. Kamman, and R. Munson. 2007. Mercury contamination in remote forest and aquatic ecosystems in the northeastern U.S.: Sources, transformations and management options. Bioscience 57:17-28.

Edmonds, S.T., D.C. Evers, D.A. Cristol, C. Mettke-Hofmann, L.L. Powell, A.J. McGann, J.W. Armiger, O.P. Lane, D.F. Tessler, P. Newell, K. Heyden, and N.J. O'Driscoll. 2010. Geographic and seasonal variation in mercury exposure of the declining Rusty Blackbird. The Condor 112(4):789-799.

Evers, D.C. 2009. Protocol for collecting bird and mammal tissue for contaminant analysis. BRI Report 2009-01, Biodiversity Research Institute, Gorham, ME.

Evers, D. C., N. M. Burgess, L. Champoux, B. Hoskins, A. Major, W. M. Goodale, R. J. Taylor, R. Poppenga, and T. Daigle. 2005. Patterns and interpretation of mercury exposure in freshwater avian communities in northeastern North America. Ecotoxicology 14:193-221.

Evers, D.C., L.J. Savoy, C.R. DeSorbo, D.E. Yates, W. Hanson, K.M. Taylor, L.S. Siegel, J.H. Cooley Jr., M.S. Bank, A. Major, K. Munney, B.F. Mower, H.S. Vogel, N. Schoch, M. Pokras, M.W. Goodale, and J. Fair. 2008. Adverse effects from environmental mercury loads on breeding common loons. Ecotoxicology 17:69-81.

Finley, M.T. and R.C. Stendell. 1978. Survival and reproductive success of black ducks fed methyl mercury. Environmental Pollution 16:51-64.

Gerstenberger, S.L. 2004. Mercury concentrations in migratory waterfowl harvested from Southern Nevada Wildlife Management Areas, USA. Environmental Toxicology 19(1):35-44.

Hamilton, D.J., C.D. Ankney, and R. C. Bailey. 1994. Predation of zebra mussels by diving ducks: an enclosure study. Ecology 75:521-531.

Heinz, G.H., D.J. Hoffman, K.R. Stebbins, S.L. Kondrad and C.A. Erwin. 2009. Species differences in the sensitivity of avian embryos to methylmercury. Archives Environmental Contamination Toxicology 56:129-138.

Heinz, G. 1974. Effects of low dietary levels of methyl mercury on mallard reproduction. Bulletin of Environmental Contamination and Toxicology 11(4):386-392.

Heinz, G. 1976. Methylmercury: Second-year feeding effects on mallard reproduction and duckling behavior. The Journal of Wildlife Management 40:82-90.

Heinz, G. 1979. Methylmercury: reproductive and behavioral effects on three generations of mallard ducks. The Journal of Wildlife Management 43(2):394-401.

Hobson, K.A. and R.G. Clark. 1992. Assessing avian diets using stable isotopes I: turnover of 13C in tissues. The Condor 94:181-188.

Hobson, K.A., L. Atwell and L.I. Wassenaar. 1999. Influence of drinking water and diet on the stable-hydrogen isotope ratios of animal tissues. Proceedings National Academy Sciences United States of America 96: 8003 - 8006.

Inger, R. and S. Bearhop. 2008. Review: Applications of stable isotope analyses to avian ecology. Ibis 150:447-461.

Jackson, A.K. 2011. BioDiversity Research Institute: Current lowest observed adverse effect level (LOAEL) for mercury in tree swallows (*Tachycineta bicolor*). BRI report #2010-27.

Jackson, A.K., D.C. Evers, M.A. Etterson, A.M. Condon, S.B. Folsom, J. Detweiler, J. Schmerfeld, and D.A. Cristol. 2011. Mercury exposure affects the reproductive success of a free-living terrestrial songbird, the Carolina wren (*Thryothorus ludovicianus*). The Auk 128(4): 759 – 769.

Johnels, A.G., T. Westermark, W. Berg, P.I. Persson, and B. Sjöstrand. 1967. Pike (*Esox lucius* L.) and some other aquatic organisms in Sweden as indicators of mercury contamination in the environment. Oikos 18:323-333.

Kalisińska, E., H. Budis, J. Podlasińska, N. Łanocha, K.M. Kavetska. 2010. Body condition and mercury concentration in apparently healthy goosander (*Mergus merganser*) wintering in the Odra estuary, Poland. Ecotoxicology 19:1382-1399.

Monteiro, L.R. and R.W. Furness. 2001. Kinetics, dose-response, excretion, and toxicity of methylmercury in free-living Cory's shearwater chicks. Environmental Toxicology Chemistry 20(8): 1816-1823.

Petrie, S.A., S.S. Badzinski, and K.G. Drouillard. 2007. Contaminants in lesser and greater scaup staging on the lower Great Lakes. Archive of Environmental Contamination and Toxicology 52:580-589.

Post, D.M. 2002. Using stable isotopes to estimate trophic position: Models, methods, and assumptions. Ecology 83:703-718.

Robertson, R.J., B.J. Stutchbury, and R.R. Cohen. 1992. Tree Swallow (*Tachycineta bicolor*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: <http://bna.birds.cornell.edu.bnaproxy.birds.cornell.edu/bna/species/011doi:10.2173/bna.11>

Roper, J.M., D.S. Cherry, J.W. Simmers, and H.E. Tatem. 1996. Bioaccumulation of toxicants in the zebra mussel, *Dreissena polymorpha*, at the Times Beach Confined Disposal Facility, Buffalo, New York. Environmental Pollution 94(2):117-129.

Rothschild, R.F.N. and L.K. Duffy. 2005. Mercury concentrations in muscle, brain and bone of Western Alaskan waterfowl. Science of The Total Environment 349:277-283.

Savoy, L. and D.C. Evers. 2007. Pilot assessment of methylmercury availability to Mallards on the South River, Virginia – 2007. Report BRI 2007-18 submitted to DuPont Corporate Remediation Group, Newark, Delaware and the U.S. Fish Wild. Serv., Gloucester, Virginia. Biodiversity Research Institute, Gorham, ME. 32pp.

Scheuhammer, A.M., A.H.K. Wong, and D. Bond. 1998. Mercury and selenium accumulation in Common Loons (*Gavia immer*) and Common Mergansers (*Mergus merganser*) from eastern Canada. Environmental Toxicology and Chemistry 17:197-201.

Secord, A.L. 2011. Onondaga Lake Summary of Winter Waterfowl Survey, 2007 – 2008. U.S. Fish and Wildlife Service, 3817 Luker Road, Cortland, NY 13045.

Spada, M.E., N.H. Ringler, S.W. Effler, and D.A. Matthews. 2002. Invasion of Onondaga Lake, New York, by the zebra mussel (*Dreissena polymorpha*) following reductions in N pollution. Journal of the North American Benthological Society 21(4):634-650.

USEPA. 2007. From 'An update of the current status of the RCRA methods development program' by Barry Lesnik and Ollie Fordham, USEPA, Office of Solid Waste, Methods Team (5307W), doc #4BLWP804.98.

Wolfe, M.F., T. Atkeson, W. Bowerman, K. Burger, D.C. Evers, M.W. Murray, and E. Zillioux. (2007) Wildlife indicators. In: Harris R., D.P. Krabbenhoft, R. Mason, M.W. Murray, R. Reash, and T. Saltman (eds) Ecosystem response to mercury contamination: indicators of change. CRC Press, SETAC, Webster, NY, pp 123-189.

APPENDIX I

Captures

Date	Lake	Territory	Species	Band #	Tissue	Hg (µg/g)
12/13/2009	Onondaga Lake	SW Corner	ABDU	1867-39210	Blood	**0.050**
12/16/2009	Onondaga Lake	Maple Bay	ABDU	1867-39219	Blood	**0.045**
12/17/2009	Onondaga Lake	Maple Bay	ABDU	1867-39223	Blood	**0.093**
12/17/2009	Onondaga Lake	Maple Bay	ABDU	1867-39226	Blood	**0.057**
2/3/2010	Onondaga Lake	9 Mile Creek	ABDU	1867-39235	Blood	**0.193**
2/3/2010	Onondaga Lake	9 Mile Creek	ABDU	1867-39242	Blood	**0.262**
2/3/2010	Onondaga Lake	9 Mile Creek	ABDU	1867-39257	Blood	**0.042**
12/13/2009	Onondaga Lake	SW Corner	ABDU	1867-39210	Feather	**2.615**
12/16/2009	Onondaga Lake	Maple Bay	ABDU	1867-39219	Feather	**2.465**
12/17/2009	Onondaga Lake	Maple Bay	ABDU	1867-39223	Feather	**4.855**
12/17/2009	Onondaga Lake	Maple Bay	ABDU	1867-39226	Feather	**7.025**
2/3/2010	Onondaga Lake	9 Mile Creek	ABDU	1867-39235	Feather	**1.194**
2/3/2010	Onondaga Lake	9 Mile Creek	ABDU	1867-39242	Feather	**1.940**
2/3/2010	Onondaga Lake	9 Mile Creek	ABDU	1867-39257	Feather	**3.274**
2/3/2010	Onondaga Lake	9 Mile Creek	ABDU	1867-39235	Muscle	**0.126**
2/3/2010	Onondaga Lake	9 Mile Creek	ABDU	1867-39242	Muscle	**0.000**
12/4/2009	Onondaga Lake	Maple Bay	BUFF	1065-33701	Blood	**1.803**
12/4/2009	Onondaga Lake	Maple Bay	BUFF	1065-33702	Blood	**0.703**
12/4/2009	Onondaga Lake	Maple Bay	BUFF	1065-33703	Blood	**1.253**
12/8/2009	Onondaga Lake	Maple Bay	BUFF	1065-33704	Blood	**0.296**
3/30/2010	Onondaga Lake	Maple Bay	BUFF	1065-33705	Blood	**0.515**
12/4/2009	Onondaga Lake	Maple Bay	BUFF	1065-33701	Feather	**1.328**
12/4/2009	Onondaga Lake	Maple Bay	BUFF	1065-33702	Feather	**0.342**
12/4/2009	Onondaga Lake	Maple Bay	BUFF	1065-33703	Feather	**2.646**
12/8/2009	Onondaga Lake	Maple Bay	BUFF	1065-33704	Feather	**1.448**
3/30/2010	Onondaga Lake	Maple Bay	BUFF	1065-33705	Feather	**1.377**
3/30/2010	Onondaga Lake	Maple Bay	BUFF	1065-33705	Muscle	**0.477**
4/3/2010	Onondaga Lake	Beach	COME	1867-39262	Blood	**1.548**
4/3/2010	Onondaga Lake	Beach	COME	1867-39262	Feather	**7.288**
4/3/2010	Onondaga Lake	Beach	COME	1867-39262	Muscle	**2.770**
12/19/2009	Onondaga Lake	9 Mile Creek	HOME (found dead)	UnNY-09004	Feather	**16.880**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1697-29468	Blood	**0.097**
12/16/2009	Onondaga Lake	Maple Bay	MALL	1717-31002	Blood	**0.032**
12/8/2009	Onondaga Lake	Maple Bay	MALL	1867-39202	Blood	**0.469**
12/8/2009	Onondaga Lake	Maple Bay	MALL	1867-39203	Blood	**0.515**
12/8/2009	Onondaga Lake	Maple Bay	MALL	1867-39204	Blood	**0.440**

12/8/2009	Onondaga Lake	Maple Bay	MALL	1867-39205	Blood	**0.317**
12/11/2009	Onondaga Lake	Maple Bay	MALL	1867-39206	Blood	**0.041**
12/11/2009	Onondaga Lake	Maple Bay	MALL	1867-39207	Blood	**0.020**
12/11/2009	Onondaga Lake	Maple Bay	MALL	1867-39208	Blood	**0.327**
12/13/2009	Onondaga Lake	SW Corner	MALL	1867-39209	Blood	**0.054**
12/14/2009	Onondaga Lake	Maple Bay	MALL	1867-39211	Blood	**0.260**
12/14/2009	Onondaga Lake	Maple Bay	MALL	1867-39212	Blood	**0.037**
12/16/2009	Onondaga Lake	Maple Bay	MALL	1867-39213	Blood	**0.021**
12/16/2009	Onondaga Lake	Maple Bay	MALL	1867-39214	Blood	**0.051**
12/16/2009	Onondaga Lake	Maple Bay	MALL	1867-39215	Blood	**0.045**
12/16/2009	Onondaga Lake	Maple Bay	MALL	1867-39216	Blood	**0.036**
12/16/2009	Onondaga Lake	Maple Bay	MALL	1867-39217	Blood	**0.118**
12/16/2009	Onondaga Lake	Maple Bay	MALL	1867-39218	Blood	**0.047**
12/16/2009	Onondaga Lake	Maple Bay	MALL	1867-39220	Blood	**0.117**
12/16/2009	Onondaga Lake	Maple Bay	MALL	1867-39221	Blood	**0.047**
12/17/2009	Onondaga Lake	Maple Bay	MALL	1867-39222	Blood	**0.244**
12/17/2009	Onondaga Lake	Maple Bay	MALL	1867-39224	Blood	**0.019**
12/17/2009	Onondaga Lake	Maple Bay	MALL	1867-39225	Blood	**0.145**
12/17/2009	Onondaga Lake	Maple Bay	MALL	1867-39227	Blood	**0.143**
12/17/2009	Onondaga Lake	Maple Bay	MALL	1867-39228	Blood	**0.014**
2/1/2010	Onondaga Lake	Outlet	MALL	1867-39229	Blood	**0.087**
2/1/2010	Onondaga Lake	Outlet	MALL	1867-39230	Blood	**0.155**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39231	Blood	**0.113**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39232	Blood	**0.061**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39233	Blood	**0.053**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39234	Blood	**0.087**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39236	Blood	**0.136**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39237	Blood	**0.343**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39238	Blood	**0.420**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39239	Blood	**0.257**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39240	Blood	**0.255**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39243	Blood	**0.034**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39244	Blood	**0.080**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39245	Blood	**0.138**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39246	Blood	**0.031**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39247	Blood	**0.134**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39248	Blood	**0.278**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39249	Blood	**0.322**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39250	Blood	**0.082**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39251	Blood	**0.165**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39252	Blood	**0.092**

2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39253	Blood	**0.054**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39254	Blood	**0.079**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39255	Blood	**0.689**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39256	Blood	**0.143**
2/5/2010	Onondaga Lake	Outlet	MALL	1867-39258	Blood	**0.032**
2/5/2010	Onondaga Lake	Outlet	MALL	1867-39259	Blood	**0.027**
2/5/2010	Onondaga Lake	Outlet	MALL	1867-39260	Blood	**0.535**
2/5/2010	Onondaga Lake	Outlet	MALL	1867-39261	Blood	**0.241**
2/5/2010	Onondaga Lake	Outlet	MALL	1867-39263	Blood	**0.132**
2/5/2010	Onondaga Lake	Outlet	MALL	1867-39264	Blood	**0.040**
12/4/2009	Onondaga Lake	Maple Bay	MALL	UnNY-09001	Blood	**0.805**
12/14/2009	Onondaga Lake	Maple Bay	MALL	UnNY-09002	Blood	**0.757**
2/1/2010	Onondaga Lake	Outlet	MALL	UnNY-10001	Blood	**0.137**
2/5/2010	Onondaga Lake	Outlet	MALL	UnNY-10003	Blood	**0.402**
2/5/2010	Onondaga Lake	Outlet	MALL	UnNY-10004	Blood	**0.418**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1697-29468	Feather	**2.775**
12/16/2009	Onondaga Lake	Maple Bay	MALL	1717-31002	Feather	**0.810**
12/8/2009	Onondaga Lake	Maple Bay	MALL	1867-39202	Feather	**3.377**
12/8/2009	Onondaga Lake	Maple Bay	MALL	1867-39203	Feather	**3.970**
12/8/2009	Onondaga Lake	Maple Bay	MALL	1867-39204	Feather	**2.893**
12/8/2009	Onondaga Lake	Maple Bay	MALL	1867-39205	Feather	**5.187**
12/11/2009	Onondaga Lake	Maple Bay	MALL	1867-39206	Feather	**1.267**
12/11/2009	Onondaga Lake	Maple Bay	MALL	1867-39207	Feather	**1.642**
12/11/2009	Onondaga Lake	Maple Bay	MALL	1867-39208	Feather	**2.323**
12/13/2009	Onondaga Lake	SW Corner	MALL	1867-39209	Feather	**0.251**
12/14/2009	Onondaga Lake	Maple Bay	MALL	1867-39211	Feather	**3.053**
12/14/2009	Onondaga Lake	Maple Bay	MALL	1867-39212	Feather	**0.715**
12/16/2009	Onondaga Lake	Maple Bay	MALL	1867-39213	Feather	**0.889**
12/16/2009	Onondaga Lake	Maple Bay	MALL	1867-39214	Feather	**0.523**
12/16/2009	Onondaga Lake	Maple Bay	MALL	1867-39215	Feather	**0.597**
12/16/2009	Onondaga Lake	Maple Bay	MALL	1867-39216	Feather	**1.114**
12/16/2009	Onondaga Lake	Maple Bay	MALL	1867-39217	Feather	**1.229**
12/16/2009	Onondaga Lake	Maple Bay	MALL	1867-39218	Feather	**0.457**
12/16/2009	Onondaga Lake	Maple Bay	MALL	1867-39220	Feather	**1.037**
12/16/2009	Onondaga Lake	Maple Bay	MALL	1867-39221	Feather	**2.342**
12/17/2009	Onondaga Lake	Maple Bay	MALL	1867-39222	Feather	**3.936**
12/17/2009	Onondaga Lake	Maple Bay	MALL	1867-39224	Feather	**0.555**
12/17/2009	Onondaga Lake	Maple Bay	MALL	1867-39225	Feather	**1.071**
12/17/2009	Onondaga Lake	Maple Bay	MALL	1867-39227	Feather	**1.878**
12/17/2009	Onondaga Lake	Maple Bay	MALL	1867-39228	Feather	**0.681**
2/1/2010	Onondaga Lake	Outlet	MALL	1867-39229	Feather	**0.618**

2/1/2010	Onondaga Lake	Outlet	MALL	1867-39230	Feather	**0.368**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39231	Feather	**1.693**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39232	Feather	**0.556**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39233	Feather	**1.359**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39234	Feather	**0.613**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39236	Feather	**0.207**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39237	Feather	**5.025**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39238	Feather	**2.898**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39239	Feather	**0.414**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39240	Feather	**1.104**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39243	Feather	**1.092**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39244	Feather	**0.564**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39245	Feather	**2.981**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39246	Feather	**0.994**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39247	Feather	**2.419**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39248	Feather	**1.981**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39249	Feather	**1.424**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39250	Feather	**1.437**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39251	Feather	**0.901**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39252	Feather	**1.306**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39253	Feather	**1.350**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39254	Feather	**1.119**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39255	Feather	**3.620**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39256	Feather	**0.618**
2/5/2010	Onondaga Lake	Outlet	MALL	1867-39258	Feather	**0.581**
2/5/2010	Onondaga Lake	Outlet	MALL	1867-39259	Feather	**0.835**
2/5/2010	Onondaga Lake	Outlet	MALL	1867-39260	Feather	**3.063**
2/5/2010	Onondaga Lake	Outlet	MALL	1867-39261	Feather	**3.381**
2/5/2010	Onondaga Lake	Outlet	MALL	1867-39263	Feather	**0.779**
2/5/2010	Onondaga Lake	Outlet	MALL	1867-39264	Feather	**1.193**
12/4/2009	Onondaga Lake	Maple Bay	MALL	UnNY-09001	Feather	**4.080**
12/14/2009	Onondaga Lake	Maple Bay	MALL	UnNY-09002	Feather	**3.288**
2/1/2010	Onondaga Lake	Outlet	MALL	UnNY-10001	Feather	**1.690**
2/5/2010	Onondaga Lake	Outlet	MALL	UnNY-10003	Feather	**2.525**
2/5/2010	Onondaga Lake	Outlet	MALL	UnNY-10004	Feather	**5.948**
4/5/2010	Onondaga Lake	9 Mile Creek	MALL	UnNY-10005	Feather	**1.540**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1697-29468	Muscle	**0.068**
2/1/2010	Onondaga Lake	Outlet	MALL	1867-39229	Muscle	**0.000**
2/1/2010	Onondaga Lake	Outlet	MALL	1867-39230	Muscle	**0.149**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39233	Muscle	**0.000**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39234	Muscle	**0.000**

2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39236	Muscle	**0.000**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL	1867-39237	Muscle	**0.128**
2/1/2010	Onondaga Lake	Outlet	MALL	Unbanded-03	Muscle	**0.472**
2/5/2010	Onondaga Lake	Outlet	MALL	Unbanded-05	Muscle	**0.149**
4/5/2010	Onondaga Lake	9 Mile Creek	MALL	UNNY-10005	Muscle	**0.341**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL/Domestic	UnNY-10002	Blood	**0.043**
2/3/2010	Onondaga Lake	9 Mile Creek	MALL/Domestic	UnNY-10002	Feather	**4.339**
12/14/2009	Onondaga Lake	Marina	RBGU	UnNY-09003	Feather	**0.580**
12/4/2009	Onondaga Lake	Maple Bay	WWSC	1867-39201	Blood	**0.977**
12/4/2009	Onondaga Lake	Maple Bay	WWSC	1867-39201	Feather	**2.427**

APPENDIX II

Prey Collection

Date	Lake	Territory	Species	Sample ID	Hg (µg/g)
12/12/2009	Onondaga Lake	Ninemile Creek	Banded Killfish	ONBK09-01	**0.2105**
12/12/2009	Onondaga Lake	Ninemile Creek	Brook Silverside	ONBS09-01	**0.2201**
12/12/2009	Onondaga Lake	Maple Bay	Quagga Mussel	ONQM09-01	**0.0382**
12/12/2009	Onondaga Lake	Maple Bay	Quagga Mussel	ONQM09-02	**0.0353**
12/12/2009	Onondaga Lake	Maple Bay	Quagga Mussel	ONQM09-03	**0.0534**
12/12/2009	Onondaga Lake	Maple Bay	Quagga Mussel	ONQM09-04	**0.0439**
12/12/2009	Onondaga Lake	Maple Bay	Quagga Mussel	ONQM09-05	**0.0479**
12/12/2009	Onondaga Lake	Maple Bay	Quagga Mussel	ONQM09-06	**0.0596**
12/12/2009	Onondaga Lake	Maple Bay	Quagga Mussel	ONQM09-07	**0.1317**
12/12/2009	Onondaga Lake	Maple Bay	Quagga Mussel	ONQM09-08	**0.0529**
12/12/2009	Onondaga Lake	Maple Bay	Quagga Mussel	ONQM09-09	**0.0579**
12/12/2009	Onondaga Lake	Maple Bay	Quagga Mussel	ONQM09-10	**0.0790**
12/12/2009	Onondaga Lake	Maple Bay	Zebra Mussel	ONZM09-01	**0.0653**
12/12/2009	Onondaga Lake	Maple Bay	Zebra Mussel	ONZM09-02	**0.0761**
12/12/2009	Onondaga Lake	Maple Bay	Zebra Mussel	ONZM09-03	**0.0363**
12/12/2009	Onondaga Lake	Maple Bay	Zebra Mussel	ONZM09-04	**0.0539**
12/12/2009	Onondaga Lake	Maple Bay	Zebra Mussel	ONZM09-05	**0.0443**
12/12/2009	Onondaga Lake	Maple Bay	Zebra Mussel	ONZM09-06	**0.1149**
12/12/2009	Onondaga Lake	Maple Bay	Zebra Mussel	ONZM09-07	**0.0388**
12/12/2009	Onondaga Lake	Maple Bay	Zebra Mussel	ONZM09-08	**0.0340**
12/12/2009	Onondaga Lake	Maple Bay	Zebra Mussel	ONZM09-09	**0.0727**
12/12/2009	Onondaga Lake	Maple Bay	Zebra Mussel	ONZM09-10	**0.1374**
12/12/2009	Onondaga Lake	Maple Bay	Scud	ONIN09-10	**0.0516**
12/14/2009	Onondaga Lake	Ninemile Creek	Pumpkinseed	ONPS09-01	**0.4618**
12/14/2009	Onondaga Lake	Ninemile Creek	Pumpkinseed	ONPS09-02	**0.1156**
12/15/2009	Onondaga Lake	Ninemile Creek	Logperch	ONLP09-01	**0.1921**
12/18/2009	Onondaga Lake	Ninemile Creek	Black Crappie	ONBC09-01	**0.4039**
12/18/2009	Onondaga Lake	Ninemile Creek	Banded Killfish	ONBK09-02	**0.3396**
12/18/2009	Onondaga Lake	Ninemile Creek	Banded Killfish	ONBK09-03	**0.3881**
12/18/2009	Onondaga Lake	Ninemile Creek	Banded Killfish	ONBK09-04	**0.4642**
12/18/2009	Onondaga Lake	Ninemile Creek	Pumpkinseed	ONPS09-03	**0.0781**
1/30/2010	Onondaga Lake	Ninemile Creek	Dragonfly Nymph	ONIN09-01	**0.2984**
1/31/2010	Onondaga Lake	Ninemile Creek	Banded Killfish	ONBK09-05	**0.4515**
1/31/2010	Onondaga Lake	Ninemile Creek	Banded Killfish	ONBK09-06	**0.3101**
1/31/2010	Onondaga Lake	Ninemile Creek	Banded Killfish	ONBK09-07	**0.4569**
1/31/2010	Onondaga Lake	Ninemile Creek	Banded Killfish	ONBK09-08	**0.2871**

1/31/2010	Onondaga Lake	Ninemile Creek	Banded Killfish	ONBK09-09	**0.2877**
2/1/2010	Onondaga Lake	Ninemile Creek	Scud	ONIN09-02	**0.0293**
2/1/2010	Onondaga Lake	Ninemile Creek	Banded Killfish	ONBK09-10	**0.2233**
2/1/2010	Onondaga Lake	Ninemile Creek	Banded Killfish	ONBK09-11	**0.1786**
2/1/2010	Onondaga Lake	Outlet	Quagga Mussel	ONQM09-11	**0.0297**
2/1/2010	Onondaga Lake	Outlet	Quagga Mussel	ONQM09-12	**0.0214**
2/1/2010	Onondaga Lake	Outlet	Quagga Mussel	ONQM09-13	**0.0355**
2/1/2010	Onondaga Lake	Outlet	Quagga Mussel	ONQM09-14	**0.0346**
2/1/2010	Onondaga Lake	Outlet	Quagga Mussel	ONQM09-15	**0.0339**
2/1/2010	Onondaga Lake	Outlet	Quagga Mussel	ONQM09-16	**0.0422**
2/1/2010	Onondaga Lake	Outlet	Quagga Mussel	ONQM09-17	**0.0367**
2/1/2010	Onondaga Lake	Outlet	Quagga Mussel	ONQM09-18	**0.0493**
2/1/2010	Onondaga Lake	Outlet	Quagga Mussel	ONQM09-19	**0.0387**
2/1/2010	Onondaga Lake	Outlet	Zebra Mussel	ONZM09-11	**0.0388**
2/1/2010	Onondaga Lake	Outlet	Zebra Mussel	ONZM09-12	**0.0437**
2/1/2010	Onondaga Lake	Outlet	Zebra Mussel	ONZM09-13	**0.0289**
2/1/2010	Onondaga Lake	Outlet	Zebra Mussel	ONZM09-14	**0.0366**
2/1/2010	Onondaga Lake	Outlet	Zebra Mussel	ONZM09-15	**0.0340**
2/1/2010	Onondaga Lake	Outlet	Zebra Mussel	ONZM09-16	**0.0290**
2/1/2010	Onondaga Lake	Outlet	Zebra Mussel	ONZM09-17	**0.0291**
2/1/2010	Onondaga Lake	Outlet	Zebra Mussel	ONZM09-18	**0.0345**
2/1/2010	Onondaga Lake	Outlet	Zebra Mussel	ONZM09-19	**0.0361**
2/1/2010	Onondaga Lake	Outlet	Zebra Mussel	ONZM09-20	**0.0328**
2/2/2010	Onondaga Lake	Ninemile Creek	Banded Killfish	ONBK09-12	**0.6208**
2/2/2010	Onondaga Lake	Ninemile Creek	Scud	ONIN09-03	**0.0171**
2/2/2010	Onondaga Lake	Ninemile Creek	Snail	ONIN09-05	**0.0573**
3/31/2010	Onondaga Lake	Maple Bay	Snail	ONIN09-06	**0.0081**
4/1/2010	Onondaga Lake	Ninemile Creek	Scud	ONIN09-08	**0.0302**
4/2/2010	Onondaga Lake	Maple Bay	Quagga Mussel	ONQM09-21	**0.0387**
4/2/2010	Onondaga Lake	Maple Bay	Quagga Mussel	ONQM09-22	**0.0379**
4/2/2010	Onondaga Lake	Maple Bay	Quagga Mussel	ONQM09-23	**0.0378**
4/2/2010	Onondaga Lake	Maple Bay	Quagga Mussel	ONQM09-24	**0.0640**
4/2/2010	Onondaga Lake	Maple Bay	Quagga Mussel	ONQM09-25	**0.0351**
4/2/2010	Onondaga Lake	Maple Bay	Quagga Mussel	ONQM09-26	**0.0334**
4/2/2010	Onondaga Lake	Maple Bay	Quagga Mussel	ONQM09-27	**0.0379**
4/2/2010	Onondaga Lake	Maple Bay	Quagga Mussel	ONQM09-28	**0.0884**
4/2/2010	Onondaga Lake	Maple Bay	Quagga Mussel	ONQM09-29	**0.0377**
4/2/2010	Onondaga Lake	Maple Bay	Quagga Mussel	ONQM09-30	**0.0700**
4/2/2010	Onondaga Lake	Maple Bay	Zebra Mussel	ONZM09-21	**0.0348**
4/2/2010	Onondaga Lake	Maple Bay	Zebra Mussel	ONZM09-22	**0.0348**
4/2/2010	Onondaga Lake	Maple Bay	Zebra Mussel	ONZM09-23	**0.0569**

4/2/2010	Onondaga Lake	Maple Bay	Zebra Mussel	ONZM09-24	**0.0320**
4/2/2010	Onondaga Lake	Maple Bay	Zebra Mussel	ONZM09-25	**0.0375**
4/2/2010	Onondaga Lake	Maple Bay	Zebra Mussel	ONZM09-26	**0.0479**
4/2/2010	Onondaga Lake	Maple Bay	Zebra Mussel	ONZM09-27	**0.0617**
4/2/2010	Onondaga Lake	Maple Bay	Zebra Mussel	ONZM09-28	**0.0518**
4/2/2010	Onondaga Lake	Maple Bay	Zebra Mussel	ONZM09-29	**0.0454**
4/2/2010	Onondaga Lake	Maple Bay	Zebra Mussel	ONZM09-30	**0.0369**
4/2/2010	Onondaga Lake	Ninemile Creek	Logperch	ONLP09-02	**0.2923**
4/2/2010	Onondaga Lake	Ninemile Creek	Logperch	ONLP09-03	**0.0663**
4/3/2010	Onondaga Lake	Ninemile Creek	Banded Killfish	ONBK09-13	**0.2436**
4/3/2010	Onondaga Lake	Ninemile Creek	Banded Killfish	ONBK09-14	**0.2064**
4/3/2010	Onondaga Lake	Ninemile Creek	Pumpkinseed	ONPS09-04	**0.0990**
4/4/2010	Onondaga Lake	Ninemile Creek	Pumpkinseed	ONPS09-05	**0.3323**
4/4/2010	Onondaga Lake	Ninemile Creek	Bluegill	ONBG09-01	**0.1340**
4/4/2010	Onondaga Lake	Ninemile Creek	Pumpkinseed	ONPS09-06	**0.1747**
4/4/2010	Onondaga Lake	Ninemile Creek	Pumpkinseed	ONPS09-07	**0.2947**
4/4/2010	Onondaga Lake	Ninemile Creek	Pumpkinseed	ONPS09-08	**0.1318**
4/4/2010	Onondaga Lake	Ninemile Creek	Pumpkinseed	ONPS09-09	**0.1113**
4/4/2010	Onondaga Lake	Ninemile Creek	Banded Killfish	ONBK09-15	**0.4794**
4/4/2010	Onondaga Lake	Ninemile Creek	Banded Killfish	ONBK09-16	**0.3848**
4/4/2010	Onondaga Lake	Ninemile Creek	Banded Killfish	ONBK09-17	**0.6967**

APPENDIX III

Abundance Surveys

Date	Time	Location	Site	Photos	Species Observed	Activity	# of Ind.	Weather	Temperature	Wind Speed	Human Activity
12/1/2009	9:00 AM	Onondaga Lake	Western shore/9-mile creek	N	BUFF	Swimming	10	Cloudy	35	5-10	None on lake
12/1/2009	7:00 AM	Onondaga Lake	Marina	N	COME	Fly-bys and swimming	14	Snow	30-35	5-10	Construction in marina, no activity on lake
12/1/2009	11:00 AM	Onondaga Lake	Seneca River/Klein Island	N	GWTE	Mixed with MALL flock	1	Cloudy	35	5-10	None
12/1/2009	7:00 AM	Onondaga Lake	Marina	N	HOME	Mixed with COME flock	1	Snow	30-35	5-10	Construction in marina, no activity on lake
12/1/2009	9:00 AM	Onondaga Lake	Western shore/9-mile creek	N	HOME	Swimming	9	Cloudy	35	5-10	None
12/1/2009	9:00 AM	Onondaga Lake	Western shore/9-mile creek	N	MALL	Swimming	12	Cloudy	35	5-10	None
12/1/2009	11:00 AM	Onondaga Lake	Seneca River/Klein Island	N	MALL	Swimming	35	Cloudy	35	5-10	None
12/1/2009	10:00 AM	Onondaga Lake	South End	N	MALL	Swimming/flying	45	Cloudy	35	5-10	None
12/1/2009	7:00 AM	Onondaga Lake	Marina	N	MALL	Swimming in marina/shore	7	Snow	30-35	5-10	Construction in marina, no activity on lake
12/16/2009	1:30 PM	Onondaga Lake	Seneca River N to Phoenix	N	CAGO	Swimming/flying	100	Cloudy/snow	26	5-10	
12/16/2009	1:30 PM	Onondaga Lake	Seneca River N to Phoenix	N	COME	Flying	3	Cloudy/snow	26	5-10	
12/16/2009	1:30 PM	Onondaga Lake	Seneca River N to Phoenix	N	HOME	Swimming/flying	14	Cloudy/snow	26	5-10	
12/16/2009	1:30 PM	Onondaga Lake	Seneca River N to Phoenix	N	MALL	Swimming	90	Cloudy/snow	26	5-10	
12/17/2009	12:30 PM	Onondaga Lake	South End	N	ABDU	Feeding	17	Sunny	22	5	
12/17/2009	12:00 PM	Onondaga Lake	9-mile Creek N to Maple Bay	Y	AMWI	Mixed w/ MALL	1	Sunny	15	5	
12/17/2009	12:00 PM	Onondaga Lake	9-mile Creek N to Maple Bay	Y	BUFF	Feeding/swimming	12	Sunny	15	5	
12/17/2009	12:00 PM	Onondaga Lake	9-mile Creek N to Maple Bay	Y	CAGO	Feeding	35	Sunny	15	5	
12/17/2009	12:30 PM	Onondaga Lake	South End	N	COGO	Swimming	11	Sunny	22	5	
12/17/2009	12:00 PM	Onondaga Lake	9-mile Creek N to Maple Bay	Y	COGO	Swimming	20	Sunny	15	5	
12/17/2009	12:30 PM	Onondaga Lake	South End	N	COME	Swimming	70	Sunny	22	5	
12/17/2009	12:00 PM	Onondaga Lake	9-mile Creek N to Maple Bay	Y	GADW	Swimming	3	Sunny	15	5	
12/17/2009	12:00 PM	Onondaga Lake	9-mile Creek N to Maple Bay	Y	HOME	Swimming	9	Sunny	15	5	
12/17/2009	12:00 PM	Onondaga Lake	9-mile Creek N to Maple Bay	Y	MALL	Feeding	55	Sunny	15	5	
12/17/2009	12:30 PM	Onondaga Lake	South End	N	MALL	Feeding	55	Sunny	22	5	
12/17/2009	12:00 PM	Onondaga Lake	9-mile Creek N to Maple Bay	Y	REDH	Feeding	20	Sunny	15	5	
12/17/2009	12:00 PM	Onondaga Lake	9-mile Creek N to Maple Bay	Y	RNDU	Feeding	10	Sunny	15	5	
12/17/2009	12:00 PM	Onondaga Lake	9-mile Creek N to Maple Bay	Y	RUDU	Swimming	4	Sunny	15	5	
1/27/2010	9:00 AM	Onondaga Lake	9 Mile Creek	N	BUFF	Swimming	9	Cloudy	28	5	None
1/27/2010	9:00 AM	Onondaga Lake	9 Mile Creek	N	CAGO	Swimming	200	Cloudy	28	5	None
1/27/2010	9:00 AM	Onondaga Lake	9 Mile Creek	N	COGO	Swimming	150	Cloudy	28	5	None
1/27/2010	9:00 AM	Onondaga Lake	9 Mile Creek	N	COME	Swimming	40	Cloudy	28	5	None
1/27/2010	10:00 AM	Onondaga Lake	South End	N	COME	Swimming	100	Cloudy	28	5	None
1/27/2010	9:00 AM	Onondaga Lake	9 Mile Creek	N	MALL	Swimming	6	Cloudy	28	5	None
1/27/2010	10:00 AM	Onondaga Lake	South End	N	MALL	Swimming	25	Cloudy	28	5	None
1/27/2010	9:00 AM	Onondaga Lake	9 Mile Creek	N	REDH	Swimming	40	Cloudy	28	5	None
1/27/2010	10:00 AM	Onondaga Lake	South End	N	Scaup spp.	Swimming	3	Cloudy	28	5	None
1/28/2010	9:00 AM	Onondaga Lake	9 Mile Creek	N	BUFF	Swimming	9	Cloudy	30	5	None
1/28/2010	9:00 AM	Onondaga Lake	9 Mile Creek	N	CAGO	Swimming	15	Cloudy	30	5	None
1/28/2010	9:00 AM	Onondaga Lake	9 Mile Creek	N	COGO	Swimming	50	Cloudy	30	5	None
1/28/2010	11:00 AM	Onondaga Lake	Seneca River N to Phoenix	N	COGO	Swimming/Flying	10	Cloudy	30	5	None
1/28/2010	9:00 AM	Onondaga Lake	9 Mile Creek	N	COME	Swimming	150	Cloudy	30	5	None
1/28/2010	9:00 AM	Onondaga Lake	9 Mile Creek	N	COOT	Swimming	4	Cloudy	30	5	None
1/28/2010	9:00 AM	Onondaga Lake	9 Mile Creek	N	MALL	Swimming	6	Cloudy	30	5	None
1/28/2010	11:00 AM	Onondaga Lake	Seneca River N to Phoenix	N	MALL	Swimming/Flying	10	Cloudy	30	5	None
1/28/2010	9:00 AM	Onondaga Lake	9 Mile Creek	N	REDH	Swimming	1	Cloudy	30	5	None
1/28/2010	9:00 AM	Onondaga Lake	9 Mile Creek	N	RNDU	Swimming	4	Cloudy	30	5	None
2/1/2010	12:00 PM	Onondaga Lake	Seneca River/Gaskin Rd.	N	BUFF	Swimming	4	Sunny	25	10	None
2/1/2010	11:00 AM	Onondaga Lake	Seneca River N to Phoenix	N	COME	Feeding	50	Sunny	25	10	None
2/1/2010	12:00 PM	Onondaga Lake	Seneca River/Gaskin Rd.	N	COME	Swimming	30	Sunny	25	10	None

2/1/2010	12:00 PM	Onondaga Lake	Seneca River/Gaskin Rd.	N	HOME	Swimming	3	Sunny	25	10	None
2/1/2010	12:00 PM	Onondaga Lake	Seneca River/Gaskin Rd.	N	MALL	Swimming	20	Sunny	25	10	None
3/29/2010	9:00 AM	Onondaga Lake	9-mile Creek N to Maple Bay	N	BUFF	Swimming	100	Sunny	55	10	None
3/29/2010	9:00 AM	Onondaga Lake	9-mile Creek N to Maple Bay	N	LESC	Swimming	100	Sunny	55	10	None
4/3/2010	10:00 AM	Onondaga Lake	South End	N	BUFF	Swimming	20	Sunny	80	5	Fishermen on lake
4/3/2010	10:00 AM	Onondaga Lake	South End	N	COME	Swimming	25	Sunny	80	5	Fishermen on lake
4/3/2010	12:00 PM	Onondaga Lake	9-mile Creek N to Maple Bay	N	NSHO	Swimming	3	Sunny	80	5	Fishermen on lake
4/5/2010	11:00 AM	Onondaga Lake	South End	N	BUFF	Swimming	5	Cloudy/Rain	65	10	None
4/5/2010	11:00 AM	Onondaga Lake	South End	N	COME	Swimming	20	Cloudy/Rain	65	10	None
4/5/2010	11:00 AM	Onondaga Lake	9-mile Creek N to Maple Bay	N	WODU	Perched	2	Cloudy/Rain	65	10	None

Survey Photos

Photo 1. 17 December 2009 Maple Bay

Photo 2. 17 December 2009: Canada goose, mallards, redhead

Photo 3. 17 December 2009: Canada goose, mallards

Photo 4. 17 December 2009: Maple Bay

Photo 5. 17 December 2009: Maple Bay

Photo 6. 17 December 2009: Ninemile Creek/Maple Bay

Photo 7. 17 December 2009: Ninemile Creek/Maple Bay

Photo 8. 17 December 2009: Mallards, redhead

Photo 9. 17 December 2009: Mallards, redhead