PILOT ASSESSMENT OF MERCURY EXPOSURE TO BATS AT ONONDAGA LAKE, NEW YORK

2008 SEASON DRAFT REPORT

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Photo caption: *Maternity colony of little brown bats at the reference site, courtesy of Tim Divoll*

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PILOT ASSESSMENT OF MERCURY EXPOSURE TO BATS AT ONONDAGA LAKE, NEW YORK 2008 FIELD SEASON

(Report BRI 2009-10)

Submitted to:

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1.0 Executive Summary

The anthropogenic input of inorganic mercury (Hg) into the environment is of broad socioeconomic concern because of the potential long-term impacts on ecological and human health. In a pilot effort to assess Hg availability to wildlife at Onondaga Lake, New York, we used bats as indicators of Hg bioaccumulation. Bats were chosen for their ability to accumulate Hg body burdens by foraging on emergent and local insects.

As a first phase to the assessment of potential injuries to invertivore mammals at Onondaga Lake, we conducted an investigation to determine total Hg concentrations in bats and compare those concentrations with effects levels from the literature. In 2008, 136 bats of various species were captured at reference (Oneida Lake) and Onondaga Lake sites. Blood and fur Hg concentrations, used as indicators of Hg exposure for bats sampled in 2008, are compelling evidence that Hg loads at Onondaga Lake have the potential to adversely affect bats. A comparison of our Onondaga Lake sites with reference sites demonstrates a significant difference in Hg uptake by bats between the two areas. Bat mean fur Hg concentrations were more than three and a half times higher at the Onondaga Lake sites compared to the reference sites; mean blood Hg concentrations at Onondaga Lake sites were more than two and a half times higher than those at reference sites.

Lowest observed effect levels (LOELs) are still being developed for bats. When comparing literature-based mouse fur and mustelid fur effect levels to our bat fur Hg concentrations collected in 2008, we found bat fur Hg concentrations at Onondaga Lake to regularly exceed these effect levels. Burton et al. (1977) found dosed mice with fur Hg concentrations of 7.8 μg/g (fw) displayed behavioral deviations and had a decrease in ambulatory activity and mice with 10.8 μg/g (fw) of Hg in fur had decreased stress tolerance and decreased swimming ability. Above a furbearer LOEL[1] of 35.0 μg/g, (fw) in fur (Basu 2006, *BioDiversity Research Institute - unpublished, 2008,* Strom 2008*),* physiological and behavioral effects were observed, such as effects on cholinergenic neurotransmission in mink and decreased swimming ability in mice. More than 50% of the bats captured at Onondaga Lake had Hg concentrations in fur that exceeded the

[1] Lowest observed effect level

mouse fur LOAEL[2] (Lowest Observed Adverse Effects Level) of 7.8 and 10.8 μg/g (fw) in fur (Burton et al. 1977), and more than 8.5% of the bats sampled at Onondaga Lake had Hg concentrations in fur that exceeded the otter/mink fur LOEL[1].

To better understand how bats accumulate Hg at the study site, we also collected wing punches for stable isotope samples and determined that individual bat species are foraging at different trophic levels and potentially on different forage items. In comparing Onondaga Lake with reference sites, respective species are feeding at the same trophic levels, but on different prey items.

[2] Lowest observed adverse effect level

2.0 Introduction

The anthropogenic input of inorganic mercury (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. 2007). Much is known about Hg distribution and availability of MeHg in the Northeast United States (Evers and Clair 2005). This large body of knowledge provides a basis for efforts to disentangle the relationship between Hg loading and biotic uptake. In a pilot effort to assess Hg availability to wildlife at Onondaga Lake, New York, we used bats as indicators of Hg bioaccumulation. Bats were chosen for their ability to accumulate Hg body burdens by foraging on emergent and local insects.

Ecologically, Onondaga Lake has been classified as a lacustrine, eutrophic, dimictic lake. That means the lake: 1) contains an aquatic community (assemblage of interacting plant and animal populations) 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 and in the center of the Haudenosaunee Confederacy. For centuries, Onondaga Nation villages were located on the shores of the Lake and the Nation relied heavily on the Lake and its tributaries in the past 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 plentiful 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 receptacle 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 US 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. Addition of Onondaga Lake to the NPL established a framework through which contamination in the Lake would be evaluated and remediation undertaken to reduce environmental and human health risk.

This study focuses on bats as indicators of contamination at Onondaga Lake. More than half of the species of bats in the U.S. can be characterized as occasionally foraging over water and on emergent aquatic insects, thereby exposing the bats to water-borne contaminants. There have been few investigations of Hg exposure in bats (Reidinger 1972; Petit and Altenbach 1973; Powell 1983; O'Shea et al. 2001a; Yates et. al 2008). Interestingly, examination of guano in other studies has shown trace amounts of metals, but this approach requires finding roost sites using radio telemetry (Petit and Altenbach 1973). Powell (1983) showed that aquatic nymphs of flying insects from a Virginia river polluted by a Hg point source had elevated Hg compared to areas upstream of the source and insectivorous Eastern Pipistrelles (*Perimyotis subflavus)* showed elevated Hg levels in liver and muscle tissues. Massa and Grippo (2000) found Hg was elevated in muscle, kidney, liver, brain, and fur of bats collected along streams in areas of Arkansas that had fish consumption warnings for Hg when compared to reference streams.

There are four studies at mercury-contaminated sites throughout the world that are useful for comparative purposes. Miura et al. (1978) examined various species of

Chiroptera from areas in Japan sprayed with Hg fungicides. In 1965 and 1966, they measured total fur Hg in these bats and found 33.0 +/- 6.3 µg/g (fw) and 33.7 +/- 4.2 µg/g (fw), respectively. Fur Hg concentrations found in Chiroptera from Onondaga Lake (mean Hg 16.78 µg/g, fw, 2008 results) were half the values from Japan.

Massa and Grippo (2000) examined various Chiroptera species from rivers in Arkansas that were under fish consumption advisories for Hg and found fur Hg levels ranging from 1 to 30 µg/g, (fw). Bats at Onondaga Lake regularly exhibited similar fur Hg levels and several samples exceeded the upper limits of Hg found in Arkansas bats from the above study.

Hickey et al. (2001) examined fur in various Chiroptera species from eastern Ontario (near Sudbury) and adjacent Quebec, Canada. In 1997, they pooled samples from 5 sites and found Hg concentrations ranging from 2.0 to 7.6 µg/g in fur. In 1998, they sampled the same sites to examine differences between years and found fur Hg concentrations that approached or exceeded 10 µg/g.

Baron et al. (1999) completed a risk assessment for aerial insectivorous wildlife on the Clinch River, Tennessee (Oak Ridge Reservation). Using a model, they determined the dose levels for the NOAEL (no observed adverse effects level) and LOAEL (lowest observed adverse effects level) for little brown bats to be 0.114 and 0.56 µg/g/d, respectively. Bats experiencing exposure equal to or greater than the LOAEL were expected to display impaired growth, reproduction, and offspring viability based on data from a rat dosing study (Verschuuren 1976).

The fact that bats accumulate Hg from consumed insects implies that bats at Onondaga Lake are accumulating Hg from aquatic insects living in vicinity of the lake. Tissue analyses provide information on current dietary exposure and contaminant pathways, allowing for improved interpretations of contaminant sources and the extent to which Hg is impacting bats. Blood Hg levels represent recent dietary uptake (Evers et al. 2005, Hobson and Clark 1993, 1994, Bearhop et al. 2000). Analysis of blood samples provides Hg levels recently accumulated by bats at Onondaga Lake. Stable isotope analyses of wing punch samples reflect current diet and can be compared to food items to characterize bat dietary habits and energy/contaminant pathways. Fur samples are indicators of Hg body burdens, reflecting both dietary uptake and body accumulation

(Mierle et al. 2000, Yates et al. 2005). Since adults have been living for more than a year, they have accumulated an overall body burden of Hg, whereas juveniles have only accumulated Hg levels from their mother's milk and the site where they have foraged. Age class may be an important predictive variable; therefore, we separated adults from juveniles to strengthen predictive abilities. Sampling both blood and fur allows for development of correlation between recent uptake of Hg and body burden.

Table 1. Bat species present in New York. Foraging preferences are from O'Shea et al. (2001b).

Scientific Name	Common Name	Species Status*	Foraging Strategy
Myotis lucifugus	Little brown myotis		Regularly forages over water
Eptesicus fuscus	Big brown bat		Occasionally forages over water
Lasionycteris noctivagans	Silver-haired bat		Occasionally forages over water
Lasiurus borealis	Eastern red bat		Occasionally forages over water
Lasiurus cinereus	Hoary bat		Occasionally forages over water
Myotis leibii	Eastern small-footed myotis	SSC	Occasionally forages over water
Myotis septentrionalis	Northern long-eared myotis		Occasionally forages over water
Myotis sodalis	Indiana myotis	FE, SE	Occasionally forages over water
Perimyotis subflavus	Eastern pipistrelle		Occasionally forages over water

*FE= Federally Endangered Species; SE= State Endangered Species; SSC= State Special Concern

Objectives: The objective of this study is to provide data useful in determining availability of mercury to bats at Onondaga Lake, comparable to other populations of the same species.

- Use Sonobat® technology for on-site determination of potential bat species on Onondaga Lake and adjacent waterbodies. Emphasis is to locate federally listed Indiana Bats (new Sonobat ® program makes this possible, released this fall);
- Capture bats for blood/fur sampling at four Onondaga Lake Sites and one reference site.
- Use stable isotope analysis of bat wing punches to determine dietary emphasis, trophic level, and percent of aquatic-based prey items in each species' diet.

3.0 Study Area

Onondaga Lake is located in Syracuse, New York (Onondaga County). Sampling was completed at four sites around the lake; three directly on the lake and one near the outflow of the lake. Oneida Lake, in Oswego and Oneida Counties, was used as the reference area as it offers similar foraging habitat to Onondaga Lake without a known point source of mercury. At Oneida Lake, two locations within Verona State Park were used for sampling. Little brown bats (*Myotis lucifigus)* were sampled from a small abandoned barn and a separate location within Verona State Park. Nine acre pond, an additional sampling location at the reference site, was used to increase species diversity (Figure 1), for comparison with samples from Onondaga Lake.

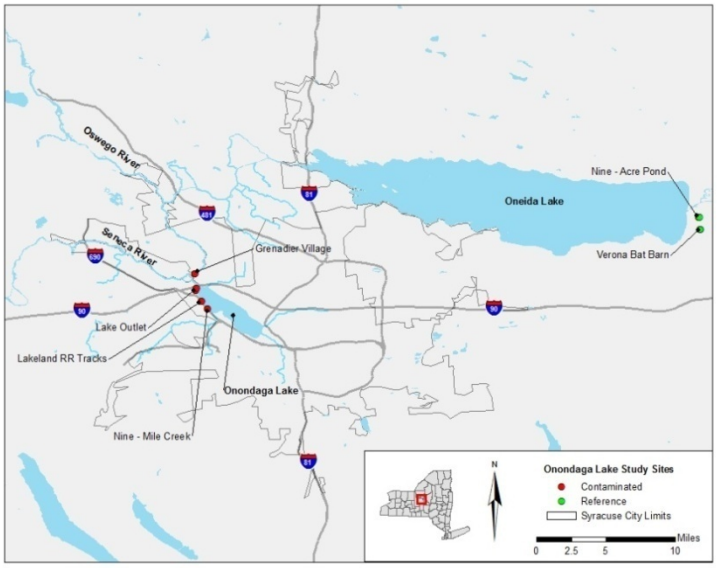

Figure 1. Bat sampling locations at Onondaga and Oneida Lakes, 2008.

3.0 Methods

3.1 Site Choice

Bat capture and sampling occurred at five different sites from 15-30 July, 2008. Seven to twelve mist nets were deployed at each site. All of these sites contained edge habitat near water, such as bike paths and gravel roads, presumably used by bats as foraging and travel corridors. Access to sites was limited so sites were chosen at logistically feasible sites that fit the criteria for setting nets, as explained in the next section.

3.2 Capture and Sample Collection

At least two triple high mist nets were used at all sites and single high mist nets were used to block any paths or corridors that may be used by bats in an attempt to bypass triple high net sets. Nets were strung between trees along small access roads or across streams that were used as corridors. From prior trapping experience, bat activity is highest on roads near water, so roads were chosen that led towards water and which were surrounded by mature trees that would provide good roosting habitat. Nets were set at dusk and monitored at least every thirty minutes until at least 0100 h; if bats were being captured, nets were left up until there was no activity for thirty minutes. An unoccupied barn with a few hundred bats was available at the reference site; bats were captured inside the barn with small hand nets. Nets were also set at a separate site within the reference area (nine acre pond) to enhance sample sizes.

Bats were held in cloth bags until processed and each bag was only used once before being washed. All bats captured were identified to species, checked for reproductive status, sexed, aged, and standard measurements were taken (forearm length, body condition and weight). Small blood samples were collected by puncturing the acute ulna or uropatagium vein with a clean 27.5 gauge needle. The blood was collected in heparinized capillary tubes, sealed with crito-caps and placed in vacutainer tubes and set on ice.

Fur samples were also collected with stainless steel scissors that were cleaned with alcohol swabs between each use and visually inspected to make sure there was no

cross contamination. The fur was put in small (2x2 in) zip lock bags. Small skin samples were obtained using a 3mm wing membrane punch for stable isotope analysis. All bats were released unharmed at the site. All nets were disinfected between trapping sites and equipment used was disinfected between bats according to the USFWS Bat Disinfection Protocol (USFWS 2008).

3.3 Indiana Bat Telemetry

Indiana bats (*Myotis sodalis)* are federally endangered and were the focus of our telemetry efforts. Once a captured bat was identified as an Indiana bat, a radio transmitter with a unique frequency was glued to its back (Figure 2) using Skin-Bond® surgical cement. Bats were tracked back to their maternity roosts by car or foot during the day when they were stationary. All bats were released unharmed at the site. Transmitters likely fall off after a maximum of 16 or 17 days (Albus A. L. & Carter T. C., 2008).

Figure 2. Indiana bat with radio transmitter glued to its back.

3.4 Sample Handling

All blood and fur samples were placed in appropriate containers, labeled with individual ID numbers, species, site, age, sex, location, and date. Bats were aged by bone examination (ossification of joints) and measurements of the forearm. For each sampling night, a small cooler with blue ice packs was used to hold all samples until there was a freezer available. At the end of each night, sample labels were checked with the data sheets and samples were transferred to a freezer.

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. All sampling efforts were in accordance with the Quality Assurance Project Plan (QAPP).

3.5 Sample Analysis

3.5a Mercury Analysis

Total mercury concentrations were analyzed in sampled tissues (blood and fur). Tissue analyses provide information on current and historic dietary exposure. Laboratory analysis was conducted by University of Connecticut, Center for Environmental Sciences and Engineering (CESE), Storrs, CT. All tissue samples were analyzed for total mercury using thermal decomposition technique with a direct Hg analyzer (DMA 80, Milestone Incorporated) using the US EPA Method 7473 (USEPA 2007). Blood mercury concentrations are presented as wet weight (ww) values. Fur values are presented as fresh weight (fw). We focused on total Hg for this study, as analyses are less costly than for MeHg, and 78.6% (+/-25.9%) of the total Hg value is typically comprised of methylmercury in otters (Evans et al. 2000). Detection limits (DLs) for all samples were 0.0025 μg/g, fw.

3.5b Stable Isotope Analysis

Wing punches were shipped to the Boston University Stable Isotope Laboratory for analysis. Samples were analyzed using automated continuous-flow isotope ratio mass spectrometry (Michener & Lajtha, 2007). All specimens were subsampled and oven dried at 60˚C for 24 hours. They were then powdered using a mortar and pestle. The samples were combusted in a EuroVector Euro EA elemental analyzer. The combustion gases (N_2 and CO_2) were separated in a GC column, passed through a reference gas box and introduced into the GV Instruments IsoPrime isotope ratio mass spectrometer; water was removed using a magnesium perchlorate water trap. Ratios of $^{13}C/^{12}C$ and $^{15}N/^{14}N$ were expressed as the relative permil (‰) difference between the samples and international standards (Vienna Pee Dee Belemnite carbonate and N_2 in air) where:

$$\delta X = (R_{sample} / R_{standard} - 1) \times 1000 \text{ (‰)}$$

Where X = ^{13}C or ^{15}N and R= ^{13}C or $^{15}N/^{14}N$

(Michener & Lajtha 2007)

The sample isotope ratio is compared to a secondary gas standard, whose isotope ratio was calibrated to international standards. For $^{13}C_{V\text{-}PDB}$ the gas was calibrated against NBS 20 (Solenhofen Limestone). For $^{15}N_{air}$ the gas was calibrated against atmospheric N_2 and IAEA (International Atomic Energy Agency) standards N-1, N-2, and N-3 (all are ammonium sulfate standards). All international standards were obtained from the National Bureau of Standards in Gaithersburg, MD. In addition to carbon and nitrogen isotopes from the same sample, continuous flow mass spectrometry also reported % C and % N data.

3.6 Statistical Analysis

All Kruskal-Wallis, Tukey HSD, Student's t-tests, and summary statistics were performed using a JMP 5.0 statistical program along with Microsoft Excel. Results of statistical tests were considered significant if the probability of a greater P-value was <0.05. Summary statistics were back-transformed for graphs and tables.

3.7 Lowest Observed Adverse Effects Level

Bat fur levels at Onondaga Lake and reference sites were compared to the mouse LOAELs[3] of 7.8 and 10.8 µg/g (fw, Total Hg) Hg in fur (Burton et al. 1977) and the otter/mink LOEL[4] of 35.0 µg/g, (fw) Hg in fur (BRI unpublished, Basu et al. 2006).

4.0 Results

4.1 Mercury Exposure by Site

Four capture locations were used at Onondaga Lake (Figure 3), three on the western shore of the lake and one slightly downstream on the Seneca River. Two sites were used at Oneida Lake (Figure 1) to obtain the bats for sampling; the two sites from Oneida Lake are combined for all statistical analyses and graphing.

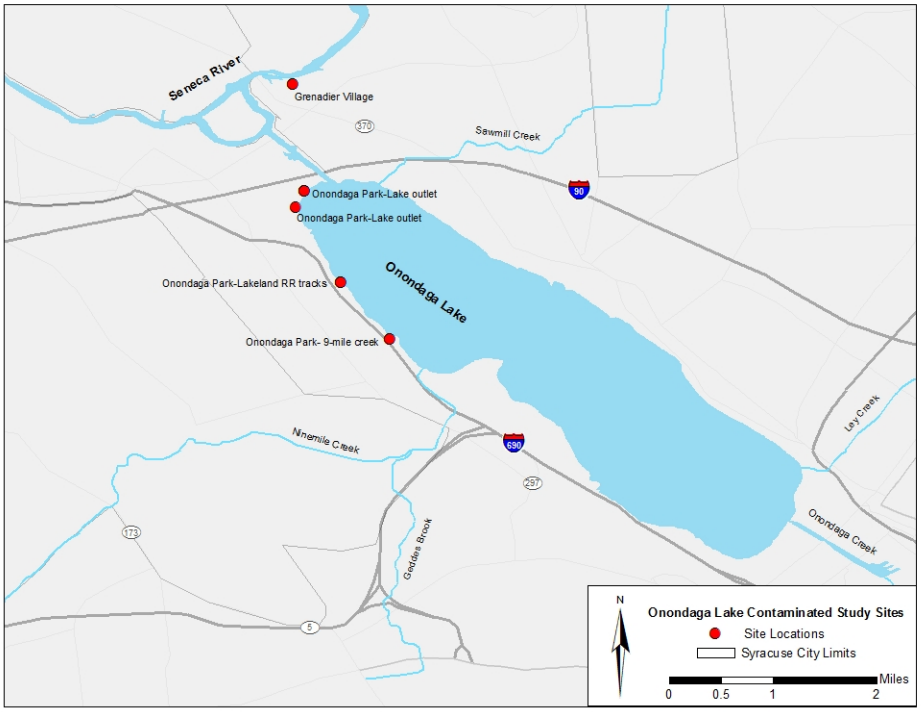

Figure 3. Capture sites at Onondaga Lake.

[3]Lowest observed adverse effect levels
[4] Lowest observed effect levels

We used a Tukey-Kramer HSD test on the data to compare blood Hg means among sites. We found that mean blood Hg concentrations at the reference site, Oneida Lake, differed significantly from mean blood concentrations at 9-mile creek and Outlet, both sites on Onondaga Lake. None of the sites at Onondaga Lake differed significantly from each other. We used a Kruskal-Wallis rank sums test to rank median Hg levels per site, which suggests correlative mercury bioavailability at each site, based on overall bat blood Hg levels. Results are ranked from left to right (Figure 4).

We used a Tukey-Kramer HSD on the data to compare fur Hg means among sites. We found that Verona SP (Oneida Lake) differed significantly from Lakeland RR, 9-mile creek, and Outlet, but not from Grenadier Village. None of the sites at Onondaga Lake differed significantly from each other. We used a Kruskal-Wallis rank sums test to rank median Hg levels per site, which suggests correlative mercury bioavailability at each site, based on overall bat fur Hg levels. Results are ranked from left to right (Figure 5).

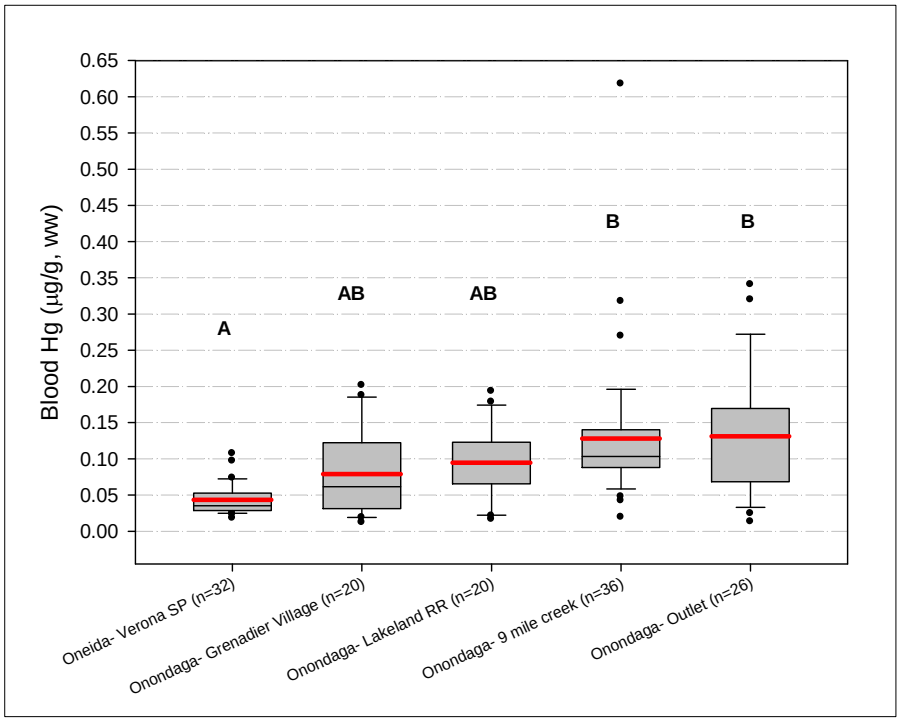

Figure 4. Blood Hg distribution by site, ranked by a Kruskal-Wallis test. Similar letter combinations represent significantly similar results.

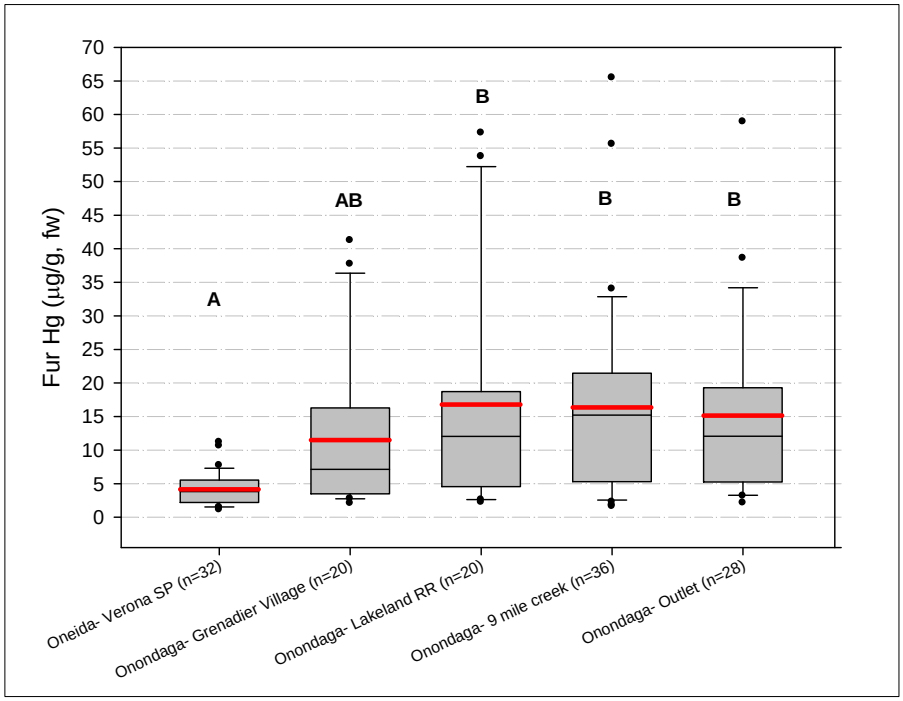

Figure 5. Fur Hg distribution by site, ranked by a Kruskal-Wallis test. Similar letter combinations represent significantly similar results.

4.2 Summary by Species

In 2008, 136 bats of six species, including the endangered Indiana bat, were caught at Onondaga Lake and the reference areas (Table 2). At Onondaga Lake, 104 bats were captured and sampled from four locations, Outlet, Lakeland RR, 9-mile creek, and Grenadier village (Table 3). At Oneida Lake, 32 bats were captured and sampled (Table 3). Twenty seven of the Oneida Lake bats were caught by hand in an abandoned barn at Verona State Park and five were caught in mist nets at nine acre pond (Figure 6).

Figure 6. Barn used by ~300-400 *Myotis lucifigus* as a maternity roost site.

Table 2. Summary of bat fur (µg/g, fw +/- standard deviation) and blood (µg/g, ww +/- standard deviation) Hg levels by species and area.

Species[1]	Site	n	Fur mean	Fur range	Blood mean	Blood range
EPFU	Onondaga	18	17.41 +/- 16.57	3.116 -- 55.551	0.13 +/- 0.078	0.0316 -- 0.3172
EPFU	Oneida	1	11.16	11.164	0.096	0.0968
LABO	Onondaga	1	2.12	2.12	0.0131	0.0131
MYLU	Onondaga	58[2]	13.72 +/- 11.26	1.617 -- 65.442	0.109 +/- 0.0796	0.0193 -- 0.6178
MYLU	Oneida	29	3.73 +/- 1.71	1.096 -- 7.6929	0.0386 +/- 0.0133	0.0181 -- 0.0734
MYSE	Onondaga	10	26.32 +/- 20.82	3.297 -- 58.893	0.174 +/- 0.101	0.0245 -- 0.3406
MYSE	Oneida	2	6.80 +/- 5.38	2.99 -- 10.6014	0.0884 +/- 0.0267	0.0695 -- 0.1073
MYSO	Onondaga	16[3]	12.36 +/- 11.06	2.066 -- 38.735	0.0764 +/- 0.0574	0.0121 -- 0.1733
MYSU	Onondaga	1	7.04	7.037	0.0624	0.0624

[1] EPFU=big brown; LABO=red; MYLU=little brown; MYSE=northern long-eared; MYSO=Indiana; MYSU=eastern pipistrelle

[2] Fifty seven blood samples taken. ; [3] Fifteen blood samples taken.

4.3 Summary by Location

Table 3. Summary of bat fur (μg/g, fw +/- standard deviation) and blood (μg/g, ww +/- standard deviation) Hg levels by species and location.

Location	Species[1]	n	Fur mean	Fur range	Blood mean	Blood range
Oneida- Verona SP	EPFU	1	11.16	11.1600	0.0968	0.0968
Oneida- Verona SP	MYLU	29	3.73 +/- 1.7	1.09 -- 7.69	0.0386 +/- 0.0133	0.018 -- 0.0734
Oneida- Verona SP	MYSE	2	6.79 +/- 5.38	2.99 --10.6	0.0884 +/- 0.0267	0.0695 -- 0.1073
Onondaga- 9 mile creek	MYSE	1	9.09	9.09	0.0995	0.0995
Onondaga- 9 mile creek	MYSO	1	24.72	24.72	0.1162	0.1162
Onondaga- 9 mile creek	MYLU	25	15.31 +/- 13.11	1.61 -- 65.44	0.1257 +/- 0.1083	0.0193 -- 0.6178
Onondaga- 9 mile creek	EPFU	9	19.21 +/- 18.68	3.11 -- 55.55	0.1391 +/- 0.0918	0.042 -- 0.3172
Onondaga- Grenadier	MYSU	1	7.04	7.04	0.0624	0.0624
Onondaga- Grenadier	MYSE	1	24.42	24.42	0.1282	0.1282
Onondaga- Grenadier	MYSO	5	3.59 +/- 1.5	2.06 -- 5.64	0.0220 +/- 0.0072	0.0121 -- 0.0303
Onondaga- Grenadier	EPFU	3	33.56 +/- 10.34	21.79 -- 41.19	0.1644 +/- 0.0523	0.1046 -- 0.2013
Onondaga- Grenadier	MYLU	10	8.02 +/- 4.64	3.22 -- 17.61	0.0787 +/- 0.0443	0.0348 -- 0.1655
Onondaga- Lakeland RR	MYSE	1	57.25	57.25	0.1783	0.1783
Onondaga- Lakeland RR	EPFU	2	10.74 +/- 9.28	4.18 --17.31	0.0504 +/- 0.0265	0.0316 -- 0.0692
Onondaga- Lakeland RR	MYLU	12	13.30 +/- 13.9	2.21 --53.74	0.0994 +/- 0.0424	0.0211 -- 0.1931
Onondaga- Lakeland RR	MYSO	5	19.47 +/- 15.64	3.29 -- 38.73	0.0842 +/- 0.0451	0.0164 -- 0.1316
Onondaga- Outlet	LABO	1	2.12	2.12	0.0131	0.0131
Onondaga- Outlet	MYSO	5	11.53 +/- 3.61	8.67 -- 17.56	0.1247 +/- 0.0627	0.0366 -- 0.1733
Onondaga- Outlet	MYLU	11	15.76 +/- 5.84	3.97 -- 22.94	0.1095 +/- 0.0449	0.054 -- 0.1779
Onondaga- Outlet	MYSE	7	24.63 +/- 20.91	3.29 -- 58.89	0.1913 +/- 0.1179	0.0245 -- 0.3406
Onondaga- Outlet	EPFU	4	4.57 +/- 2.05	3.15 -- 7.62	0.1167 +/- 0.0645	0.0569 -- 0.1943

[1]EPFU=big brown; LABO=red; MYLU=little brown; MYSE=northern long-eared; MYSO=Indiana; MYSU=eastern pipistrelle

4.4 Onondaga vs. Reference

Mean fur and blood Hg values at Onondaga Lake sites were significantly higher than at reference areas (Table 4).

Table 4. Mean fur (μg/g, fw +/- standard deviation) and blood (μg/g, ww +/- standard deviation) Hg levels at Onondaga and reference sites, 2008.

	Fur Hg	Blood Hg
Onondaga	15.18 +/-13.73	0.112 +/- 0.0816
Reference	4.15 +/- 2.40	0.0435 +/- 0.0206

We pooled sites and species for blood and fur Hg concentrations and subsequently used a Student's t-test to assess the difference in bat blood Hg between the Onondaga and reference sites. We found that the blood in bats captured at Onondaga Lake, representing recent dietary uptake, was significantly higher than blood in bats captured at Oneida Lake (Figure 7). Mean blood mercury (+/- S.D.) levels in bats at the Onondaga Lake sites

(0.1127µg/g, ww +/- 0.0816) were more than two and a half times higher than at reference sites (0.0435 +/- 0.0206).

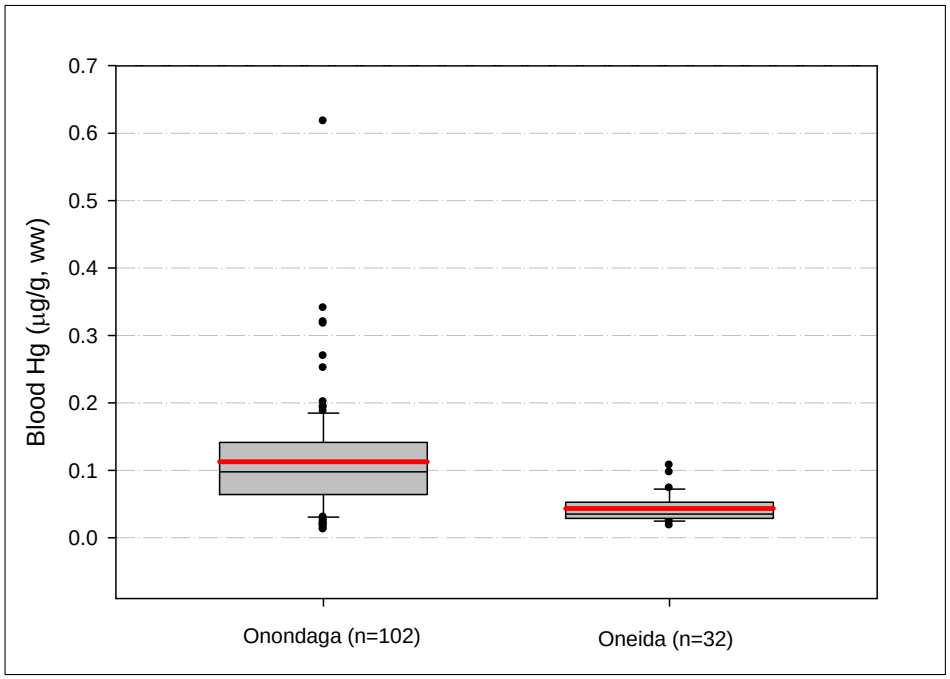

Figure 7. Overall mean blood bat Hg for combined species by area. Box represents 25th and 75th percentiles with median (black) and mean (red) shown. Whiskers represent 10th and 90th percentiles.

We used a Student's t-test to assess the difference in bat fur Hg between the Onondaga and reference sites. We found that Hg in fur from bats captured at Onondaga Lake, representing total body burden from Hg, was significantly higher than Hg in fur from bats captured at Oneida Lake (Figure 8). Mean fur mercury (+/- S.D.) levels at contaminated sites (15.188 µg/g, fw+/- 13.739) were more than three and a half times higher than at reference areas (4.157 +/- 2.401).

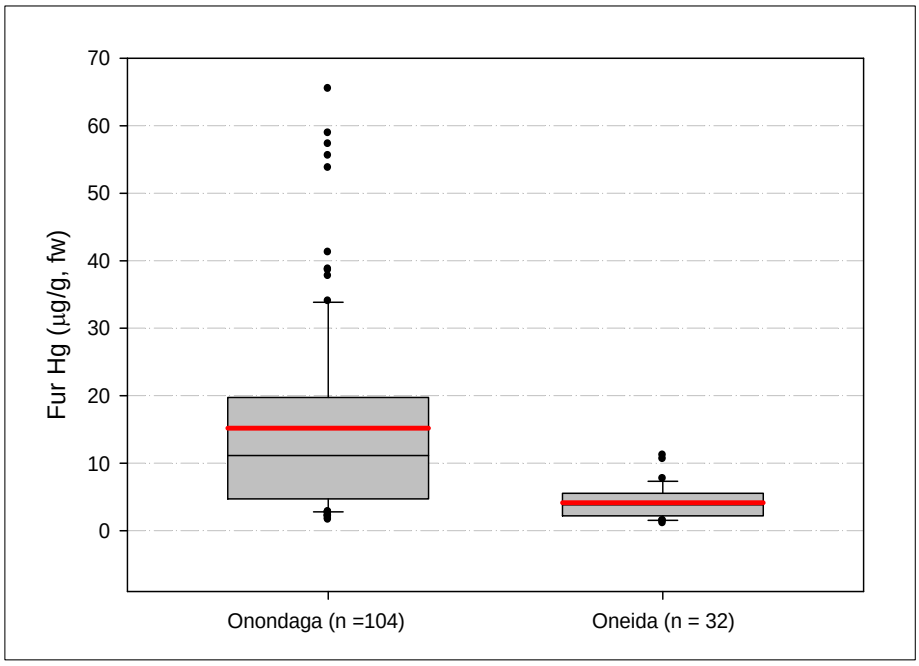

Figure 8. Overall mean fur Hg for combined species by area. Box represents 25th and 75th percentiles with median (black) and mean (red) shown. Error bars represent 10th and 90th percentiles.

4.5 Blood/Fur Correlation

We found a positive significant relationship (p<0.0001, r^2=0.5025 Adult*;* p<0.0001, r^2=0.4749 Juvenile) between adult and juvenile blood and fur Hg concentrations using a multivariate pairwise correlation to test the strength of association between blood and fur Hg values (Figure 9). A predictive relationship for Hg concentration in blood based on fur concentrations may facilitate future sample collection given that samples of blood are more difficult to obtain and fur can be stored more easily long-term.

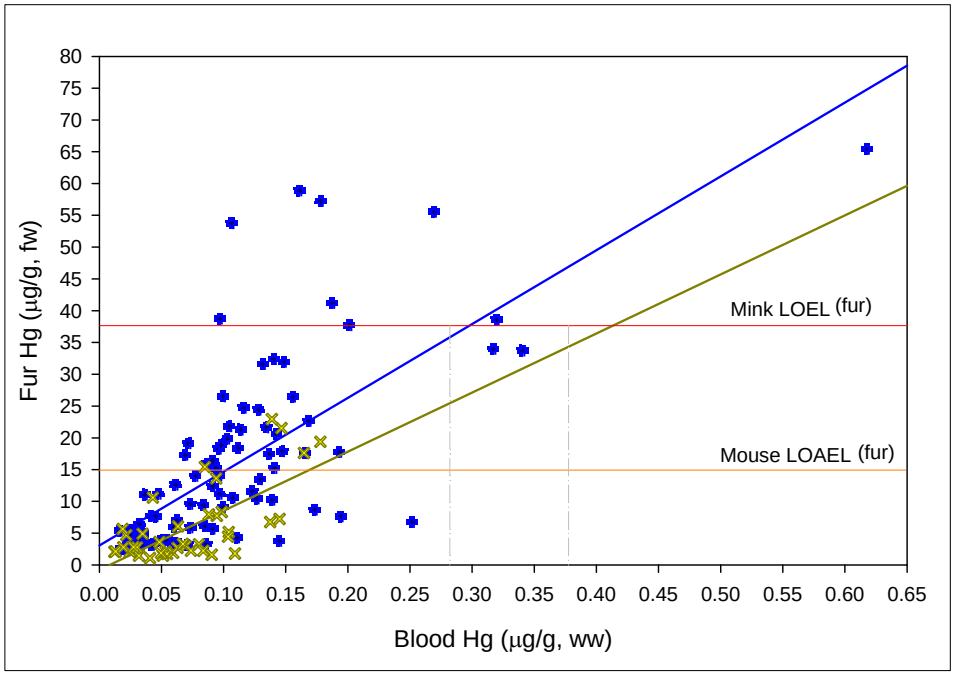

Figure 9. Fur/Blood Hg correlation by age class for all bats captured; Adults=blue dot, n=96, Juveniles=gold cross, n=40 (n=136).

4.6 Mercury Exposure by Species

Six species of bats were caught during the pilot study. All of these species presumably breed around Onondaga Lake with the possible exception of the red bat (n=1) and the eastern pipistrelle (n=1). We were not able to determine if these individuals were breeding at Onondaga. The female red bat captured could have migrated from somewhere else and the eastern pipistrelle was an adult male, whose reproductive status is only apparent in autumn.

Blood samples were taken from 134 bats during the 2008 field season effort. We were not able to obtain blood from the other two bats captured during the study. We used a Tukey-Kramer HSD test to assess mercury bioaccumulation differences between species and found that Indiana bats and little brown bats differed significantly from all other species but not from each other. We used a Kruskal-Wallis test to determine which species are ranked higher by median blood Hg, suggesting that certain species are subject to higher Hg exposure than others, shown left to right (Figure 10).

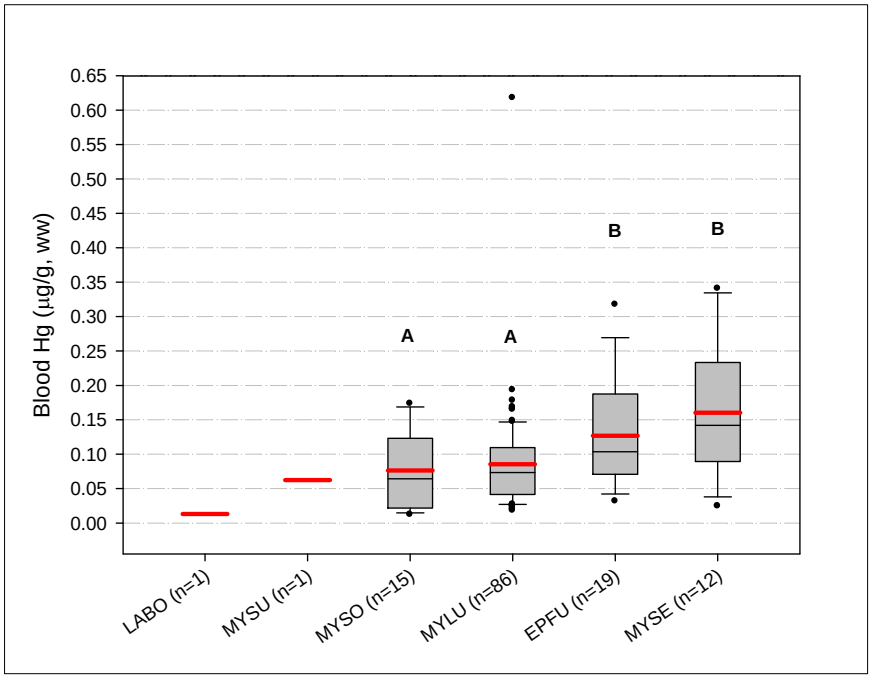

Figure 10. Blood Hg distribution by species (all bats sampled for blood). LABO=Red bat, MYSU= Eastern pipistrelle, MYSO= Indiana bat, MYLU= Little brown, EPFU= Big brown, MYSE= Northern long-eared. LABO and MYSU were not included in statistical analyses due to low sample sizes. Species are in order based on the results of a Kruskal-Wallis test. Similar letter combinations represent significantly similar results. Box represents 25th and 75th percentiles and whisker represent 10th and 90th percentiles.

Fur samples were taken from 136 bats during the 2008 field season effort. We used a Tukey-Kramer HSD test to assess differences in mercury bioaccumulation between species and found that little brown bats differed significantly from all other species. It should be noted that differences in sample size of each species could affect statistical analyses. We used a Kruskal-Wallis test to determine which species are ranked higher by fur Hg median, suggesting that certain species are subject to higher exposure than others, shown left to right (Figure 11).

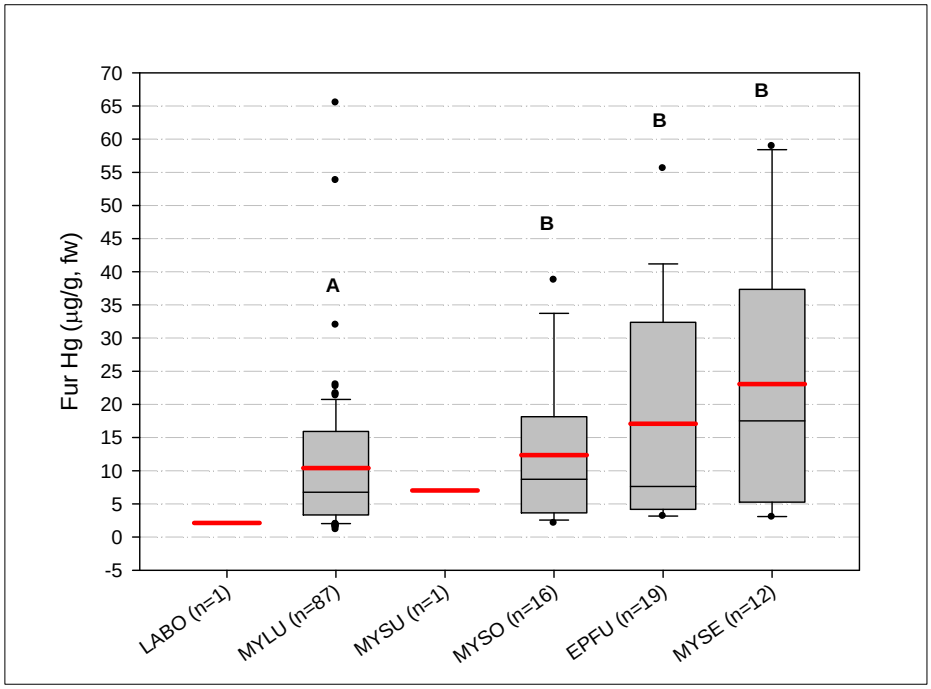

Figure 11. Fur Hg distribution by species (all bats sampled). LABO=Red bat, MYSU= Eastern pipistrelle, MYSO= Indiana bat, MYLU= Little brown, EPFU= Big brown, MYSE= Northern long-eared. LABO and MYSU were not included in statistical analyses due to low sample sizes. Species are in order based on the results of a Kruskal-Wallis test. Similar letter combinations represent significantly similar results.

4.7 Indiana Bat Roosts

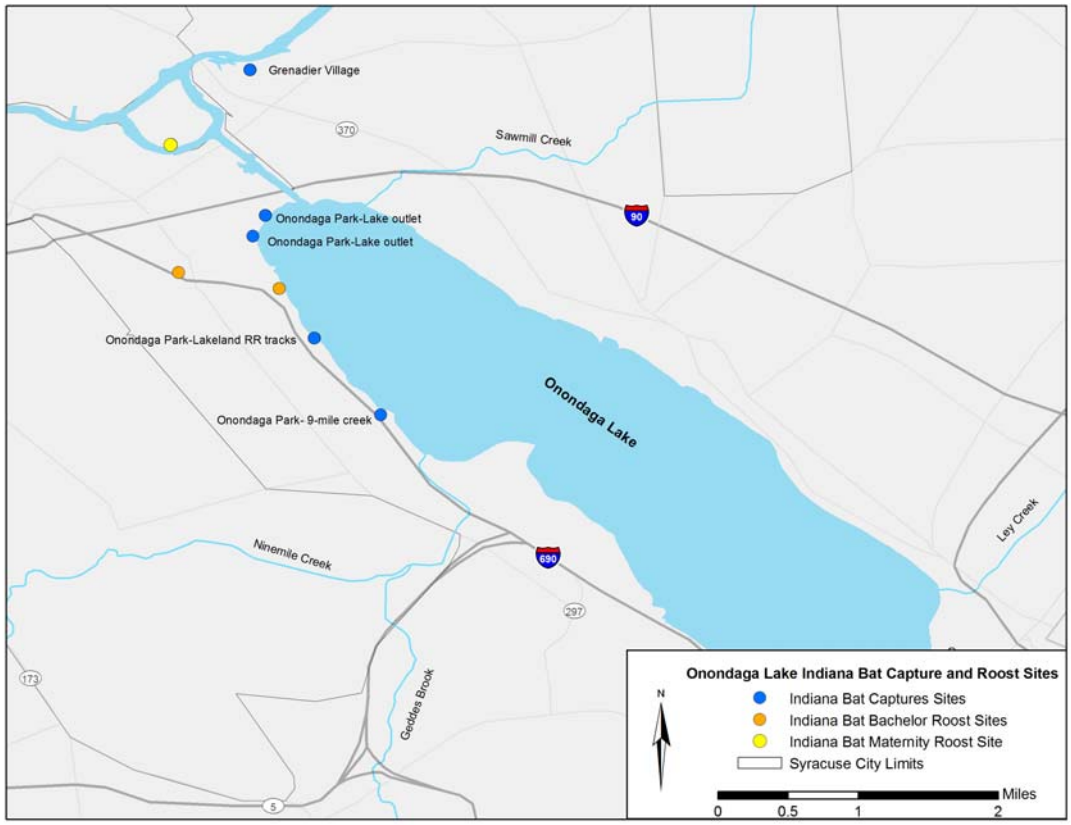

Figure 12. Indiana bat capture locations and roost sites found.

We radio tracked Indiana bat individuals that we caught foraging at Onondaga Lake back to their day roosts. We put transmitters on six individuals and tracked four bats back to day roosts. Three of those were adult males in two separate roost locations, one in a mature shagbark hickory tree and two in dead snags in a swamp. The last individual was a lactating adult female that we tracked to a dead tree ~15 ft. high with exfoliating bark on the southern end of Klein Island. Upon finding this maternity roost, we estimated >50 bats using this single tree. This estimation was based on sounds of bats crawling under the bark and the amount of chatter in the roost and was not as reliable as an exit count would have been. Males travelled no more than a mile from capture locations whereas females travelled ~2.5 miles from capture locations (Figure 12).

4.8 Stable Isotopes

When comparing stable isotopes between species, $\delta^{15}N$ gives an idea of the predator's foraging status in its respective food web. The higher the value, the higher on the food chain the species is feeding. $\delta^{13}C$ is more representative of specifically what type of invertebrate the species is consuming. Little brown bats appear to be feeding at the highest relative trophic level whereas big brown bats seem to be feeding at the lowest relative trophic level. All bats from all sites were combined to develop a general isotopic species profile (Figure 13).

4.8.1 Isotopes by Species

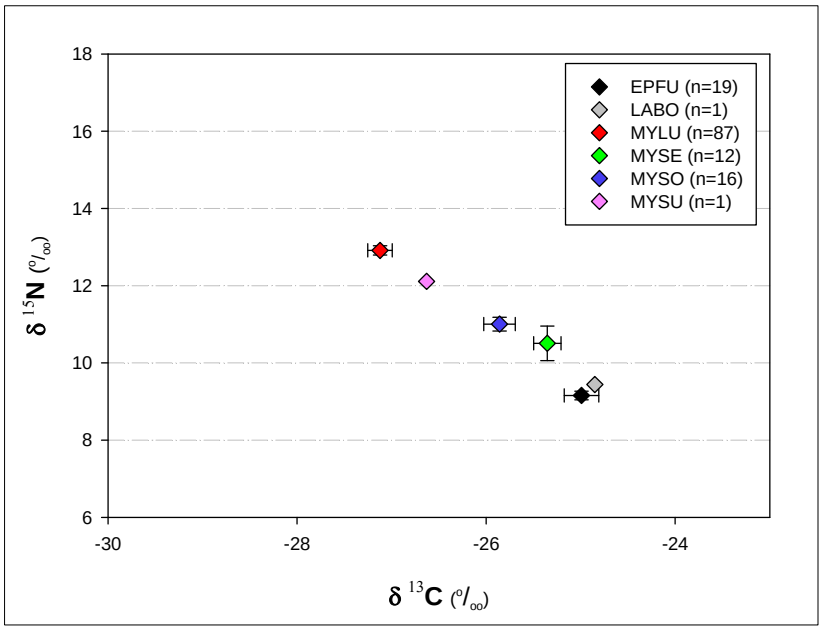

Figure 13. Trophic level vs. forage for all bats captured (Onondaga + reference). Error bars represent standard error of the mean.

4.8.2 Isotopes – Onondaga vs Reference

Species that were commonly caught at the Onondaga and reference areas were plotted to compare the stable isotope signatures at the different sites. For each species there is a difference in prey type consumption between sites, shown by the $\delta^{13}C$ value, but no difference in food web placement (ie.trophic level), displayed by $\delta^{15}N$ (Figure 14).

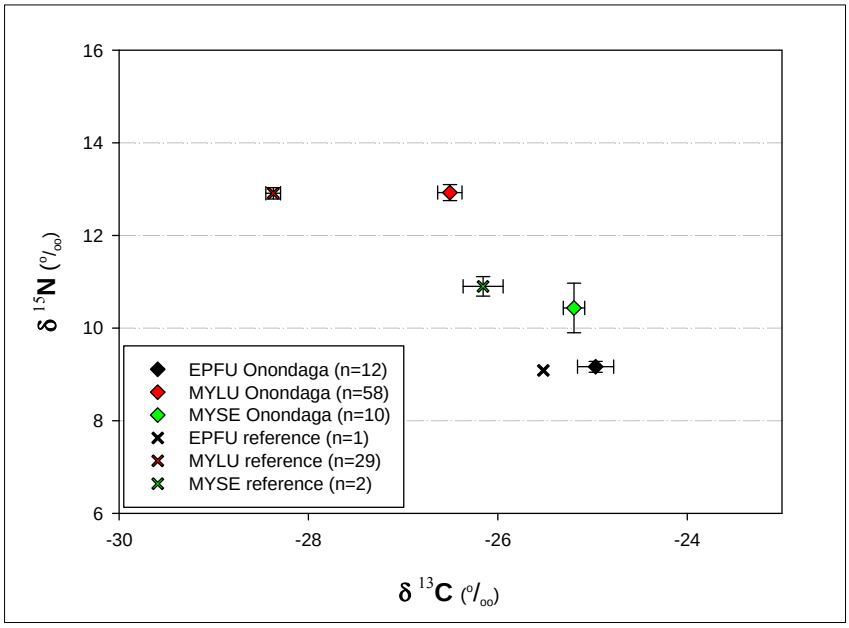

Figure 14. Carbon and Nitrogen values for common species captured at the Onondaga and reference areas. Error bars represent standard error of the mean.

4.8.3 Isotopes – MYLU $\delta^{13}C$ and $\delta^{15}N$

Since little brown bats were the most common species caught (64% of all bats captured), we plotted blood mercury levels against $\delta^{13}C$ and $\delta^{15}N$ to assess differences in age or location (Onondaga vs. reference). It appears that adults and juveniles feed on similar prey items, depending on location. The carbon signatures for adults and juveniles were consistent at Onondaga Lake and reference areas, respectively (Figure 15).

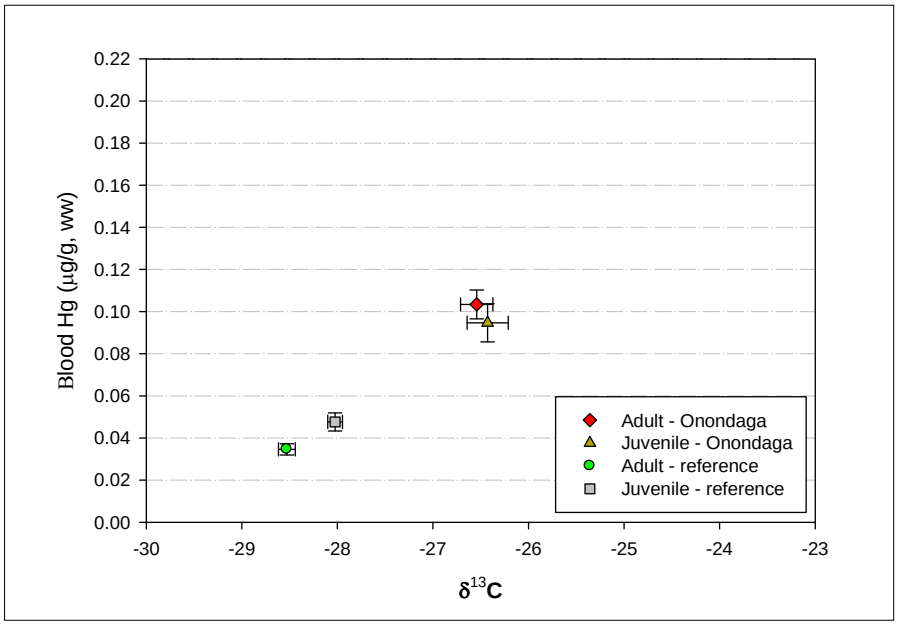

Figure 15. Recent dietary uptake of Hg in relation to $\delta^{13}C$ for little brown bats by age and site. Error bars represent standard error of the mean.

Blood mercury levels show that adult and juvenile little browns, respectively, have similar values independent of location (Figure 16). Juveniles consistently have higher nitrogen signatures than adults, also independent of location.

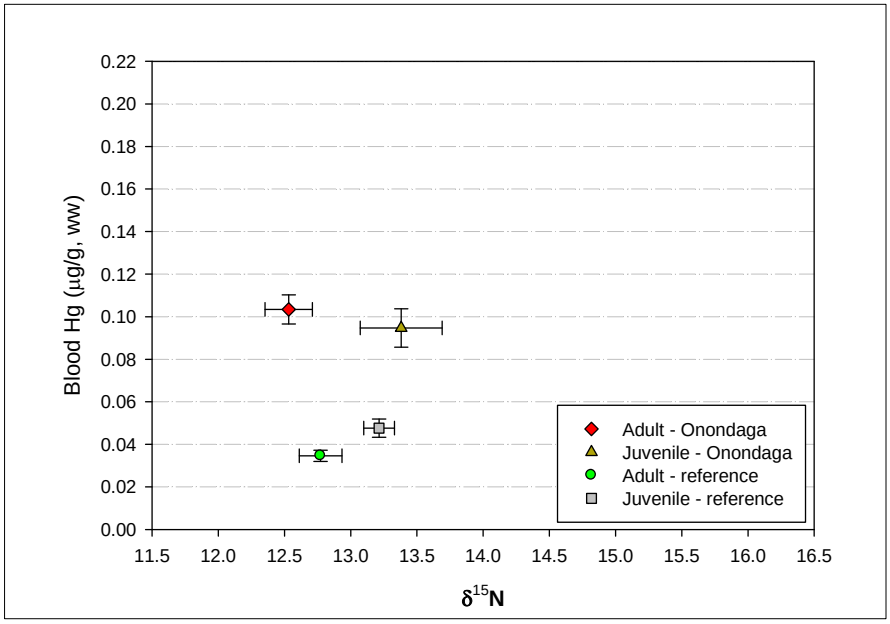

Figure 16. Recent dietary uptake Hg in relation to $\delta^{15}N$ for little brown bats by age and site. Error bars show standard error of the mean.

5.0 Discussion

5.1 Mercury exposure to bats at Onondaga Lake

5.1.1 Comparisons with other bat Hg levels

When compared to bats at a Hg contaminated site in Japan (Miura et al. 1978), fur Hg concentrations found in Chiroptera from Onondaga Lake (mean Hg 16.78 µg/g, fw, 2008 results) were half the values from Japan.

Bats at Onondaga Lake regularly exhibited similar fur Hg levels and several exceeded the upper limits of levels found in bats from a Hg enriched area of Arkansas (Massa and Grippo 2000).

Nearly 54% of the bats captured at Onondaga Lake exceeded 10 µg/g Hg in fur, a conservative threshold proposed by Hickey et al. (2001) for their study conducted at a contaminated site in Ontario, Canada.

5.1.2 Comparison with other mammal Hg levels

Generally, there are few investigations that have evaluated the effects of Hg on mammals in the wild. Most studies are lab-controlled dosing studies and a few are inferences from *in situ* evaluations. A lab-controlled study with domestic mice found that individuals with total fur Hg concentrations of 7.8 µg/g (fw) showed behavioral deviations and decreases in ambulatory activity, while those with 10.8 µg/g (fw) showed decreases in stress tolerance and swimming ability (Burton et al. 1977). The brain is a particularly relevant tissue for evaluating toxic effects from MeHg because it is the site where mercury is known to negatively alter neurochemical receptor-binding characteristics (Basu et al. 2005, 2007a,b). The lowest observed effect level (LOEL), based on negative alterations to the brain's cholinergic system from a mink dosing study, is 1.03 µg/g (ww; or 4.10 µg/g, dw) in the brain (Basu et al. 2006). Strom (2008) demonstrated a significant relationship between Hg in fur and liver (r^2=0.45), kidney (r^2=0.47), muscle (r^2=0.55), and most importantly the target organ of MeHg toxicity, brain (r^2=0.51). Based on regression models between Hg in fur and brain from Strom (2008) for river otter (*Lontra canadensis*) and from a similar and even more robust dataset from BioDiversity Research Institute for river otter and mink (*Mustela vison*), we

found brain Hg concentrations of 1.03 µg/g (ww) were equivalent to a fur Hg concentration of 35.0 µg/g (fw) in mink and 45.0 µg/g (fw) in river otter. Bat brain Hg thresholds are still being developed; thus we use other mammals for comparison.

More than fifty percent of the bats captured at Onondaga Lake (n=104) exceeded the mouse fur LOAEL of 10.8 µg/g, (fw) whereas less than one percent of the bats captured at Oneida Lake (n=32) exceeded this same LOAEL. Over eight and a half percent of the bats at Onondaga Lake exceeded the mink fur LOEL of 35 µg/g, (fw) whereas zero percent of bats at Oneida Lake exceeded this LOEL. Using the higher mink LOEL (Figure 6) and taking into consideration the observed relationship between blood and fur mercury concentration, adult bats with blood mercury levels of 0.2749 µg/g (Fig. 6), (ww) or higher would be expected to exceed effects levels. Juveniles with blood mercury levels of 0.3848 µg/g (Fig. 6), (ww) or higher would be expected to exceed effects levels when compared to this mink LOEL. The differences in blood Hg effect levels from juvenile and adult bats are from the differences in fur Hg accumulation rates between adult and juvenile bats. Adults have Hg that has accumulated over their lives, some species more than 30 years, and juvenile bats have not accumulated as much over their short life span.

5.1.3 Projected level of potential impacts to bats from ingestion of Hg at Onondaga Lake, NY

When applying the above described mouse and otter/mink effect levels to our bat fur Hg dataset from 2008, we found bat fur Hg concentrations at Onondaga Lake to regularly exceed these effect levels. Over 50% of the bats sampled for this study had fur Hg concentrations that exceeded the mouse fur LOAEL of 10.8 µg/g (fw). Over 8.5% of the bats sampled for this study had fur Hg concentrations that exceeded the otter/mink fur LOEL of 35.0 µg/g, (fw). Since the projected dietary LOAEL for bats (Baron et. al 1999) is in units of µg Hg/gm food/d, we cannot compare blood and fur Hg levels from our study since we do not know how much food is ingested per day, nor how much Hg prey items at the study site contain.

Based on the results of our pilot study, it appears as though the Outlet site provided more available Hg to bats, relative only to the other sites used as capture locations (Figure 1). The species with the greatest Hg concentrations is the northern long eared bat (*M. septentrionalis*), followed by the big brown bat (*E. fuscus*). This is likely due to the food items that these species are eating at Onondaga Lake. Other species that may be exposed to concentrations of Hg that exceed effects thresholds are the Indiana bat (*M. sodalis*) and the little brown bat (*M. lucifigus*), both species that form maternity colonies near Onondaga Lake. Within these colonies, contaminants can be more detrimental in juvenile bats as mercury is a neurotoxin and can be more disruptive to a bat's nervous system as it is more sensitive while still developing (Spyker and Smithberg 1972).

5.1.4 Prey choice in temperate bat species

When bats emerge from their day roosting areas, they require drinking water. Bats use both aerial and gleaning techniques when foraging over river surfaces and floodplain edges. Carter et al. (2003) found northern long-eared bats' main prey was Coleoptera and Lepidoptera, followed by Diptera. They found diets of northern long-eared bats from West Virginia did not differ from diets in other regions of the United States. Other studies (Whitaker and Hamilton 1998; Brack and Whitaker 2001) found northern long-eared bats typically preyed on moths and beetles, but overall had a varied diet, including spiders. Spiders have been shown to accumulate Hg (Cocking et al. 1991; Adair et al. 2002; BRI unpubl. data). Spiders collected at the South River, Virginia had Hg concentrations exceeding 8.0 μg/g (dry weight[5]) (D. Cristol pers. com.). It is unknown what exact prey species comprise the bulk of each bat species' diet at Onondaga Lake. Stable isotope analysis reveals that each bat species' diet is comprised of different forage items (Figure 12). It is possible that northern long-eared bats at Onondaga are foraging on spiders, bioaccumulating more Hg than other bat species; however, analysis of available prey items is needed to confirm this.

[5] Using an average percent moisture of 68% in spiders from BRI databases, South River spiders may have upwards of 2.56 μg/g (ww) (Cristol et al 2008).

5.2 Indiana bats at Onondaga Lake

It is unknown what percentage of Indiana bats are foraging on Onondaga Lake but it should be noted that we caught another lactating female in the net at the exact same time as the female that led us to the maternity roost on Klein Island. This suggests that individuals forage together in the same areas and it is highly likely that the second female came from the same roost since females roost in maternity colonies with many individuals of the same species (Britzke et. al 2003; Gardner et. al 1991; Humphrey et. al 1977; Kurta et. al 1993). We also caught two male Indiana bats in succession on the same night and tracked both of them to the same bachelor roost area (Appendix 3), supporting the idea that bats forage together from common roosting areas. This species prefers maternity roosts in dying trees and occasionally tree cavities (Gardner et al. 1991). Only a few trees within a colony's range provide the appropriate microhabitat to be used as primary roosts (Barclay and Kurta 2007). Indiana bats are site fidelic and many return to the same maternity colony each year (Kurta and Murray 2002). The Indiana bats at Onondaga are likely site fidelic because of available roost trees, commuting corridors, and profitable prey around the lake, up the Oswego River and down the Seneca River. The difference in distances travelled by male and female Indiana bats at Onondaga Lake could be explained by the need of females to produce milk for young while males only need food for daily energetic purposes. Females of other temperate bat species, such as Bechstein's bats (Kerth and Reckardt 2003) and evening bats (Wilkinson 1992) communicate information on profitable foraging areas. The female Indiana bats at Onondaga Lake likely do the same and risk flying farther to forage in areas known to produce high quality and available prey; necessary to be able to feed young pups.

5.3 Stable isotope analysis

The distinct difference in isotope values between bat species suggests that each species has its own foraging strategy. Depending on location, bats may be foraging on different prey items. Big brown bats have been noted to forage on different prey based on availability at respective locations (Sullivan et al. 2006). We potentially found similar results with *M. lucifigus* between Onondaga and Oneida Lakes in New York and this could be attributed to available prey species at respective sites. Since adults and juveniles

had similar carbon signatures within each sampling location (Onondaga vs. Oneida), this further suggests that forage may be driven by available prey at each given locality.

It appears that if adults and juveniles are feeding on the same items, based on $\delta^{13}C$ values, that they should have similar $\delta^{15}N$ values. However, there is still a difference in food web placement between adults and juveniles, with juveniles consistently being slightly higher on the food web. It is possible that juvenile bats have a higher nitrogen signature because of high levels of nitrogen gained through milk. Nitrogen is directly related to protein and is the predominant elemental component of bat milk (Studier & Kunz 1995). We started capturing bats on July 15th, 2008 and did not catch a juvenile bat until July 22nd, 2008. Thereafter we consistently caught juveniles on all subsequent trapping nights. Previous to trapping at Onondaga Lake, we had been capturing bats at other sites in New York for separate projects and had not captured any juveniles at those sites. This evidence strongly suggests that we started catching juveniles as soon as they had finished weaning, left the roost, and were foraging on their own. The difference in nitrogen signatures may be explained by juveniles accreting nitrogen during parturition and by suckling milk, decreasing adult levels as nitrogen is transferred from parent to offspring. Juveniles only start to consume solid foods once they can independently fly on their own (Voigt et al. 2008). If we were catching juveniles on or close to first foraging bouts, close to 100% of nitrogen in their tissues was transferred from mothers. Another explanation may be that juveniles need to feed on high-protein forage during development and out-compete adults during this time for preferred high-protein invertebrates. Adults allow them to do so since females no longer need large amounts of protein to produce so much milk, and forage on something different than when they were producing milk.

The only sure way to assess differences in stable isotopes between species, age, and location is to collect available food items and compare those isotope values across these variables. Prey items being consumed can be verified with fecal diet analysis (Kunz & Whitaker 1983; Moosman et al. 2007); a reliable and non-invasive way of linking predator with prey.

6.0 Conclusions

Based on a comparison of blood and fur Hg concentrations in bats collected at Onondaga Lake in 2008 to effects thresholds from the literature for other mammalian species, there is compelling evidence that environmental Hg loads at Onondaga Lake may have the potential to cause negative impacts to bats. A comparison of sites at Onondaga Lake with reference areas demonstrates significantly greater fur and blood Hg concentrations in bats from Onondaga Lake. Bat mean fur Hg concentrations were three and a half times higher at the Onondaga sites compared to the reference sites, and mean blood Hg concentrations at Onondaga sites were two and a half times higher than those at reference sites.

Bats are increasingly of high conservation concern to conservation agencies and other entities. Mercury is one anthropogenic stressor on bat populations that may be compounded by other stressors such as wind turbines and white-nose syndrome (WNS), a syndrome that has been causing mass mortality among hibernating bats throughout the northeast and mid-Atlantic states over the last three years. Therefore, high resolution investigations to determine spatially explicit Hg effects on reproductive success, survival, and physiological effects are of even greater importance.

7.0 Acknowledgements

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Appendix 1. List of samples with Hg and stable isotope results from bats sampled at Onondaga Lake and reference sites, 2008.

Location	Fur ID	Fur Hg level	Blood ID	Blood Hg level	Species	Sex	Age	Repro	Site	$\delta^{13}C$	$\delta^{15}N$
Oneida- Verona SP	ONNY0805-F	1.096	ONNY0805-B	0.0408	MYLU	M	J	NR	reference	-28.13	13.87
Oneida- Verona SP	ONNY0811-F	1.451	ONNY0811-B	0.0319	MYLU	M	J	NR	reference	-28.25	13.29
Oneida- Verona SP	ONNY0802-F	1.453	ONNY0802-B	0.0512	MYLU	F	J	NR	reference	-28.05	12.83
Oneida- Verona SP	ONNY0807-F	1.746	ONNY0807-B	0.0546	MYLU	M	J	NR	reference	-27.85	13.20
Oneida- Verona SP	ONNY0808-F	1.895	ONNY0808-B	0.0496	MYLU	M	J	NR	reference	-27.83	12.95
Oneida- Verona SP	ONNY0809-F	1.913	ONNY0809-B	0.0593	MYLU	M	J	NR	reference	-27.62	13.43
Oneida- Verona SP	ONNY0806-F	2.080	ONNY0806-B	0.0533	MYLU	F	J	NR	reference	-28.06	13.37
Oneida- Verona SP	ONNY0803-F	2.095	ONNY0803-B	0.0245	MYLU	F	J	NR	reference	-28.05	13.27
Oneida- Verona SP	ONNY0816-F	2.5713	ONNY0816-B	0.0181	MYLU	F	A	PL	reference	-28.47	13.43
Oneida- Verona SP	ONNY0824-F	2.7842	ONNY0824-B	0.0267	MYLU	F	A	PL	reference	-29.41	12.84
Oneida- Verona SP	ONNY0810-F	2.990	ONNY0810-B	0.0695	MYSE	M	J	NR	reference	-26.37	11.11
Oneida- Verona SP	ONNY0815-F	3.154	ONNY0815-B	0.0420	MYLU	F	A	PL	reference	-28.17	13.12
Oneida- Verona SP	ONNY0826-F	3.1889	ONNY0826-B	0.0343	MYLU	F	A	PL	reference	-28.40	13.32
Oneida- Verona SP	ONNY0830-F	3.3354	ONNY0830-B	0.0431	MYLU	F	A	NR	reference	-28.72	12.76
Oneida- Verona SP	ONNY0818-F	3.7646	ONNY0818-B	0.0275	MYLU	F	A	NR	reference	-28.63	12.87
Oneida- Verona SP	ONNY0823-F	3.7907	ONNY0823-B	0.0276	MYLU	F	A	PL	reference	-28.43	13.61
Oneida- Verona SP	ONNY0827-F	3.8680	ONNY0827-B	0.0492	MYLU	F	A	PL	reference	-28.83	10.44
Oneida- Verona SP	ONNY0820-F	3.9458	ONNY0820-B	0.0232	MYLU	F	A	PL	reference	-28.71	13.41
Oneida- Verona SP	ONNY0821-F	3.9520	ONNY0821-B	0.0264	MYLU	F	A	PL	reference	-28.81	12.69
Oneida- Verona SP	ONNY0813-F	4.046	ONNY0813-B	0.0351	MYLU	F	A	PL	reference	-28.68	11.91
Oneida- Verona SP	ONNY0801-F	4.198	ONNY0801-B	0.0344	MYLU	F	A	PL	reference	-27.87	12.39
Oneida- Verona SP	ONNY0819-F	4.3198	ONNY0819-B	0.0330	MYLU	F	A	PL	reference	-28.50	12.73
Oneida- Verona SP	ONNY0828-F	4.9232	ONNY0828-B	0.0351	MYLU	F	A	PL	reference	-28.15	13.21
Oneida- Verona SP	ONNY0825-F	5.4553	ONNY0825-B	0.0316	MYLU	F	A	PL	reference	-28.86	12.26
Oneida- Verona SP	ONNY0812-F	5.576	ONNY0812-B	0.0254	MYLU	F	A	PL	reference	-28.58	12.97
Oneida- Verona SP	ONNY0817-F	5.6045	ONNY0817-B	0.0318	MYLU	F	A	PL	reference	-28.89	12.28
Oneida- Verona SP	ONNY0804-F	5.877	ONNY0804-B	0.0734	MYLU	F	A	NR	reference	-27.58	12.87
Oneida- Verona SP	ONNY0814-F	6.0577	ONNY0814-B	0.0633	MYLU	M	J	NR	reference	-28.37	12.73
Oneida- Verona SP	ONNY0829-F	6.4502	ONNY0829-B	0.0323	MYLU	M	A	NR	reference	-28.43	12.67
Oneida- Verona SP	ONNY0822-F	7.6929	ONNY0822-B	0.0417	MYLU	F	A	PL	reference	-28.46	13.69

Oneida- Verona SP	ONNY0831-F	10.6014	ONNY0831-B	0.1073	MYSE	M	A	NR	reference	-25.94	10.69
Oneida- Verona SP	ONNY0832-F	11.1640	ONNY0832-B	0.0968	EPFU	M	A	NR	reference	-25.52	9.08
Onondaga- 9 mile creek	OLNY0850-F	1.617	OLNY0850-B	0.0904	MYLU	F	J	NR	contaminated	-27.00	14.58
Onondaga- 9 mile creek	OLNY0866-F	1.786	OLNY0866-B	0.1092	MYLU	M	J	NR	contaminated	-23.57	15.05
Onondaga- 9 mile creek	OLNY0860-F	2.259	OLNY0860-B	0.0737	MYLU	F	J	NR	contaminated	-26.23	12.95
Onondaga- 9 mile creek	OLNY0847-F	2.687	OLNY0847-B	0.0629	MYLU	F	J	NR	contaminated	-27.45	11.58
Onondaga- 9 mile creek	OLNY0846-F	2.777	OLNY0846-B	0.0193	MYLU	M	J	NR	contaminated	-27.87	13.45
Onondaga- 9 mile creek	OLNY0853-F	3.116	OLNY0853-B	0.0420	EPFU	M	A	NR	contaminated	-24.77	8.70
Onondaga- 9 mile creek	OLNY0854-F	3.297	OLNY0854-B	0.0673	MYLU	M	J	NR	contaminated	-27.39	12.77
Onondaga- 9 mile creek	OLNY0863-F	4.438	OLNY0863-B	0.1036	EPFU	M	J	NR	contaminated	-25.12	9.41
Onondaga- 9 mile creek	OLNY0844-F	5.168	OLNY0844-B	0.1041	EPFU	F	J	NR	contaminated	-24.46	9.28
Onondaga- 9 mile creek	OLNY0842-F	5.702	OLNY0842-B	0.0912	EPFU	M	A	NR	contaminated	-26.33	10.24
Onondaga- 9 mile creek	OLNY0851-F	6.120	OLNY0851-B	0.0847	EPFU	F	A	NR	contaminated	-24.46	8.62
Onondaga- 9 mile creek	OLNY0872-F	7.741	OLNY0872-B	0.0945	MYLU	F	J	NR	contaminated	-25.91	13.53
Onondaga- 9 mile creek	OLNY0857-F	8.332	OLNY0857-B	0.0985	MYLU	F	J	NR	contaminated	-27.70	12.77
Onondaga- 9 mile creek	OLNY0852-F	9.093	OLNY0852-B	0.0995	MYSE	M	A	NR	contaminated	-24.38	8.58
Onondaga- 9 mile creek	OLNY0875-F	10.249	OLNY0875-B	0.1392	MYLU	M	A	NR	contaminated	-24.03	11.90
Onondaga- 9 mile creek	OLNY0865-F	11.189	OLNY0865-B	0.0476	MYLU	M	A	NR	contaminated	-25.16	11.01
Onondaga- 9 mile creek	OLNY0873-F	13.467	OLNY0873-B	0.1294	MYLU	M	A	NR	contaminated	-26.06	11.50
Onondaga- 9 mile creek	OLNY0867-F	15.184	OLNY0867-B	0.0943	MYLU	M	A	NR	contaminated	-27.31	12.78
Onondaga- 9 mile creek	OLNY0859-F	15.238	OLNY0859-B	0.1410	MYLU	M	A	NR	contaminated	-26.61	11.75
Onondaga- 9 mile creek	OLNY0874-F	15.420	OLNY0874-B	0.0849	MYLU	F	J	NR	contaminated	-25.17	11.74
Onondaga- 9 mile creek	OLNY0858-F	15.923	OLNY0858-B	0.0872	MYLU	M	A	NR	contaminated	-24.82	11.65
Onondaga- 9 mile creek	OLNY0861-F	17.477	OLNY0861-B	0.1366	MYLU	M	A	NR	contaminated	-25.66	12.70
Onondaga- 9 mile creek	OLNY0870-F	17.619	OLNY0870-B	0.1647	MYLU	M	J	NR	contaminated	-26.75	12.20
Onondaga- 9 mile creek	OLNY0849-F	18.267	OLNY0849-B	0.0960	MYLU	M	A	NR	contaminated	-26.36	12.75
Onondaga- 9 mile creek	OLNY0856-F	19.857	OLNY0856-B	0.1030	MYLU	M	A	NR	contaminated	-28.69	12.79
Onondaga- 9 mile creek	OLNY0869-F	20.623	OLNY0869-B	0.1426	MYLU	F	A	PL	contaminated	-25.85	13.45
Onondaga- 9 mile creek	OLNY0841-F	21.273	OLNY0841-B	0.1137	MYLU	M	A	NR	contaminated	-24.54	12.03
Onondaga- 9 mile creek	OLNY0855-F	21.517	OLNY0855-B	0.1466	MYLU	F	J	NR	contaminated	-25.18	14.34
Onondaga- 9 mile creek	OLNY0862-F	21.625	OLNY0862-B	0.1344	MYLU	F	A	PL	contaminated	-26.12	14.05
Onondaga- 9 mile creek	OLNY0876-F	24.723	OLNY0876-B	0.1162	MYSO	F	A	L	contaminated	-26.84	12.19
Onondaga- 9 mile creek	OLNY0843-F	26.510	OLNY0843-B	0.0996	EPFU	M	A	NR	contaminated	-24.71	9.81

Onondaga- 9 mile creek	OLNY0868-F	31.942	OLNY0868-B	0.1486	MYLU	F	A	PL	contaminated	-27.05	13.23
Onondaga- 9 mile creek	OLNY0848-F	32.373	OLNY0848-B	0.1405	EPFU	M	A	NR	contaminated	-26.05	9.71
Onondaga- 9 mile creek	OLNY0845-F	33.982	OLNY0845-B	0.3172	EPFU	M	A	NR	contaminated	-25.30	9.25
Onondaga- 9 mile creek	OLNY0864-F	55.551	OLNY0864-B	0.2694	EPFU	M	A	NR	contaminated	-24.72	9.70
Onondaga- 9 mile creek	OLNY0871-F	65.442	OLNY0871-B	0.6178	MYLU	M	A	NR	contaminated	-26.86	15.36
Onondaga- Grenadier Village	OLNY0893-F	2.066	OLNY0893-B	0.0121	MYSO	F	J	NR	contaminated	-25.64	10.35
Onondaga- Grenadier Village	OLNY0898-F	2.751	OLNY0898-B	0.0303	MYSO	F	J	NR	contaminated	-25.00	10.82
Onondaga- Grenadier Village	OLNY08103-F	2.823	OLNY08103-B	0.0275	MYSO	M	J	NR	contaminated	-25.04	11.02
Onondaga- Grenadier Village	OLNY0890-F	3.228	OLNY0890-B	0.0801	MYLU	F	J	NR	contaminated	-26.08	12.98
Onondaga- Grenadier Village	OLNY0888-F	3.467	OLNY0888-B	0.0608	MYLU	M	A	NR	contaminated	-26.67	12.42
Onondaga- Grenadier Village	OLNY0889-F	3.595	OLNY0889-B	0.0484	MYLU	M	J	NR	contaminated	-26.36	13.47
Onondaga- Grenadier Village	OLNY0891-F	4.703	OLNY0891-B	0.0217	MYSO	M	J	NR	contaminated	-25.11	10.95
Onondaga- Grenadier Village	OLNY0896-F	4.896	OLNY0896-B	0.0348	MYLU	M	J	NR	contaminated	-26.15	14.96
Onondaga- Grenadier Village	OLNY0899-F	5.646	OLNY0899-B	0.0188	MYSO	F	J	NR	contaminated	-25.66	10.78
Onondaga- Grenadier Village	OLNY0895-F	7.037	OLNY0895-B	0.0624	MYSU	M	A	NR	contaminated	-26.64	12.12
Onondaga- Grenadier Village	OLNY0886-F	7.242	OLNY0886-B	0.1450	MYLU	F	J	NR	contaminated	-25.90	15.35
Onondaga- Grenadier Village	OLNY0897-F	7.617	OLNY0897-B	0.0453	MYLU	M	A	NR	contaminated	-26.32	11.50
Onondaga- Grenadier Village	OLNY0892-F	9.591	OLNY0892-B	0.0732	MYLU	M	A	NR	contaminated	-26.43	12.85
Onondaga- Grenadier Village	OLNY0887-F	10.605	OLNY0887-B	0.0431	MYLU	M	J	NR	contaminated	-25.78	12.10
Onondaga- Grenadier Village	OLNY0894-F	12.363	OLNY0894-B	0.0912	MYLU	M	A	NR	contaminated	-25.54	11.76
Onondaga- Grenadier Village	OLNY0885-F	17.616	OLNY0885-B	0.1655	MYLU	F	A	L	contaminated	-26.20	12.65
Onondaga- Grenadier Village	OLNY08100-F	21.790	OLNY08100-B	0.1046	EPFU	M	A	NR	contaminated	-23.97	9.20
Onondaga- Grenadier Village	OLNY08104-F	24.417	OLNY08104-B	0.1282	MYSE	F	A	L	contaminated	-25.44	12.18
Onondaga- Grenadier Village	OLNY08101-F	37.702	OLNY08101-B	0.2013	EPFU	M	A	NR	contaminated	-23.50	8.92
Onondaga- Grenadier Village	OLNY08102-F	41.199	OLNY08102-B	0.1875	EPFU	F	A	PL	contaminated	-25.87	9.03
Onondaga- Lakeland RR	OLNY0834-F	2.217	OLNY0834-B	0.0837	MYLU	F	J	NR	contaminated	-27.20	12.18
Onondaga- Lakeland RR	OLNY0826-F	2.573	OLNY0826-B	0.0211	MYLU	M	A	NR	contaminated	-26.75	11.53
Onondaga- Lakeland RR	OLNY0822-F	3.297	OLNY0822-B	0.0644	MYSO	M	A	NR	contaminated	-25.93	11.42
Onondaga- Lakeland RR	OLNY0828-F	4.181	OLNY0828-B	0.0316	EPFU	M	A	NR	contaminated	-24.15	8.32
Onondaga- Lakeland RR	OLNY0840-F	4.305	OLNY0840-B	0.1109	MYLU	F	A	PL	contaminated	-27.54	12.11
Onondaga- Lakeland RR	OLNY0829-F	5.388	OLNY0829-B	0.0164	MYSO	M	A	NR	contaminated	-25.82	11.29
Onondaga- Lakeland RR	OLNY0833-F	5.948	OLNY0833-B	0.0602	MYLU	M	A	NR	contaminated	-26.57	11.72
Onondaga- Lakeland RR	OLNY0832-F	6.747	OLNY0832-B	0.1375	MYLU	M	J	NR	contaminated	-27.23	13.53

Onondaga- Lakeland RR	OLNY0825-F	9.382	OLNY0825-B	0.0838	MYLU	M	A	NR	contaminated	-26.32	12.21
Onondaga- Lakeland RR	OLNY0824-F	10.458	OLNY0824-B	0.1267	MYLU	F	A	L	contaminated	-27.27	13.75
Onondaga- Lakeland RR	OLNY0835-F	13.612	OLNY0835-B	0.0941	MYLU	F	J	NR	contaminated	-26.59	15.65
Onondaga- Lakeland RR	OLNY0827-F	14.000	OLNY0827-B	0.0773	MYLU	F	A	PL	contaminated	-28.01	13.27
Onondaga- Lakeland RR	OLNY0831-F	17.314	OLNY0831-B	0.0692	EPFU	M	A	NR	contaminated	-24.89	8.92
Onondaga- Lakeland RR	OLNY0837-F	17.778	OLNY0837-B	0.1931	MYLU	M	A	NR	contaminated	-26.58	12.40
Onondaga- Lakeland RR	OLNY0830-F	18.356	OLNY0830-B	0.1117	MYSO	F	A	L	contaminated	-24.91	9.86
Onondaga- Lakeland RR	OLNY0839-F	18.850	OLNY0839-B	0.0982	MYLU	F	A	PL	contaminated	-27.08	13.17
Onondaga- Lakeland RR	OLNY0836-F	31.597	OLNY0836-B	0.1316	MYSO	M	A	NR	contaminated	-27.03	11.86
Onondaga- Lakeland RR	OLNY0823-F	38.735	OLNY0823-B	0.0970	MYSO	M	A	NR	contaminated	-26.03	11.11
Onondaga- Lakeland RR	OLNY0838-F	53.746	OLNY0838-B	0.1065	MYLU	F	A	PL	contaminated	-26.41	14.36
Onondaga- Lakeland RR	OLNY0821-F	57.254	OLNY0821-B	0.1783	MYSE	M	A	NR	contaminated	-25.25	12.94
Onondaga- Outlet	OLNY0882-F	2.120	OLNY0882-B	0.0131	LABO	F	J	NR	contaminated	-24.86	9.44
Onondaga- Outlet	OLNY0818-F	3.154	OLNY0818-B	0.0708	EPFU	M	A	NR	contaminated	-24.35	8.88
Onondaga- Outlet	OLNY0817-F	3.297	OLNY0817-B	0.0860	MYSE	F	A	L	contaminated	-25.55	8.91
Onondaga- Outlet	OLNY0812-F	3.721	OLNY0812-B	0.0569	EPFU	M	A	NR	contaminated	-25.00	8.70
Onondaga- Outlet	OLNY0813-F	3.778	OLNY0813-B	0.1448	EPFU	M	A	NR	contaminated	-26.40	9.61
Onondaga- Outlet	OLNY0819-F	3.973	OLNY0819-B	0.0540	MYLU	M	A	NR	contaminated	-27.74	15.63
Onondaga- Outlet	OLNY0806-F	4.763	OLNY0806-B	0.0245	MYSE	M	A	NR	contaminated	-24.95	8.08
Onondaga- Outlet	OLNY0811-F	6.747	OLNY0811-B	0.2517	MYSE	M	A	NR	contaminated	-25.27	10.42
Onondaga- Outlet	OLNY0809-F	7.628	OLNY0809-B	0.1943	EPFU	F	A	L	contaminated	-25.36	8.63
Onondaga- Outlet	OLNY0884-F	7.935	OLNY0884-B	0.0881	MYLU	M	J	NR	contaminated	-26.55	16.29
Onondaga- Outlet	OLNY0807-F	8.672	OLNY0807-B	0.1733	MYSO	F	A	L	contaminated	-26.68	11.86
Onondaga- Outlet	OLNY0816-F	8.778	no sample		MYSO	F	A	L	contaminated	-26.00	10.81
Onondaga- Outlet	OLNY0820-F	11.079	OLNY0820-B	0.0366	MYSO	M	A	NR	contaminated	-25.43	9.50
Onondaga- Outlet	OLNY0877-F	11.580	OLNY0877-B	0.1231	MYSO	F	A	L	contaminated	-26.42	10.79
Onondaga- Outlet	OLNY0815-F	12.595	OLNY0815-B	0.0613	MYLU	M	A	NR	contaminated	-27.16	13.39
Onondaga- Outlet	OLNY0803-F	14.071	OLNY0803-B	0.0966	MYLU	F	A	NR	contaminated	-27.54	13.45
Onondaga- Outlet	OLNY0814-F	16.362	OLNY0814-B	0.0911	MYLU	M	A	NR	contaminated	-26.27	11.93
Onondaga- Outlet	OLNY0810-F	16.442	no sample		MYLU	M	A	NR	contaminated	-26.73	13.79
Onondaga- Outlet	OLNY0805-F	17.569	OLNY0805-B	0.1658	MYSO	F	A	L	contaminated	-26.29	11.55
Onondaga- Outlet	OLNY0802-F	17.874	OLNY0802-B	0.1471	MYLU	M	A	NR	contaminated	-27.47	10.51
Onondaga- Outlet	OLNY0804-F	19.128	OLNY0804-B	0.0717	MYLU	F	A	L	contaminated	-27.01	11.28

Onondaga- Outlet	OLNY0879-F	19.371	OLNY0879-B	0.1779	MYLU	M	J	NR	contaminated	-25.88	11.61
Onondaga- Outlet	OLNY0801-F	22.673	OLNY0801-B	0.1684	MYLU	M	A	NR	contaminated	-27.28	12.60
Onondaga- Outlet	OLNY0883-F	22.948	OLNY0883-B	0.1389	MYLU	M	J	NR	contaminated	-27.47	11.31
Onondaga- Outlet	OLNY0880-F	26.447	OLNY0880-B	0.1558	MYSE	M	A	NR	contaminated	-24.90	9.55
Onondaga- Outlet	OLNY0878-F	33.705	OLNY0878-B	0.3406	MYSE	M	A	NR	contaminated	-25.45	10.61
Onondaga- Outlet	OLNY0808-F	38.577	OLNY0808-B	0.3197	MYSE	F	A	NR	contaminated	-25.50	12.51
Onondaga- Outlet	OLNY0881-F	58.893	OLNY0881-B	0.1611	MYSE	M	A	NR	contaminated	-25.26	10.56

Appendix 2. Indiana bat capture log of bats captured at Onondaga Lake, 2008.

County	Town	Site	Date	Lat	Long	Species	Sex	Age	Repro	FA (mm)	weight (g)	Roost found?
Onondaga, NY	Liverpool	Onondaga-Lake outlet	7/15/2008	43.11385	76.24607	MYSO	F	A	L	38.3	8.2	N
Onondaga, NY	Liverpool	Onondaga-Lake outlet	7/15/2008	43.11385	76.24607	MYSO	F	A	L	37.6	6.8	N
Onondaga, NY	Liverpool	Onondaga-Lake outlet	7/16/2008	43.11385	76.24607	MYSO	F	A	L	38.7	7.8	N
Onondaga, NY	Liverpool	Onondaga-Lake outlet	7/19/2008	43.11385	76.24607	MYSO	M	A	NR	36.1	6.7	Y
Onondaga, NY	Lakeland	Onondaga-Lakeland RR tracks	7/20/2008	43.10113	76.241	MYSO	M	A	NR	39.9	7.1	Y
Onondaga, NY	Lakeland	Onondaga-Lakeland RR tracks	7/20/2008	43.10113	76.241	MYSO	M	A	NR	39.4	7.9	Y
Onondaga, NY	Lakeland	Onondaga-Lakeland RR tracks	7/21/2008	43.10113	76.241	MYSO	M	A	NR	39.5	6.6	N
Onondaga, NY	Lakeland	Onondaga-Lakeland RR tracks	7/22/2008	43.10113	76.241	MYSO	F	A	L	37.8	7.5	N
Onondaga, NY	Lakeland	Onondaga-Lakeland RR tracks	7/22/2008	43.10113	76.241	MYSO	M	A	NR	36.8	6.8	N
Onondaga, NY	Lakeland	Onondaga-near 9-mile creek	7/24/2008	43.09322	76.23416	MYSO	F	A	L	38.4	8	Y
Onondaga, NY	Liverpool	Onondaga-Lake outlet	7/26/2008	43.11169	76.24735	MYSO	F	A	L	38.9	8.8	N
Onondaga, NY	Elmcrest	creek behind Grenadier Village	7/27/2008	43.12888	76.24767	MYSO	M	J	NR	39.8	6	N
Onondaga, NY	Elmcrest	creek behind Grenadier Village	7/27/2008	43.12888	76.24767	MYSO	F	J	NR	39.4	6.3	N
Onondaga, NY	Elmcrest	creek behind Grenadier Village	7/30/2008	43.12888	76.24767	MYSO	F	J	NR	37.2	6.2	N
Onondaga, NY	Elmcrest	creek behind Grenadier Village	7/30/2008	43.12888	76.24767	MYSO	F	J	NR	39.1	6	N
Onondaga, NY	Elmcrest	creek behind Grenadier Village	7/30/2008	43.12888	76.24767	MYSO	M	J	NR	40	6.5	N

Appendix 3. Indiana bat roost log for bats tracked to roost from Onondaga Lake, 2008.

Bat ID	Frequency	Band #	Sex	Age	Repro	Tree type	Roost site	Roost type	Roost tree Lat	Roost tree Long
OLNY0820	148.597	NYDEC2461	M	A	NR	mature shagbark	exit 5 off Rte.690	bachelor	43.107947	76.255031
OLNY0822	148.637		M	A	NR	dead snag	swamp Lakeland trail and Rte. 690	bachelor	43.106258	76.244647
OLNY0823	148.675		M	A	NR	dead snag	swamp Lakeland trail and Rte. 690	bachelor	43.106258	76.244647
OLNY0876	148.757		F	A	L	dead tree ~15 ft. high	southern end of Klein Island	maternity	43.121167	76.255806