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

2009 FIELD SEASON

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To obtain copies of this report contact:

Anne Secord
U.S. Fish and Wildlife Service
3817 Luker Road
Cortland, NY 13045

Anne_secord@fws.gov

Or

Dave Yates
Biodiversity Research Institute
19 Flaggy Meadow Road
Gorham, ME 04038

Dave.yates@briloon.org

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

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ASSESSMENT OF MERCURY EXPOSURE TO BATS AT ONONDAGA LAKE, NEW YORK: 2009 FIELD SEASON

(Report BRI 2010-11)

Submitted to:

Anne Secord
U.S. Fish and Wildlife Service
Cortland, New York

Submitted by:

Dave Yates, Sofia Angelo, Tim Divoll and David C. Evers

BioDiversity Research Institute
19 Flaggy Meadow Road
Gorham, Maine 04038
(Corresponding Institution)

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1.0 Executive Summary

The anthropogenic input of inorganic mercury (Hg) into the environment is of concern because of the potential long-term impacts on ecological health. Bacterial methylation of inorganic Hg converts it into the more biologically toxic methylmercury (MeHg) (Driscoll et al. 2007). Geographic differences in atmospheric deposition and waterborne point sources of Hg create biological Hg hotspots (Evers et al. 2007). Much is known about Hg and MeHg distribution and bioavailability in the Northeast United States (Evers and Clair 2005). This large body of knowledge provides a basis for assessing the relationship between Hg loading and biotic uptake. In an effort to evaluate Hg availability to mammalian wildlife at Onondaga Lake, New York, we used bats as indicators of Hg bioaccumulation. Bats were chosen because their foraging behavior and long life span make them potentially susceptible to high Hg exposure through the consumption of emergent insects (Hickey et al. 2001, Wada et al. 2010).

Activities conducted in 2009 constitute the second year of a two-year study evaluating Hg exposure to bats at Onondaga Lake. In 2009, 151 bats of various species were captured at the reference (Oneida Lake) and Onondaga Lake sites. Fur Hg concentrations, used as indicators of Hg exposure for bats, are evidence that Hg at Onondaga Lake has the potential to accumulate in bats. A comparison of the Onondaga Lake sites with the reference site demonstrates a significant difference in Hg concentrations in the fur of bats between the two areas. Mean bat fur Hg concentrations were nearly two times higher in adult bats from Onondaga Lake (15.4 ug/g Hg) than the reference site (8.7 ug/g Hg) and nearly four times higher in juvenile bats at Onondaga Lake (6.8 ug/g Hg) compared to the reference site (1.8 ug/g Hg).

Lowest observed adverse effect levels (LOAEL) have not been developed for bats; however, some bats sampled at Onondaga Lake may have concentrations of Hg that have been associated with adverse effects in species such as mink and deer mice. Approximately 53% of the adult bats (42% of juvenile and adult bats combined) captured at Onondaga Lake in 2009 had fur Hg concentrations (range = 1.43 - 60.78 μg/g) that exceeded a deer mouse fur LOAEL of 10.8 μg/g (fw) (Burton et al. 1977). Approximately 28% of adult bats (17 % of juvenile and adult bats) captured at the reference site had fur Hg concentrations in excess of a deer mouse fur LOAEL of 10.8 μg/g. A small number of bats from Onondaga Lake also had fur Hg concentrations that exceeded an adverse effects threshold for mink (40 – 50 μg/g), as described in Basu et al. (2007).

2.0 Introduction

Onondaga Lake is located in Onondaga County, near the City of Syracuse, New York. A number of industries and municipalities have discharged hazardous substances into the Lake and its tributaries. 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 (Effler and Harnett 1996).

On December 16, 1994, Onondaga Lake and upland areas of the Lake that were contributing or had contributed to contamination of 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. The 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 (New York State Department of Environmental Conservation [NYSDEC] 2011).

This is a follow-up study focusing on bats as indicators of contamination at Onondaga Lake. Data were also collected in 2008 and the results were analyzed and reported separately (Divoll et al. 2008). All New York bat species, and more than half of all species of bats in the U.S., can be characterized as foraging (at least occasionally) on emergent aquatic insects over water (Table 1), thereby exposing the bats to water-borne contaminants. Bats may also glean insects from vegetation, feeding on more terrestrial species such as spiders and larvae, organisms that may also accumulate Hg (Brack and Whitaker 2001, Cristol et al. 2008).

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

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

3.0 Background

3.1 Mercury Exposure of Bats

There have been few investigations of Hg exposure in bats (Reidinger 1972, Petit and Altenbach 1973, Powell 1983, O'Shea et al. 2001b, Yates et al. 2008). Powell (1983) showed that aquatic nymphs of flying insects from the North Fork of the Holston River in Virginia, which has been polluted by a Hg point source, had elevated Hg compared to areas upstream of the source. Insectivorous Eastern Pipistrelles (*Perimyotis subflavus)* feeding over this river also showed elevated Hg levels in liver and muscle tissues when compared to a reference site.

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). They also found Hg was elevated in bat muscle, kidney, liver, and brain when compared to a reference site.

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 mean Hg concentrations of 33.0 µg/g (fw) and 33.7 µg/g (fw), respectively. Wada et al. (2010) found that big brown bats at a Hg contaminated site in Virginia contained an average of 28 µg/g Hg in fur.

Hickey et al. (2001) examined fur in various Chiroptera species from eastern Ontario and adjacent Quebec, Canada. While none of the sites have reported Hg contamination, the sites in eastern Ontario were near a Sudbury industrial mining complex. In 1997, they pooled samples from five sites and found Hg concentrations ranging from 2.0 to 7.6 µg/g (fw) in fur. In 1998, Hickey et al. (2001) sampled the same sites to examine differences between years and found fur Hg concentrations that exceeded 10 µg/g.

Osborne et al. (2011) summarized data on mercury concentrations in bats sampled at 44 sites across New England and the mid-Atlantic states (including New York). Adult fur Hg concentrations ranged from 0.69 µg/g in a red bat from the Monongahela National Forest in West Virginia to 120.31 µg/g in a big brown bat from along the Little River in New Hampshire. The mean fur Hg concentration for all bats sampled as part of the Osborne et al. (2011) study was approximately 7 µg/g for females (n=389) and 10 µg/g (n=213) for males (see Figure 44 of Osborne et al. 2011).

3.2 Mercury Toxicity to Bats and other Mammals

There has been very little research into the effects of Hg on bats, and there are no well accepted thresholds for adverse effects associated with Hg in bat fur. Mercury effect levels for aerial insectivores were assessed on the Clinch River, Tennessee (Oak Ridge Reservation) a Hg contaminated site. A NOAEL (no observed adverse effects level) of 0.114 µg/g/day and LOAEL of 0.56 µg/g/day for little brown bats was modeled based on a dietary dose shown to adversely affect reproduction in rats (Baron et al. 1999).

Dong-Ha Nam et al. (2010) observed that bats exhibited neurochemical changes at ~ 1-5 µg/g Hg in the brain (corresponding to ~ 10 – 50 µg/g Hg in fur). The significance of the observed changes in brain enzymes and receptor activity to bats is unknown.

There has been more research performed to evaluate the effects of Hg on other mammals. Burton et al. (1977) dosed deer mice (*Peromyscus maniculatus*) with Hg and found that deer mice with fur Hg concentrations of 7.8 µg/g (fw) or higher displayed behavioral deviations and had a decrease in ambulatory activity when compared to a control group. These authors also found that at a concentration of 10.8 μg/g (fw) of Hg in fur, deer mice showed altered behavior and decreased swimming ability.

Wobeser and Swift (1976) fed dietary Hg to mink at concentrations ranging from 1.1 μg/g to 15 μg/g. Mink in all dosage groups experienced lesions of the brain and nervous system (with no lesions detected in control animals). Overt neurological dysfunction was noted in animals dosed with greater than 1.8 μg/g Hg in feed. Clinical signs ranged from ataxia to convulsions and death. Mink on a diet with 1.1 μg/g Hg in feed had a Hg concentration in fur of 1.8 μg/g at the end of the experiment (n=2). Mercury concentrations in fur did not generally increase with increasing dietary concentrations of Hg because, according to the authors, no significant fur growth was likely during the study period. The average Hg content in the brain of mink that died was 11.9 μg/g.

Wada et al. (2010) found that fur Hg concentrations in big brown bats at a Hg contaminated site in Virginia contained an average of 28 μg/g Hg in fur. There was no statistically significant difference in the adrenocorticol response to handling between these bats and reference area bats (with mean fur Hg concentration of 11μg/g).

Female mink fed a diet containing 1 μg/g Hg experienced mortality after long-term exposure. Ninety days of exposure resulted in 30 out of 50 first generation females dying; six out of seven second generation females died after 330 days of exposure (Danseraeu et al. 1999). No fur Hg concentrations were reported.

Laboratory studies have shown that concentrations of Hg in the brain of mink between 4 and 5 μg/g resulted in neuronal lesions, behavioral deficits and sometimes death (Aulerich et al. 1974, Wobeser and Swift 1976, Wren et al. 1987a, 1987b, as cited in Basu et al. 2007). Brain Hg concentrations in mink tend to be approximately an order of magnitude lower than fur Hg concentrations (Klenavic et al. 2008). It follows that a fur Hg concentration of approximately 40 – 50 μg/g in mink would be associated with neuronal lesions as described above. We note that brain concentrations of Hg in little brown bats were also found to be approximately an order of magnitude lower than Hg concentrations in fur (Dong-Ha Nam et al. 2010).

For comparative purposes later in this report, we use the 10.8 μg/g fur Hg adverse effects threshold from the deer mouse study (Burton 1977) and the 40 – 50 μg/g fur Hg adverse effects threshold estimated from a mink brain adverse effects level (Aulerich et al. 1974, Wobeser and Swift 1976, Wren et al. 1987a, 1987b, as cited in Basu et al. 2007).

3.3 Mercury Concentrations in Blood vs. Fur

Tissue analyses provide information on dietary exposure to Hg. Specifically, different tissues show Hg exposure during specific time frames. Blood Hg levels are likely to represent recent dietary uptake, as has been shown for birds (Hobson and Clark 1993, Bearhop et al. 2000, Evers et al. 2005) whereas, fur samples are indicators of longer term Hg exposure, reflecting both dietary uptake and body accumulation (Mierle et al. 2000, Yates et al. 2005). Mercury data from both blood and fur may provide information on more recent (blood) vs. longer term (fur) Hg exposure. For purposes of this report, we focus only on analysis of Hg in fur.

3.4 Mercury Concentrations in Adults vs. Juveniles

Adults have accumulated an overall body burden of Hg; juveniles, however, have only accumulated Hg levels from their mother’s milk and from the site where they have foraged. Therefore, age class may be an important predictive variable. To account for this, adults should be separated from juveniles during statistical analyses when a significant difference is found.

4.0 Methods

Study Objective: The objective of this study is to provide data useful in determining availability of Hg to bats at Onondaga Lake. To achieve this objective, we performed the following activities:

1. Captured bats for fur sampling at four Onondaga Lake locations and one reference site at Oneida Lake.

2. Tracked 25 individual bats to their roosts around Onondaga Lake to develop information about the potential geographic extent of Hg in bats around Onondaga Lake.

4.1 Study Sites

Sampling was completed at four locations around Onondaga Lake: two directly on the Lake (one at the “Southwest Corner” and another comprising four sub-sites at the lake “Outlet”), one on a stream flowing into the Lake (“Nine Mile Creek”), and one on a river flowing out of the Lake (“Oswego River”) (Figure 1). Sites were chosen or shifted from previous years sampling locations because the field crews sought the sites with the best chances for catching bats and the southwest corner of Onondaga Lake had not been sampled in the previous year.

Figure 1. Capture sites at Onondaga Lake.

Verona Beach State Park at Oneida Lake in Oneida County was used as the reference area as it offers similar foraging habitat to Onondaga Lake without a known point source of Hg (Figure 2). All sites contained mature deciduous trees with a variety of shrubs and second growth plants close to water and wetlands. Those sites can be classified as edge habitat near water, presumably used by bats as foraging and travel corridors. Sampling sites were chosen at logistically feasible locations, where access was available, that fit the criteria for setting nets, as explained in the next section.

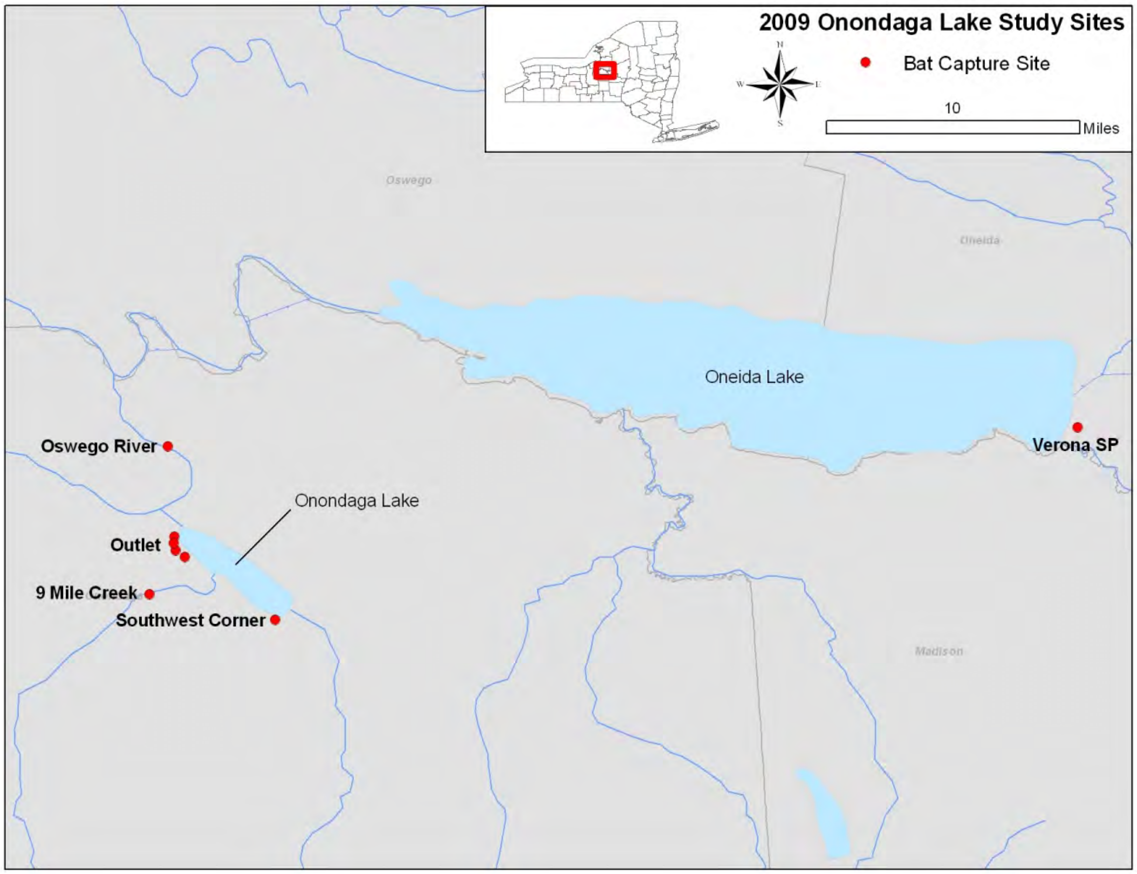

Figure 2. Bat sampling sites at Onondaga and Oneida Lakes, 2009.

4.2 Capture and Sample Collection

Bat capture and sampling occurred from June 22 to July 27, 2009. Seven to twelve mist nets were deployed at each site. 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 by bats as travel corridors. From prior trapping experience, bat activity is highest on roads near water, so roads were chosen that led toward 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 01:00 hours the following morning; if bats were being captured, nets were left up until there was no activity for thirty minutes.

Bats were held in disposable paper bags until processed and each bag was only used once. All bats captured were identified to species, checked for reproductive status, sexed, aged, and standard measurements were taken (forearm length, body condition, and weight). Fur samples were 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 between bats. The fur was put in small (2x2 inch) zip-lock bags.

Blood and skin samples were also collected, but were archived and not analyzed for this report. Small blood samples were collected by puncturing the acute ulnar 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. Small skin samples were obtained using a 3mm wing membrane punch for potential stable isotope analysis in the future. 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).

4.3 Sample Handling

All 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. 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 against the data sheets and all samples were transferred to a freezer.

Chain-of-custody procedures were observed at all times for all samples, from the initial sample collection until samples were transferred to the laboratory. All samples were transferred with appropriate chain of custody forms. All sampling efforts were in accordance with the Quality Assurance/ Quality Control Plan.

4.4 Mercury Analysis

Total mercury concentrations were analyzed in sampled tissue (fur). Laboratory analysis was conducted at the Wildlife Mercury Research Lab (WMRL) at BRI. All fur samples were analyzed for total Hg using a thermal decomposition technique with a direct Hg analyzer (DMA 80, Milestone Incorporated) and USEPA Method 7473 (USEPA 2007). Detection limits for all samples were 0.0025 µg Hg/g fur. Fur Hg concentrations are presented on a fresh weight (fw) basis. We focused on total Hg for this study, as analyses for this form is less costly than for MeHg, and 78.6% (+/-25.9%) of total Hg in otters has been shown to be in the MeHg form (Evans et al. 2000). Blood and wing punch samples have been properly stored and archived at the WMRL until funding is available to conduct the Hg analyses.

4.5 Statistical Analysis

Shapiro Wilks W tests were performed on all Hg data to test for normality. The data found not to be normally distributed were log transformed and retested for normality. None of the data were normally distributed after transformation; therefore, nonparametric tests were used for all statistical analysis. Kruskal-Wallis tests were used for comparisons with more than two groups, followed by a Tukey-Kramer HSD to assess individual significance within the groups. Wilcoxon rank sum tests were used for comparisons between two unpaired groups. All statistical analysis was performed using the JMP 5.0 statistical program in conjunction with Microsoft Excel. Results of statistical tests were considered significant at a P-value <0.05.

4.6 Bat Roost Telemetry

Four species of bats (little brown, big brown, northern long-eared, and Indiana bats) were the focal species used to determine roosting locations of bats around Onondaga Lake. Indiana bats (*Myotis sodalis)* are Federally endangered and were of special interest during our telemetry efforts. Once a captured bat was identified and tissue samples were collected, a radio transmitter with a unique frequency was glued to its back (Figure 3) using Skin-Bond® surgical cement. The bat was released unharmed at the site. Bats were then tracked to their day-time maternity roosts by car or foot. Transmitters likely fall off after a maximum of 16 or 17 days (Albus and Carter 2008).

Figure 3. Little brown bat with radio transmitter glued to its back.

5.0 Results

Fur samples were taken from 151 bats, consisting of six species, during the 2009 field season effort at Onondaga and Oneida Lakes (Table 2). Each of these species presumably breeds in the vicinity of its capture location, with the possible exception of red bats (n=4) and the eastern pipistrelle (n=1). We were not able to determine if these five individuals were breeding at Onondaga Lake because red bats are migratory and the eastern pipistrelle was an adult male, whose reproductive status is only apparent in autumn.

Table 1. Summary of bats caught at Onondaga and Oneida Lakes.

Location	EPFU	LABO	MYLU	MYSE	MYSO	MYSU
Oneida Lake	14	~	16	~	~	~
Onondaga Lake	25	4	68	13	10	1

EPFU = big brown bat, LABO = eastern red bat, MYLU = little brown bat,
MYSE = northern small footed bat, MYSO = Indiana bat, MYSU = eastern pipistrelle bat

5.1 Mercury Exposure by Age Class

Bats at Onondaga and Oneida Lakes were placed in one of two age categories: adult and juvenile. Fur Hg concentrations were significantly higher in adults than juveniles at Onondaga Lake (Wilcoxon rank sum, $P < 0.0001$) and Oneida Lake (Wilcoxon rank sum, $P = 0.0001$). Therefore, all further analysis is separated by age class.

5.2 Mercury Exposure by Species and Sex at Onondaga Lake

A Wilcoxon rank sum test was used to compare the fur Hg concentrations between sexes at Onondaga Lake; no significant difference was found in fur Hg concentrations between sexes in either adult ($p = 0.539$) or juvenile bats ($p = 0.335$, Table 3).

Table 2. Summary of bat fur (µg Hg/g fur, fw) Hg levels by sex at Onondaga Lake.

Sex	Age[1]	n	Mean	Median	Min	Max	sd +/-
F	A	50	13.56	10.59	1.44	44.97	9.88
M	A	37	17.96	12.77	1.43	60.78	16.01
F	J	17	5.16	4.99	0.63	20.48	4.38
M	J	17	8.52	5.51	1.29	35.63	8.77

[1] Age Class: A = adult, J = juvenile

We used a Kruskal-Wallis test to assess differences in Hg bioaccumulation between species at Onondaga Lake (Figure 4); there was no significant difference in fur Hg concentrations between species of adult ($p = 0.715$) or juvenile bats ($p = 0.247$).

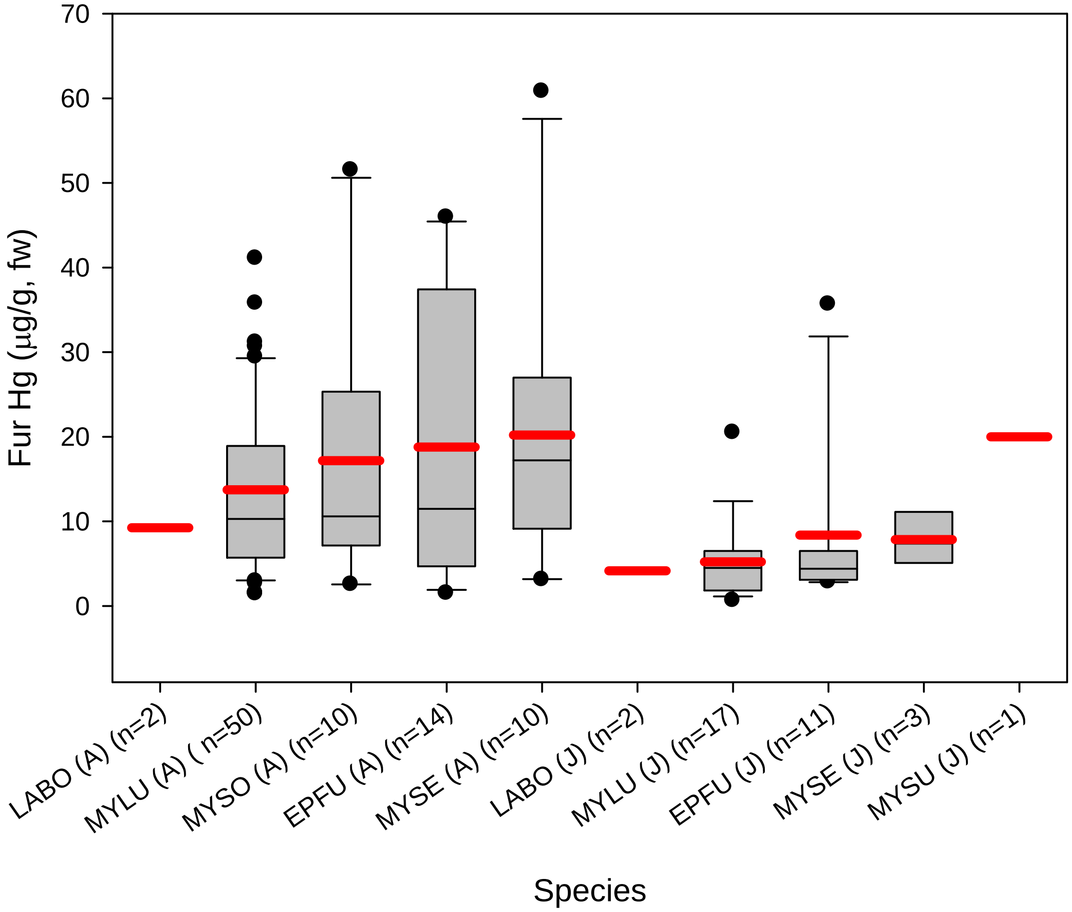

Figure 4. Fur Hg concentration by species caught at Onondaga Lake. LABO= Red bat, MYLU= Little brown, EPFU= Big brown, MYSE= Northern long-eared, MYSO= Indiana bat, MYSU= Eastern pipistrelle. (A) = Adult, (J) = Juvenile. Box represents 25th and 75th percentiles with median (black) and mean (red) shown. Error bars represent 10th and 90th percentiles.

5.3 Mercury Exposure by Species and Sex at Oneida Lake

A Wilcoxon rank sum test was used to compare the fur Hg concentrations between sexes at Oneida Lake; no significant difference between sexes was detected for adults ($p = 0.375$) or juveniles ($p = 0.667$, Table 4).

Table 4. Summary of bat fur (µg Hg/g fur, fw) Hg levels by sex at Oneida Lake.

Sex	Age[1]	n	Mean	Median	Min	Max	sd +/-
F	A	13	7.58	4.57	2.10	24.34	6.84
M	A	5	11.7	6.46	2.59	24.53	10.17
F	J	10	1.78	1.47	0.55	3.46	1.05
M	J	2	2.09	2.09	1.87	2.30	0.30

[1] Age Class: A = adult, J = juvenile

At Oneida Lake, there were only two species caught (little brown bat and big brown bat). A Wilcoxon rank sum test was used to compare fur Hg concentrations between species (Figure 5). There was a significant difference between the Hg concentration in fur of big brown bats and little brown bats for adults (P = 0.010) and juveniles (p = 0.023).

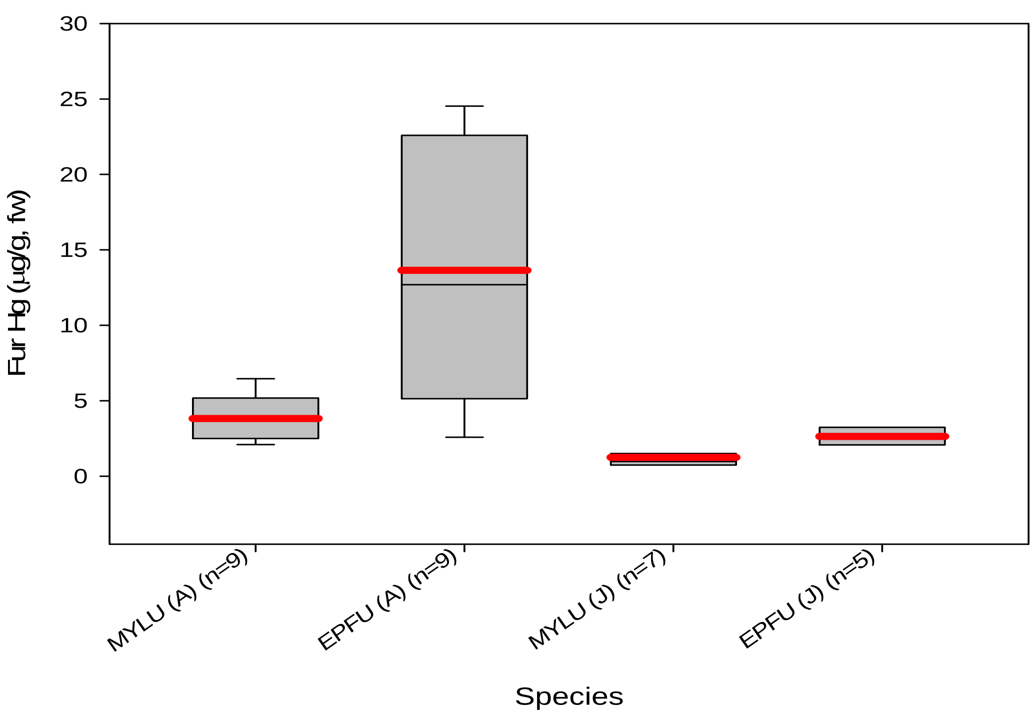

Figure 5. Fur Hg concentration by species caught at Oneida Lake. MYLU= Little brown, EPFU= Big brown. (A) = Adult, (J) = Juvenile. Box represents 25th and 75th percentiles with median (black) and mean (red) shown. Error bars represent 10th and 90th percentiles.

5.4 Onondaga vs. Reference

We pooled fur Hg concentrations across all Onondaga sites and found mean fur Hg levels at Onondaga pooled sites were nearly two times higher for adult bats and nearly four times higher for juvenile bats than at the Oneida Lake reference area (Table 5).

Table 5. Summary of bat fur (μg/g, fw) Hg levels at Onondaga and reference site, 2009.

Site	Age[1]	n	Mean	Median	Min	Max	sd +/-
Onondaga	A	87	15.43	10.92	1.43	60.78	12.95
Oneida	A	18	8.73	5.14	2.1	24.53	7.18
Onondaga	J	34	6.84	5.03	0.63	35.63	7.03
Oneida	J	12	1.82	1.68	0.55	3.46	0.96

[1] Age Class: A = adult, J = juvenile

We used a Wilcoxon rank sum test to assess the difference in bat fur Hg concentrations between the pooled Onondaga sites and the Oneida Lake reference site. We found that the Hg concentration in fur from bats captured at Onondaga Lake was significantly higher than Hg in fur from bats captured at Oneida Lake for adult bats ($p = 0.019$) and juvenile bats ($p = 0.000$, Figure 6).

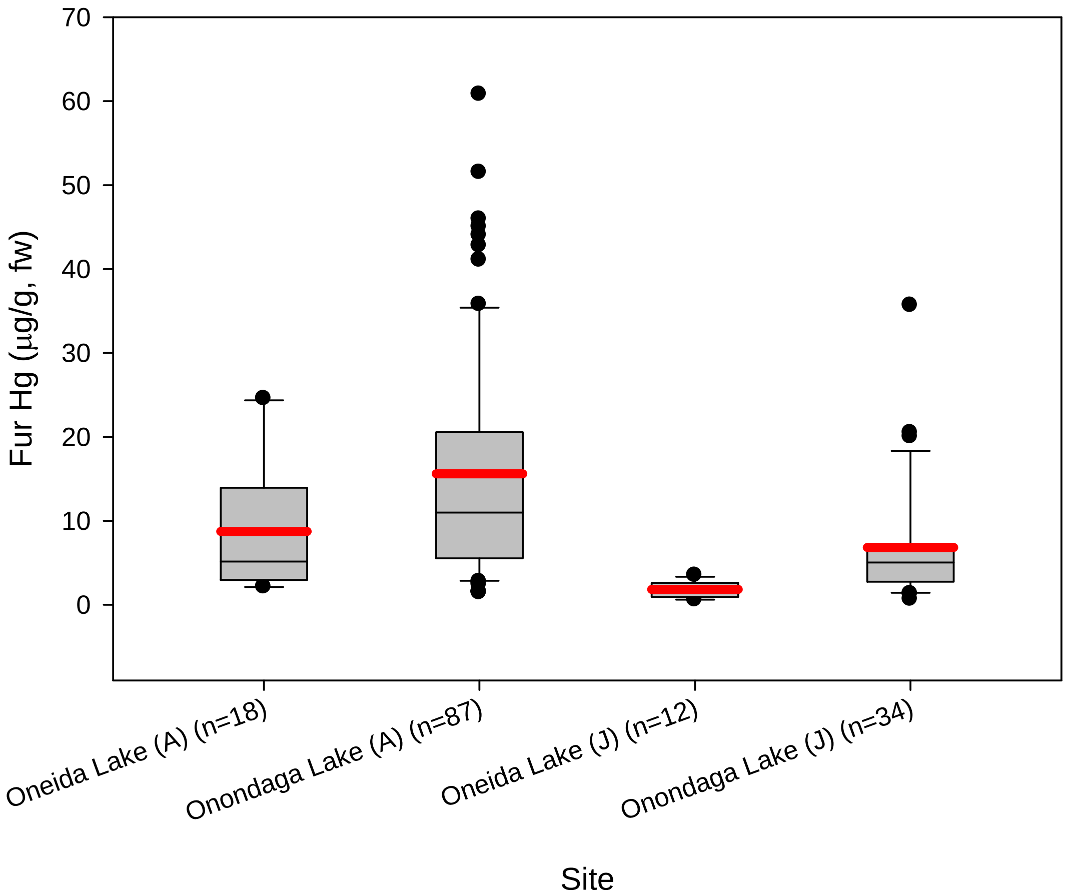

Figure 6. Overall mean fur Hg for combined species by site. (A) = Adult, (J) = Juvenile. Box represents 25th and 75th percentiles with median (black) and mean (red) shown. Error bars represent 10th and 90th percentiles.

Only the little brown bat and big brown bat were caught at both the Oneida Lake reference site and at Onondaga Lake. We used a Wilcoxon rank sum test to assess differences in mean fur Hg levels for little brown and big brown bats between Onondaga Lake and the Oneida Lake reference site. A significant difference was found between sites for fur Hg levels in adult ($p = 0.000$) and juvenile ($p = 0.006$) little brown bats. Big brown bat fur Hg concentrations did not differ significantly between locations for adults ($p = 0.875$); however, there was a significant difference in fur Hg means for juvenile big brown bats ($p = 0.011$).

5.5 Mercury Exposure by Site

We used a Kruskal-Wallis test to compare fur Hg means among the five sites (four at Onondaga Lake and one at Oneida Lake). We found that there was no significant difference among sites in fur Hg concentrations for adult bats ($p = 0.139$); however, there was a significant difference in Hg concentrations for juvenile bats ($p = 0.0009$) between sites (Figure 7, Table 6). Due to a small sample size, we were not able to separate bats by species.

Table 6. Summary of bat fur (μg/g, fw) Hg levels by species and site.

Site	Species	Age	n	Mean	Median	Min	Max	sd +/-
Oneida-Verona SP	EPFU	A	9	13.64	12.69	2.59	24.53	8.54
Oneida-Verona SP	EPFU	J	5	2.64	2.52	1.87	3.46	0.62
Oneida-Verona SP	MYLU	A	9	3.83	3.7	2.1	6.46	1.57
Oneida-Verona SP	MYLU	J	7	1.25	0.97	0.55	2.63	0.70
Onondaga-9 mile creek	MYLU	A	22	15.77	15.62	2.91	41.04	10.10
Onondaga-9 mile creek	MYLU	J	7	2.46	2.40	0.63	5.32	1.56
Onondaga-9 mile creek	MYSU	A	0	~	~	~	~	~
Onondaga-9 mile creek	MYSU	J	1	19.99	19.99	19.99	19.99	~
Onondaga-Oswego River	EPFU	A	8	29.08	31.76	3.74	45.91	16.15
Onondaga-Oswego River	EPFU	J	2	2.95	2.95	2.81	3.09	0.20
Onondaga-Oswego River	MYLU	A	14	7.18	6.31	1.44	17.70	3.93
Onondaga-Oswego River	MYLU	J	1	5.18	5.18	5.18	5.18	~
Onondaga-Oswego River	MYSE	A	4	16.48	17.22	3.10	28.40	10.53
Onondaga-Oswego River	MYSE	J	1	7.38	7.38	7.38	7.38	~
Onondaga-Outlet	LABO	A	0	~	~	~	~	~
Onondaga-Outlet	LABO	J	1	6.05	6.05	6.05	6.05	~
Onondaga-Outlet	MYLU	A	7	8.88	5.62	1.43	24.31	8.95
Onondaga-Outlet	MYLU	J	4	8.53	6.20	1.25	20.48	8.98
Onondaga-Outlet	MYSE	A	6	22.68	17.10	3.85	60.78	20.22
Onondaga-Outlet	MYSE	J	2	8.10	8.10	5.07	11.12	4.28
Onondaga-Outlet	MYSO	A	10	17.18	10.59	2.52	51.48	16.63
Onondaga-Outlet	MYSO	J	0	~	~	~	~	~
Onondaga-Southwest corner	EPFU	A	6	5.01	5.13	1.48	9.18	2.84
Onondaga-Southwest corner	EPFU	J	9	9.58	5.51	2.87	35.63	10.58
Onondaga-Southwest corner	LABO	A	2	9.26	9.26	3.92	14.59	7.54
Onondaga-Southwest corner	LABO	J	1	2.24	2.24	2.24	2.24	~
Onondaga-Southwest corner	MYLU	A	8	22.23	24.41	1.43	31.12	9.42
Onondaga-Southwest corner	MYLU	J	5	6.42	5.74	4.49	9.66	2.08

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

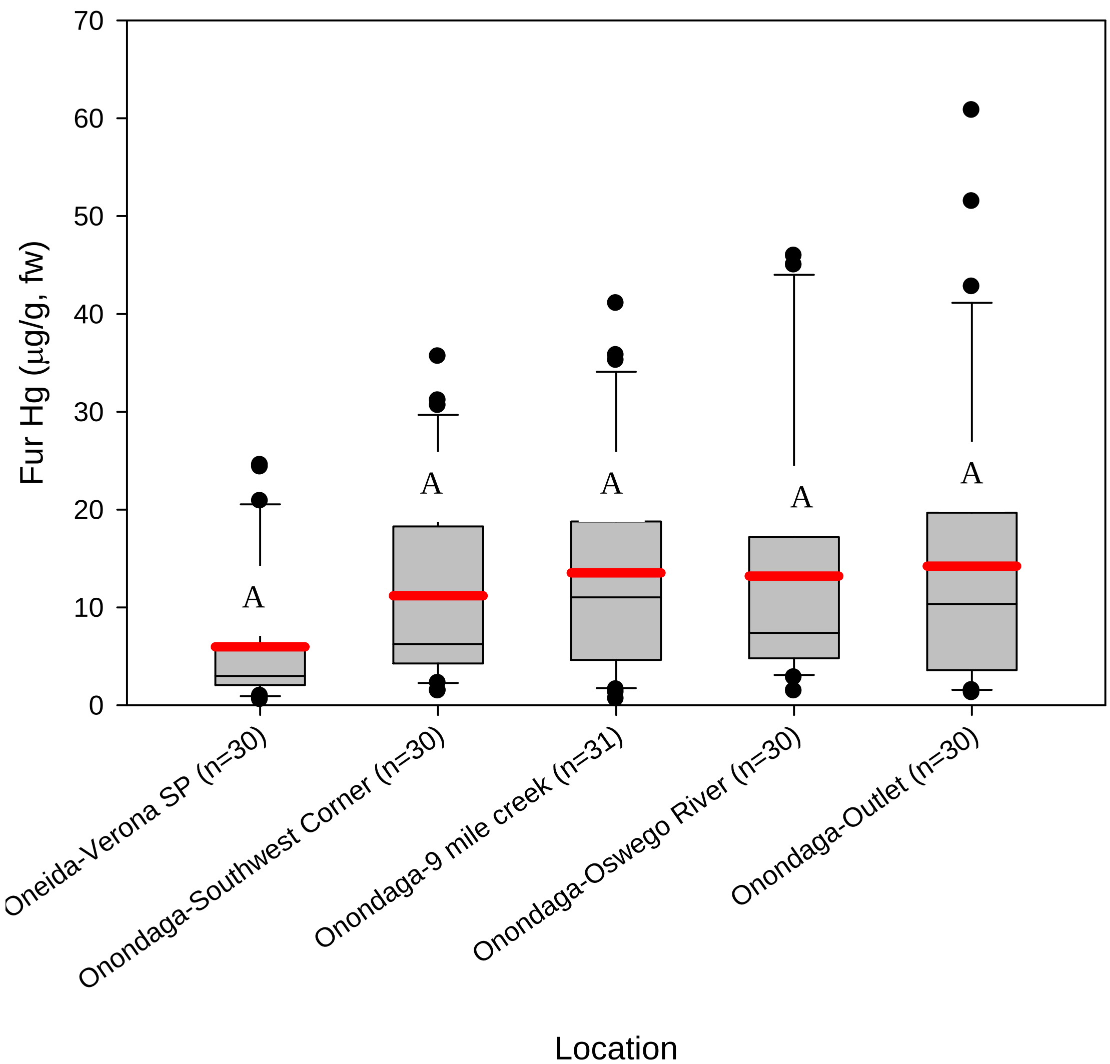

Figure 7. Fur Hg distribution by site, ranked by a Kruskal-Wallis test. Similar letter combinations represent significantly similar results. Box represents 25th and 75th percentiles with median (black) and mean (red) shown. Error bars represent 10th and 90th percentiles.

5.6 Bat Roost Telemetry

Twenty-three bats caught at foraging sites at Onondaga Lake were radio tagged. Sixteen bats were tracked from four of the capture locations back to day roosts (Appendix 3). Five of the tracked bats were Indiana bats, five were northern long-eared bats, five were little brown bats, and one was a big brown bat (Figure 8).

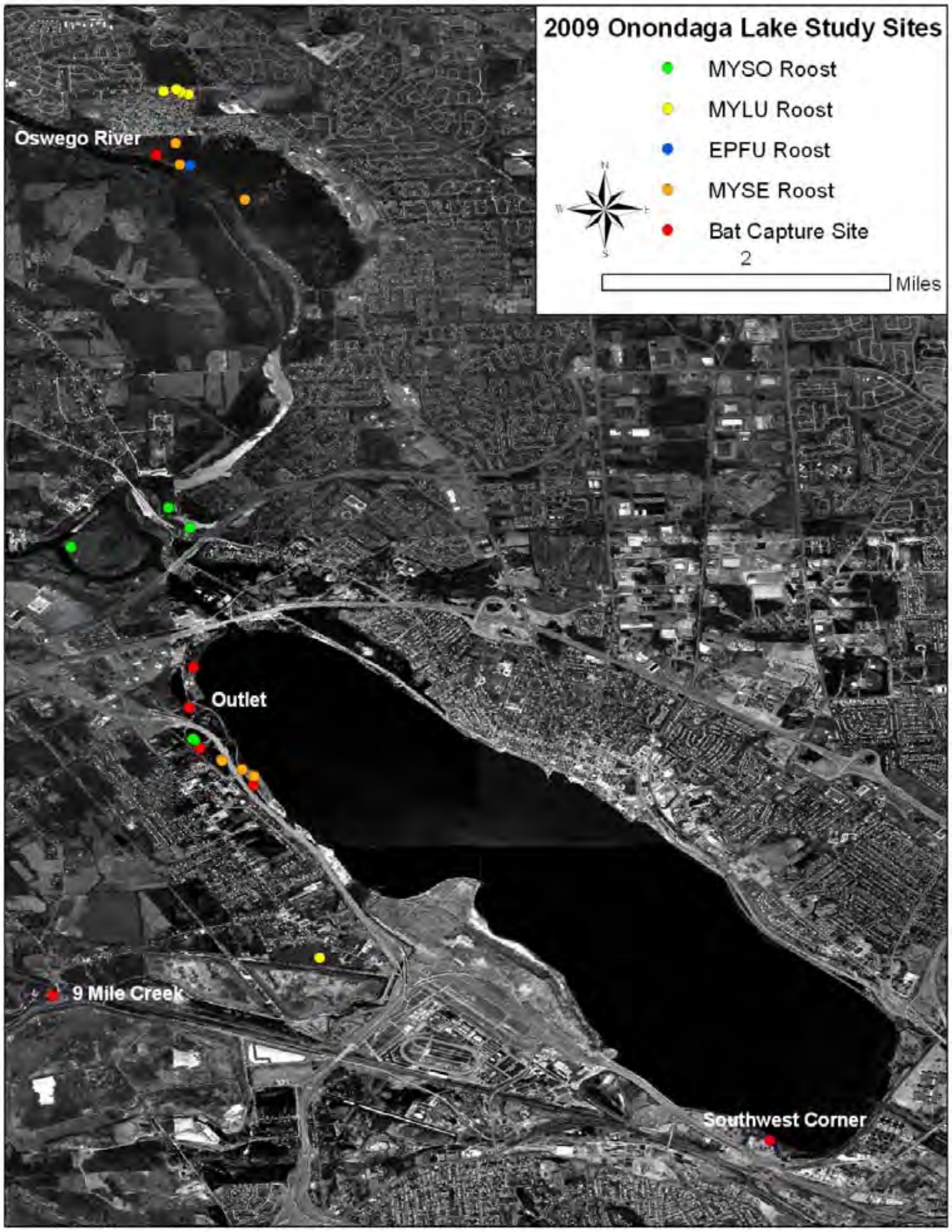

Figure 8. Bat capture locations and roost sites found. MYSO= Indiana bat, MYLU= Little brown bat, EPFU= Big brown bat, MYSE= Northern long-eared bat.

6.0 Discussion

6.1 Evaluation of Hg Concentrations in Study Area Bats

Comparison of Hg fur concentration in bats from Onondaga Lake and the reference area is complicated because of potential species and age difference in fur Hg concentrations. Only little brown bats and big brown bats were collected at both the Onondaga Lake sites and the Oneida Lake reference site. The mean fur Hg concentration in little brown bat adults from all four Onondaga Lake sites was 13.9 μg/g, compared with a 3.8 μg/g mean Hg concentration in the fur of adult little brown bats from the reference site. The mean concentration of Hg in adult big brown bats from Onondaga Lake sites was 21.6 μg/g, compared with a mean Hg concentration of 13.6 μg/g in big brown bats from the reference site.

Although the mean Hg concentrations in fur from these two species is higher at the Onondaga Lake sites than the reference site, it is also informative to note the variability in Hg concentrations. Little brown bat adults at Onondaga Lake had fur Hg concentrations as low as 1.43 μg/g and as high as 41.04 μg/g, compared with reference area adult little brown bats with fur Hg concentrations from 2.10 – 6.46 μg/g. Adult big brown bats from the Onondaga Lake sites had fur Hg concentrations ranging from 3.74 to 45.91 μg/g, compared with a range of 2.59 –24.53 μg/g Hg in the fur of adult big brown bats from the reference site. These data suggest that individual bats foraging at Hg enriched locations around Onondaga Lake may not always have higher Hg concentrations in fur than bats foraging at the Oneida Lake reference site. This may simply reflect natural variation among bats or be an indication that fur Hg concentrations do not always reflect local short-term Hg concentrations in bat prey.

The overall mean Hg concentration in fur of Onondaga Lake adult bats was 13.6 μg/g in females and 18 μg/g in males, compared with 7.6 μg/g Hg in females and 11.7 μg/g Hg in males from the reference site (Tables 3 & 4). These values compare with mean Hg concentrations from a large number of bats sampled throughout New England and the mid-Atlantic states of 7 μg/g for females (n=389) and 10 μg/g (n=213) for males (Osborne et al. 2011).

Ten Onondaga Lake bats had fur Hg in excess of 30 μg/g, the maximum levels found in bat fur from a Hg enriched area in Arkansas (30 μg/g) (Massa and Grippo 2000). None of the Hg fur concentrations in bats from the reference site reached the maximum Hg concentrations in bats from Arkansas. Eight Onondaga Lake bats had fur Hg in excess of concentrations of Hg (33 – 37 μg/g) found in bat fur from an area of Japan sprayed with Hg fungicides (Miura et al. 1978).

Onondaga Lake bats had higher mean concentrations of Hg in fur than bats from the Oneida Lake reference area. Onondaga bats also had fur Hg concentrations in excess of mean fur Hg concentrations in bats from a broad area of the Northeastern United States (as summarized in Osborne et al. 2011). Also, a small percentage (~8%) of Onondaga Lake bats had fur Hg concentrations in excess of 30 μg/g, a concentration of Hg found in bat fur from known Hg-enriched areas in Japan and Arkansas. These data support that Onondaga Lake is a source of Hg to bats.

6.2 Hg Data Comparison with other Bat and Mammal Hg Effect Concentrations

Fifty-three percent of the adult fur Hg levels at Onondaga Lake exceeded the reported level of 10.8 μg/g found to cause behavioral changes in deer mice compared with 28 % of adult bats caught at the Oneida Lake reference site.

Six bats from the Onondaga Lake sites exceeded the 40 μg/g Hg adverse effects threshold for mink fur discussed in Section 3.2. No bats from the reference area exceeded this threshold. Although the 10.8 μg/g fur Hg (deer mouse) and 40 μg/g fur Hg (mink) thresholds are presented here, they may not be appropriate adverse effects thresholds for bats. In the absence of toxicity information on the effects of Hg on bats, these adverse effects Hg thresholds from other species are presented to provide a context for data interpretation.

6.3 Indiana Bats at Onondaga Lake

Eleven Indiana bats were caught during the 2009 sampling period (Appendix 2). We caught two lactating females simultaneously, one of which led us to a maternity roost. 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 (Humphrey et al. 1977, Gardner et al. 1991, Kurta et al. 1993, Britzke et al. 2003). 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' site fidelity is high and many return to the same maternity colony each year (Kurta and Murray 2002), which may increase the total Hg load over a lifetime for bats roosting within contaminated areas. The Indiana bats at Onondaga are likely site fidelic because of available roost trees and favorable habitat.

7.0 Conclusions

A comparison of sites at Onondaga Lake to the Oneida Lake reference area demonstrates significantly greater fur Hg concentrations in bats from Onondaga Lake. Bat fur mean Hg concentrations were nearly two times higher for adult bats and nearly four times higher for juveniles at Onondaga Lake compared to the Oneida Lake samples when all species were pooled. The mean Hg concentration in Onondaga Lake bats is about double the mean Hg concentration in bats sampled in New England and the mid-Atlantic states (Osborne et al. 2011).

Approximately 53% of the adult bats (42% of combined juvenile and adult bats) captured at Onondaga Lake in 2009 had fur Hg concentrations that exceeded a deer mouse fur LOAEL of 10.8 μg/g (fw) (Burton et al. 1977). Approximately 28% of adult bats (17 % of combined juvenile and adult bats) captured at the reference site had fur Hg concentrations in excess of a deer mouse fur LOAEL of 10.8 μg/g (Burton et al. 1977). See Appendix A.

A few bats from Onondaga Lake, but not the reference site, also had fur Hg concentrations that exceeded an adverse effects threshold for mink (40 – 50 μg/g Hg).

Bats are increasingly of high conservation concern to biological agencies and other entities. Mercury is an 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 1 – 3 years. Therefore, high resolution investigations to determine spatially explicit Hg effects on reproductive success, survival, and physiological effects are of even greater importance.

8.0 Acknowledgements

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Appendix 1. List of samples with Hg results from bats sampled at Onondaga Lake and reference sites, 2009.

Site name	Location	Date	Species[1]	Sex	Age[2]	Repro. Status[3]	RS[4]	FA (mm)[5]	weight (g)	band #	Fur Hg[6]
9 mile creek	Onondaga	7/5/2009	MYLU	F	J	NR	0	35.5	6.8	NYSDEC31531	0.63
9 mile creek	Onondaga	7/5/2009	MYLU	M	J	NR	0	38	6.4	NYSDEC31530	1.29
9 mile creek	Onondaga	7/5/2009	MYLU	F	J	NR	0	34.7	6.5	NYSDEC31534	2.40
9 mile creek	Onondaga	7/5/2009	MYLU	F	A	NR	1	36	8.4	NYSDEC31535	2.91
9 mile creek	Onondaga	7/5/2009	MYLU	F	J	NR	0	35.8	7.4	NYSDEC31525	3.41
9 mile creek	Onondaga	7/5/2009	MYLU	F	A	L	1	37.1	8.5	NYSDEC31539	4.63
9 mile creek	Onondaga	7/5/2009	MYLU	F	A	L	1	39.2	9.5	NYSDEC31537	7.21
9 mile creek	Onondaga	7/5/2009	MYLU	F	A	L	0	37.8	9.2	NYSDEC31536	8.24
9 mile creek	Onondaga	7/5/2009	MYLU	M	A	NR	0	34.6	7	NYSDEC31528	11.03
9 mile creek	Onondaga	7/5/2009	MYLU	M	A	NR	0	37.9	7.4	NYSDEC31527	15.14
9 mile creek	Onondaga	7/5/2009	MYLU	F	A	L	1	34.7	7	NYSDEC31533	17.15
9 mile creek	Onondaga	7/5/2009	MYSU	M	J	NR	0	32.9	6.4	NYSDEC31529	19.99
9 mile creek	Onondaga	7/5/2009	MYLU	F	A	L	0	35.8	8.2	NYSDEC31538	29.41
9 mile creek	Onondaga	7/5/2009	MYLU	F	A	L	1	37.7	7.7	NYSDEC31526	35.74
9 mile creek	Onondaga	7/6/2009	MYLU	F	J	NR	0	36.9	8	NYSDEC31543	2.56
9 mile creek	Onondaga	7/6/2009	MYLU	F	A	L	1	35.9	9	NYSDEC31541	6.83
9 mile creek	Onondaga	7/6/2009	MYLU	F	A	L	0	35.6	9.8	NYSDEC31540	9.64
9 mile creek	Onondaga	7/6/2009	MYLU	F	A	L	0	37.9	9.7	NYSDEC31542	17.84
9 mile creek	Onondaga	7/19/2009	MYLU	M	J	NR	0	37.7	7.5	DEY0885	1.59
9 mile creek	Onondaga	7/19/2009	MYLU	F	J	NR	0	36.3	7.8	DEY0886	5.32

[1] MYLU=little brown; EPFU=big brown; LABO=red; MYSE=northern long-eared; MYSO=Indiana; MYSU=eastern pipistrelle
2 Age classes: J = Juvenile; A = Adult
[3] Reproductive status: NR = non-reproductive; L = lactating; PL = post-lactating; P = pregnant
[4] Riecher scale for membrane damage due to white nose syndrome: 0-4
[5] Forearm length (mm)
[6] Fur mercury levels (μg/g (fw))

9 mile creek	Onondaga	7/19/2009	MYLU	F	A	PL	1	36.8	8.3	DEY0896	6.68
9 mile creek	Onondaga	7/19/2009	MYLU	F	A	PL	0	38.2	8.7	DEY0893	6.72
9 mile creek	Onondaga	7/19/2009	MYLU	F	A	PL	1	40.1	9.1	DEY0889	11.41
9 mile creek	Onondaga	7/19/2009	MYLU	F	A	PL	0	36.5	8.3	DEY0895	16.11
9 mile creek	Onondaga	7/19/2009	MYLU	F	A	PL	0	36.4	10	DEY0891	16.28
9 mile creek	Onondaga	7/19/2009	MYLU	F	A	PL	0	38	8.8	DEY0890	16.95
9 mile creek	Onondaga	7/19/2009	MYLU	F	A	PL	0	38.4	9.5	DEY0894	18.76
9 mile creek	Onondaga	7/19/2009	MYLU	F	A	PL	1	37.3	8.9	DEY0887	19.34
9 mile creek	Onondaga	7/19/2009	MYLU	F	A	PL	0	37.7	9.4	DEY0892	27.93
9 mile creek	Onondaga	7/19/2009	MYLU	F	A	PL	1	37.3	9.5	DEY0888	41.04
Oswego River	Onondaga	6/29/2009	MYLU	F	A	L	0	35.8	8.4	NYSDEC31511	4.85
Oswego River	Onondaga	6/29/2009	MYLU	F	A	L	0	35.8	7.7	NYSDEC31513	5.06
Oswego River	Onondaga	6/29/2009	MYLU	F	A	L	1	38.7	8.3	NYSDEC31512	5.18
Oswego River	Onondaga	6/29/2009	MYLU	F	A	NR	0	38.3	7.8	NYSDEC31515	5.73
Oswego River	Onondaga	6/29/2009	MYLU	M	A	NR	0	36	6.7	NYSDEC31510	6.89
Oswego River	Onondaga	6/29/2009	MYLU	M	A	NR	1	38.1	7.3	NYSDEC31516	7.13
Oswego River	Onondaga	6/29/2009	MYLU	F	A	NR	0	36.1	8	NYSDEC31518	7.76
Oswego River	Onondaga	6/29/2009	MYLU	F	A	L	0	36.5	7.9	NYSDEC31514	9.40
Oswego River	Onondaga	6/29/2009	MYLU	F	A	L	0	37.3	8	NYSDEC31519	10.95
Oswego River	Onondaga	6/29/2009	MYLU	F	A	L	0	37.1	8.9	NYSDEC31517	17.70
Oswego River	Onondaga	6/30/2009	MYLU	F	A	L	0	37.4	8.2	NYSDEC31521	4.09
Oswego River	Onondaga	6/30/2009	MYLU	F	A	L	1	38.3	9.5	NYSDEC31522	4.75
Oswego River	Onondaga	7/1/2009	MYLU	F	A	L	0	39.5	8.4	NYSDEC31523	1.44
Oswego River	Onondaga	7/1/2009	MYLU	F	A	L	0	34.6	7.7	NYSDEC31520	9.58
Oswego River	Onondaga	7/1/2009	EPFU	M	A	NR	0	45.8	18.5	NYSDEC32352	35.23
Oswego River	Onondaga	7/1/2009	EPFU	M	A	NR	1	42.3	15.9	NYSDEC32353	45.91
Oswego River	Onondaga	7/10/2009	EPFU	M	J	NR	0	45.8	16.4	NYSDEC32358	2.81
Oswego River	Onondaga	7/10/2009	EPFU	M	J	NR	1	45.5	15.9	NYSDEC32359	3.09

Oswego River	Onondaga	7/10/2009	MYSE	M	A	NR	1	36	6.3	NYSDEC31544	3.10
Oswego River	Onondaga	7/10/2009	MYSE	M	J	NR	0	33	4.4	NYSDEC31546	7.38
Oswego River	Onondaga	7/10/2009	EPFU	F	A	NR	1	42.7	15.6	NYSDEC32354	13.80
Oswego River	Onondaga	7/10/2009	MYSE	F	A	L	0	37.4	5.8	NYSDEC31547	14.94
Oswego River	Onondaga	7/10/2009	EPFU	F	A	L	1	45	17.8	NYSDEC32357	16.69
Oswego River	Onondaga	7/10/2009	EPFU	M	A	NR	1	45.6	20.4	NYSDEC32355	28.28
Oswego River	Onondaga	7/10/2009	MYSE	F	A	L	1	37.5	7	NYSDEC31545	28.40
Oswego River	Onondaga	7/10/2009	EPFU	M	A	NR	1	44	18.2	NYSDEC32356	43.99
Oswego River	Onondaga	7/13/2009	EPFU	F	A	L	1	46.6	21.4	NYSDEC32360	3.74
Oswego River	Onondaga	7/13/2009	MYLU	F	J	NR	0	39.8	7.9	NYSDEC31548	5.18
Oswego River	Onondaga	7/13/2009	EPFU	F	A	L	1	46.1	21.3	NYSDEC32361	44.97
Oswego River	Onondaga	7/23/2009	MYSE	F	A	NR	1	36.5	6.8	DEY0913	19.49
Outlet	Onondaga	6/22/2009	MYLU	M	A	NR	1	37.6	8.4	DEY0877	2.65
Outlet	Onondaga	6/22/2009	MYSO	F	A	P	0	38.5	11	DEY0876	19.50
Outlet	Onondaga	6/23/2009	MYLU	M	A	NR	1	37.6	7.6	NYSDEC31501	1.43
Outlet	Onondaga	6/23/2009	MYLU	M	A	NR	1	37.4	8.1	NYSDEC31504	1.51
Outlet	Onondaga	6/23/2009	MYSO	F	A	P	1	39.2	10.2	NYSDEC31506	2.52
Outlet	Onondaga	6/23/2009	MYSO	F	A	NR	1	38.2	8.1	NYSDEC31508	2.72
Outlet	Onondaga	6/23/2009	MYSO	F	A	P	0	40	9.9	NYSDEC31502	8.62
Outlet	Onondaga	6/23/2009	MYSO	F	A	P	1	38	9.9	NYSDEC31507	10.30
Outlet	Onondaga	6/23/2009	MYSO	F	A	P	0	40.1	10.6	NYSDEC31505	10.88
Outlet	Onondaga	6/23/2009	MYLU	F	A	L	0	37.5	7.3	NYSDEC31500	18.00
Outlet	Onondaga	6/23/2009	MYSE	M	A	NR	0	35.2	6.5	NYSDEC31503	60.78
Outlet	Onondaga	7/15/2009	MYLU	F	A	PL	0	37.7	9.4	DEY0884	24.31
Outlet	Onondaga	7/22/2009	LABO	M	J	NR	0	40.1	13.7	NYSDEC32377	6.05
Outlet	Onondaga	7/25/2009	MYLU	F	J	NR	0	38.5	8.3	DEY0918	1.25
Outlet	Onondaga	7/25/2009	MYLU	F	J	NR	1	32.5	6.2	DEY0922	2.03
Outlet	Onondaga	7/25/2009	MYLU	M	A	NR	1	35.1	7	DEY0917	5.62

Outlet	Onondaga	7/25/2009	MYLU	M	A	NR	0	36.2	7.2	DEY0914	8.65
Outlet	Onondaga	7/25/2009	MYLU	M	J	NR	0	38.9	7.7	DEY0915	10.36
Outlet	Onondaga	7/25/2009	MYSO	M	A	NR	1	39.9	7.4	DEY0916	12.77
Outlet	Onondaga	7/25/2009	MYSE	M	A	NR	0	37.4	6.6	DEY0920	13.85
Outlet	Onondaga	7/25/2009	MYSE	M	A	NR	0	35.9	5.9	DEY0919	20.17
Outlet	Onondaga	7/25/2009	MYSO	M	A	NR	1	39	8.4	DEY0921	51.48
Outlet	Onondaga	7/27/2009	MYSE	M	A	NR	1	35.6	5.6	DEY0927	3.85
Outlet	Onondaga	7/27/2009	MYSE	F	J	NR	1	35.9	5.6	DEY0931	5.07
Outlet	Onondaga	7/27/2009	MYSO	F	A	NR	0	39.2	7.2	DEY0934	10.23
Outlet	Onondaga	7/27/2009	MYSE	M	A	NR	0	35	6.1	DEY0928	10.91
Outlet	Onondaga	7/27/2009	MYSE	M	J	NR	1	36	6.2	DEY0929	11.12
Outlet	Onondaga	7/27/2009	MYLU	F	J	NR	1	37.2	7.3	DEY0933	20.48
Outlet	Onondaga	7/27/2009	MYSE	M	A	NR	1	36.3	6.3	DEY0932	26.53
Outlet	Onondaga	7/27/2009	MYSO	M	A	NR	0	38.5	7.6	DEY0926	42.75
Southwest corner	Onondaga	6/26/2009	EPFU	M	A	NR	0	44.5	14.9	NYSDEC32351	5.00
Southwest corner	Onondaga	6/26/2009	EPFU	M	A	NR	0	45.6	14.5	NYSDEC32350	5.25
Southwest corner	Onondaga	6/26/2009	MYLU	M	A	NR	0	40	8.1	NYSDEC31509	18.27
Southwest corner	Onondaga	7/2/2009	MYLU	F	J	NR	0	37.5	8.5	NYSDEC31524	4.49
Southwest corner	Onondaga	7/14/2009	LABO	M	J	NR	0	38.3	11.3	NYSDEC32362	2.24
Southwest corner	Onondaga	7/14/2009	MYLU	F	J	NR	0	39	7.5	DEY0880	5.74
Southwest corner	Onondaga	7/14/2009	MYLU	M	J	NR	0	36.4	6.9	NYSDEC32549	9.66
Southwest corner	Onondaga	7/14/2009	MYLU	M	A	NR	1	36.4	8	DEY0879	23.86
Southwest corner	Onondaga	7/14/2009	MYLU	M	A	NR	1	37.9	8	DEY0881	24.95
Southwest	Onondaga	7/14/2009	MYLU	M	A	NR	1	34.6	8.4	DEY0878	25.93

corner											
Southwest corner	Onondaga	7/14/2009	MYLU	M	A	NR	1	36.9	8.4	DEY0882	30.61
Southwest corner	Onondaga	7/14/2009	MYLU	M	A	NR	0	36.1	7.5	DEY0883	31.12
Southwest corner	Onondaga	7/14/2009	MYLU	M	A	NR	1			NYSDEC31501	
Southwest corner	Onondaga	7/26/2009	EPFU	M	A	NR	1	45.1	15.3	NYSDEC32391	1.48
Southwest corner	Onondaga	7/26/2009	EPFU	M	A	NR	1	45.5	16.8	NYSDEC32383	2.34
Southwest corner	Onondaga	7/26/2009	EPFU	M	J	NR	1	45.2	17.2	NYSDEC32387	2.87
Southwest corner	Onondaga	7/26/2009	LABO	M	A	NR	0	39.7	11.9	NYSDEC32378	3.92
Southwest corner	Onondaga	7/26/2009	EPFU	M	J	NR	0	45.5	16	NYSDEC32382	4.17
Southwest corner	Onondaga	7/26/2009	EPFU	F	J	NR	1	44	18.2	NYSDEC32381	4.26
Southwest corner	Onondaga	7/26/2009	EPFU	M	J	NR	1	45.3	15	NYSDEC32392	4.40
Southwest corner	Onondaga	7/26/2009	MYLU	F	J	NR	0	38	6.4	DEY0924	4.99
Southwest corner	Onondaga	7/26/2009	EPFU	M	J	NR	1	43.5	16.5	NYSDEC32385	5.51
Southwest corner	Onondaga	7/26/2009	EPFU	F	J	NR	1	45	18.3	NYSDEC32384	6.25
Southwest corner	Onondaga	7/26/2009	EPFU	F	J	NR	1	47.4	16.4	NYSDEC32388	6.48
Southwest corner	Onondaga	7/26/2009	EPFU	F	A	P	1	45.6	19.4	NYSDEC32379	6.83
Southwest corner	Onondaga	7/26/2009	MYLU	F	J	NR	0	36.7	7.2	DEY0925	7.23
Southwest corner	Onondaga	7/26/2009	EPFU	M	A	NR	1	42.6	17.8	NYSDEC32390	9.18
Southwest corner	Onondaga	7/26/2009	LABO	F	A	NR	0	41.1	17.9	NYSDEC32386	14.59

Southwest corner	Onondaga	7/26/2009	EPFU	M	J	NR	1	45.9	17.6	NYSDEC32389	16.67
Southwest corner	Onondaga	7/26/2009	MYLU	M	A	NR	1	37.1	6.8	DEY0923	21.70
Southwest corner	Onondaga	7/26/2009	EPFU	M	J	NR	1	45.7	17.3	NYSDEC32380	35.63
Verona SP	Oneida	7/20/2009	MYLU	F	J	NR	1	37.7	6.7	DEY0909	0.55
Verona SP	Oneida	7/20/2009	MYLU	F	J	NR	0	38.3	7	DEY0901	0.74
Verona SP	Oneida	7/20/2009	MYLU	F	J	NR	0	37.5	6.7	DEY0898	0.93
Verona SP	Oneida	7/20/2009	MYLU	F	J	NR	0	37.4	6.1	DEY0900	0.97
Verona SP	Oneida	7/20/2009	MYLU	F	J	NR	0	37.3	6.3	DEY0902	1.43
Verona SP	Oneida	7/20/2009	MYLU	F	J	NR	1	38	7.1	DEY0904	1.50
Verona SP	Oneida	7/20/2009	EPFU	M	J	NR	1	46	15.3	NYSDEC32374	1.87
Verona SP	Oneida	7/20/2009	MYLU	F	A	PL	0	36.8	8	DEY0899	2.10
Verona SP	Oneida	7/20/2009	MYLU	F	A	PL	0	36.7	7.9	DEY0908	2.11
Verona SP	Oneida	7/20/2009	EPFU	M	J	NR	2	43.7	13.4	NYSDEC32370	2.30
Verona SP	Oneida	7/20/2009	EPFU	F	J	NR	0	45.7	15.8	NYSDEC32376	2.52
Verona SP	Oneida	7/20/2009	EPFU	M	A	NR	2	45.2	16.4	NYSDEC32366	2.59
Verona SP	Oneida	7/20/2009	MYLU	F	J	NR	1	38.2	8	DEY0911	2.63
Verona SP	Oneida	7/20/2009	MYLU	F	A	PL	0	38.1	9.8	DEY0912	2.91
Verona SP	Oneida	7/20/2009	MYLU	F	A	PL	0	37.8	8	DEY0907	2.96
Verona SP	Oneida	7/20/2009	EPFU	F	J	NR	1	44.5	14.9	NYSDEC32373	3.03
Verona SP	Oneida	7/20/2009	EPFU	F	J	NR	0	47	14.7	NYSDEC32367	3.46
Verona SP	Oneida	7/20/2009	MYLU	F	A	PL	0	37	7.8	DEY0910	3.70
Verona SP	Oneida	7/20/2009	MYLU	F	A	PL	0	37.7	8.6	DEY0905	3.84
Verona SP	Oneida	7/20/2009	MYLU	M	A	NR	0	36.9	7.1	DEY0897	4.27
Verona SP	Oneida	7/20/2009	EPFU	F	A	PL	0	44.5	19.5	NYSDEC32369	4.57
Verona SP	Oneida	7/20/2009	EPFU	F	A	PL	1	45.2	19.4	NYSDEC32375	5.70
Verona SP	Oneida	7/20/2009	MYLU	F	A	PL	0	39	8.7	DEY0906	6.10
Verona SP	Oneida	7/20/2009	MYLU	M	A	NR	1	36.4	7.2	DEY0903	6.46

Verona SP	Oneida	7/20/2009	EPFU	F	A	PL	1	46	17.7	NYSDEC32363	9.83
Verona SP	Oneida	7/20/2009	EPFU	F	A	L	2	49.2	21.5	NYSDEC32368	12.69
Verona SP	Oneida	7/20/2009	EPFU	F	A	L	1	47.4	23	NYSDEC32371	17.66
Verona SP	Oneida	7/20/2009	EPFU	M	A	NR	2	44.4	17.3	NYSDEC32372	20.85
Verona SP	Oneida	7/20/2009	EPFU	F	A	NR	0	43.8	17.7	NYSDEC32365	24.34
Verona SP	Oneida	7/20/2009	EPFU	M	A	NR	1	45.4	17.4	NYSDEC32364	24.53

Appendix 2. Indiana bat capture log of bats captured at Onondaga Lake, 2009.

Site name	Date	Lat	Long	Sex	Age[7]	Repro. Status[8]	RS[9]	FA (mm)[10]	weight (g)	band #	transmitter freq.
Outlet	7/25/2009	43.10357	76.24647	M	A	NR	1	39.9	7.4	DEY0916	219.052
Outlet	7/25/2009	43.10357	76.24647	M	A	NR	1	39	8.4	DEY0921	219.092
Outlet	7/27/2009	43.10766	76.24752	M	A	NR	0	38.5	7.6	DEY0926	219.172
Outlet	7/27/2009	43.10766	76.24752	F	A	NR	0	39.2	7.2	DEY0934	219.206
Outlet	6/23/2009	43.09986	76.24110	F	A	P	0	40.1	10.6	NYSDEC31505	219.506
Outlet	6/23/2009	43.09986	76.24110	F	A	P	0	40	9.9	NYSDEC31502	219.557
Outlet	6/23/2009	43.09986	76.24110	F	A	P	0	38.5	10.8	DEY0876	219.625
Outlet	6/22/2009	43.11170	76.24712	F	A	P	0	38.5	11	DEY0876	
Outlet	6/23/2009	43.09986	76.24110	F	A	P	1	39.2	10.2	NYSDEC31506	
Outlet	6/23/2009	43.09986	76.24110	F	A	P	1	38	9.9	NYSDEC31507	
Outlet	6/23/2009	43.09986	76.24110	F	A	NR	1	38.2	8.1	NYSDEC31508	

[7] Age class: A = Adult
[8] Reproductive status: NR = non-reproductive; P = pregnant
[9] Riecher scale for membrane damage due to white nose syndrome: 0-4
[10] Forearm length (mm)

Appendix 3. Transmitter frequencies and locations for bats tracked to day roosts around Onondaga Lake, 2009.

Trans. #	Species[11]	Sex	Age[12]	Date	Tracking Method	Location[13]	Lat	Long	Actual or estimated[14]
219.024	MYSE	F	A	7/25/09	boat and foot	*undefined*	43.16236	76.24848	estimated
219.052	MYSO	M	A	7/26/09	boat and foot	*undefined*	43.12576	76.24748	estimated
219.073	MYSE	M	A	7/26/09	truck and foot	swamp near highway	43.10241	76.24429	actual
219.073	MYSE	M	A	7/28/09	truck and foot	swamp near highway	43.10229	76.24425	actual
219.092	MYSO	M	A	7/26/09	truck and foot	swamp near lake	43.10434	76.24693	actual
219.092	MYSO	M	A	7/28/09	truck and foot	swamp near lake	43.10449	76.24717	actual
219.172	MYSO	M	A	7/28/09	truck and foot	swamp near lake	43.10449	76.24717	actual
219.256	MYSE	F	A	7/17/09	boat and foot	*undefined*	43.15886	76.24195	estimated
219.289	MYSE	M	A	7/1/09	truck and foot	trailer park woods	43.16450	76.24886	estimated
219.322	EPFU	M	A	7/11/09	boat and foot	*undefined*	43.16232	76.24744	estimated
219.406	MYLU	F	A	6/30/09	truck and foot	casual estates	43.16943	76.24757	actual
219.406	MYLU	F	A	7/2/09	truck and foot	casual estates	43.16970	76.24838	actual
219.442	MYLU	F	A	6/30/09	truck and foot	casual estates	43.16993	76.24881	actual
219.466	MYLU	M	A	7/1/09	truck and foot	casual estates	43.16977	76.25014	actual
219.506	MYSO	F	A	7/3/09	boat and foot	Klein Island	43.12384	76.25945	estimated
219.593	MYLU	F	A	6/25/09	truck and foot	Pope's grove golf course	43.08239	76.23440	estimated
219.625	MYSO	F	A	7/4/09	truck and foot	Grenadier Village	43.12773	76.24959	estimated
219.655	MYSE	M	A	6/25/09	truck and foot	cottonwood stand	43.10143	76.24224	estimated
219.655	MYSE	M	A	7/1/09	truck and foot	cottonwood stand	43.10075	76.24103	actual
219.707	MYLU	F	J	7/4/09	truck and foot	Pope's grove golf course	43.08239	76.23440	actual

[11] MYLU=little brown; EPFU=big brown; MYSE=northern long-eared; MYSO=Indiana
[12] Age class: A = Adult; J = Juvenile
[13] Descriptive location of day roost; undefined = no description available
[14] Estimated = day roost location approximated due to inaccessibility; actual = day roost location verified