2008-2009

ASSESSMENT OF MERCURY IN BIRDS AT ONONDAGA LAKE: 2008-2009 BREEDING SEASON FINAL REPORT

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Biodiversity Research Institute

ASSESSMENT OF MERCURY IN BIRDS AT ONONDAGA LAKE:

2008-2009 BREEDING SEASON FINAL REPORT

BRI Report #2011-17

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Biodiversity Research Institute (BRI) is a 501(c)3 nonprofit organization located in Gorham, Maine. Founded in 1998, BRI is dedicated toward supporting global health through collaborative ecological research, assessment of ecosystem health, improving environmental awareness, and informing science based decision making.

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FRONT PHOTO CAPTION (EDMONDS)*: Left: Male red-winged blackbird captured on Onondaga Lake. Right: Mistnetting birds on Onondaga Lake*

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List of Acronyms

ANOVA	analysis of variance
BERA	Baseline Ecological Risk Assessment
BRI	Biodiversity Research Institute
CI	Confidence Interval
dw	dry weight
HSD	honestly significant difference
ww	wet weight
fw	fresh weight
Hg	mercury
MeHg	methylmercury
NPL	National Priorities List
NYSDEC	New York State Department of Environmental Conservation

NRDA	Natural Resource Damage Assessment
RWBL	red-winged blackbird
SOSP	song sparrow
SPSA	spotted sandpiper
TERL	Trace Element Research Laboratory
TRES	tree swallow
WMRL	wildlife mercury research laboratory
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service

Executive Summary

The 2008 pilot study conducted by Biodiversity Research Institute (BRI) demonstrated that mercury (Hg) concentrations in all target bird species were significantly higher on Onondaga Lake than the reference site on Oneida Lake (Lane et al. 2011). The Hg exposure assessment in birds breeding on Onondaga and Oneida Lakes was continued in 2009. Findings from the 2008 and the 2009 breeding season indicate that a number of songbirds and most breeding shorebirds sampled had blood Hg concentrations that exceed recently proposed effect levels for songbirds. These effect levels are based on Carolina wren (*Thryothorus ludovicianus*) data (Jackson et al. 2011) and tree swallow (*Tachycineta bicolor*) reproductive effect levels proposed in the 2008 report (Lane et al. 2011) that point to a blood Hg threshold effect level of about 0.70 and 0.63 µg/g respectively. We generally use 0.70 µg/g as an effect level in this report as it is based on a field study presented in the peer-reviewed literature (Jackson et al. 2011). At this time we are unaware of a more appropriate published effects threshold for the effects of Hg on songbirds. We recognize that effect levels will vary by species and by individual characteristics such as age or sex. One of the most comprehensive studies of the variability in avian species sensitivity to Hg was conducted by Heinz et al. (2009). These authors injected Hg into the eggs of 26 bird species and documented egg mortality. The tree swallow was found to be moderately sensitive to Hg, more sensitive than species such as the mallard and hooded merganser, but less sensitive than species such as the American kestrel and osprey. Heinz et al. (2009) did not evaluate the sensitivity of the Carolina wren or other wren species to injected Hg.

The Carolina wren effect concentration used here is associated with modeled reduction in nest success. A nest was defined as successful if it fledged at least one young. The effect levels were based on a 10% and 20% reduction in nest success at 0.70 µg/g and 1.2 µg/g, respectively, in adult Carolina wren blood Hg. The blood Hg concentrations associated with a 10% and 20% reduction in nest success for Carolina wrens correspond to 0.11 µg/g and 0.2 µg/g Hg (wet weight) in eggs and 3.0 µg/g and 4.7 µg/g Hg (fresh weight) in tail feathers (Jackson et al. 2011). Extrapolating the model to higher mercury values predicts 99% reduction in reproductive success at blood concentrations of 5.6 µg/g, body feather concentrations of 12.8 µg/g, tail feather concentrations of 19.5 µg/g, and egg concentrations of 0.97 µg/g (Jackson et al. 2011). Of 367 invertivorous birds sampled in 2008 and 2009 from Onondaga Lake, 117 (32%) had blood Hg concentrations exceeding the 0.70 µg/g effect level for Carolina wrens and 75 birds (20%) exceeded the 1.2 µg/g Hg effect level associated with a predicted 20% nesting success reduction for the Carolina wren. Of 19 adult spotted sandpipers (*Actitis macularius*) sampled in 2008-2009, 17 (89%) exceeded the lowest effect level for blood Hg in Carolina wrens (0.7 µg/g) and 10 of 19 (53%) had Hg concentrations in blood in excess of 1.2 µg/g.

We analyzed tail feather Hg from selected species (American redstart, *Setophaga ruticilla*; red-winged blackbird, *Agelaius phoeniceus*; common grackle, *Quiscalus quiscula*; song sparrow, *Melospiza melodia*; and spotted sandpiper). Twenty of 122 tail feathers (16%) exceeded 3.0 µg/g Hg and 16 (13%) exceeded 4.7 µg/g Hg (associated with 10% and 20% reduction in nest success in Carolina wrens, respectively). Twenty-two of 53 tree swallow eggs (42%) exceeded 0.11 µg/g-Hg, four of which (8%) exceeded 0.20 µg/g-Hg (associated with 10% and 20% reduction in nest success in Carolina wrens, respectively). Only two of 15 (13%) red-winged blackbird eggs were over the 0.11 µg/g-Hg, with one exceeding 0.20 µg/g-Hg. Tree swallow and red-winged blackbird eggs collected at the Harbor Brook site on Onondaga Lake had the highest Hg concentration of all sites sampled. No bird blood, feather, or eggs sampled at the reference site on Oneida Lake had Hg concentrations that exceeded the effect levels discussed above.

Stable isotope data revealed differences in the foraging behavior between the three target songbirds (tree swallow, red-winged blackbird, and song sparrow). Within species, the dietary preferences were similar at all sites. Therefore, the observed differences in blood Hg among sites are likely due to higher concentrations of Hg at Onondaga Lake and not due to different diet selection.

INTRODUCTION

Biodiversity Research Institute (BRI), under the direction of the Natural Resource Trustees, conducted a second year of avian sampling at Onondaga Lake to develop an understanding of Hg exposure to birds breeding along this lake. The Natural Resource Trustees for Onondaga Lake include the U.S. Department of the Interior – Fish and Wildlife Service, the New York Department of Environmental Conservation (NYSDEC), and the Onondaga Nation. The Trustees are participating in a Natural Resource Damage Assessment (NRDA) for the lake, a process that is specifically designed to address natural resource injuries related to exposure to hazardous substances and to identify and evaluate alternatives for restoration of those resources.

As a result of the 2008 pilot assessment of Hg contamination of birds on Onondaga Lake (Lane et al. 2011), there is evidence that several species are exposed to concentrations of Hg that exceed effects thresholds reported in the literature for other bird species and may, therefore, adversely impact them. Onondaga Lake is located between two primary corridors of the Atlantic Flyway for migratory birds and provides habitat for over 112 species of birds during the breeding season (TAMS and YEC 2002; USFWS 2005).

The 2009 study was designed to further document potential Hg exposure of indicator resident and migratory birds that nest and forage within the littoral zone and wetlands of Onondaga Lake. Three insectivorous songbirds that forage within the Onondaga Lake floodplain were selected as primary target indicators of Hg contamination in both the 2008 and 2009 studies because they (1) are primarily invertivores during the breeding season, (2) are ubiquitous, and (3) have been proven to be an appropriate indicator species of Hg exposure in previous studies (Evers et al. 2006, Hallinger et al. 2010, Lane et al. 2011). The target species selected were the song sparrow (*Melospiza melodia*), red-winged blackbird (*Agelaius phoeniceus*), and tree swallow (*Tachycineta bicolor*). Based on elevated blood Hg concentrations presented in the 2008 study, we also targeted spotted sandpipers (*Actitis macularia*) as an indicator for shorebird exposure in 2009. All bird species captured were sampled regardless of being classified as a target species. Information on these species follows:

- **Tree swallow (TRES):** Arrives at New York lakes typically in April and initiates nesting in early to mid-May. TRES are cavity nesting birds that readily occupy artificial nest boxes (Robertson et al. 1992) and are commonly used as a study species for contaminant exposure studies (Secord et al. 1999; Custer et al. 2001; Gerrard and St. Louis 2001). TRES foraging territory is generally within ~400 m of their nest (Quinney and Ankney 1985), making this species a reliable indicator of local contamination. The TRES feeds predominantly on flying insects. Food items include Dipterans (flies), Hemipterans (leaf-hoppers, etc.), and Odonates (dragonflies and damselflies) (McCarty and Winkler 1999; Quinney and Ankney 1985). Food of aquatic origin constituted 65% of the nestling diet by mass in Ontario (Blancher and McNicol 1991) and 47% in North Dakota (Custer et al. 2008).

- **Red-winged Blackbird (RWBL):** The RWBL is an omnivorous wetland breeding species common throughout most of North America. Nesting habitat is typically characterized by tall grass, cattail, sedge, and reed (*Phragmites* sp.). They are found breeding at multiple sites around Onondaga Lake and its watershed. This species arrives in New York in late February to early April, beginning to breed in April and May. During the breeding season, its diet is mainly animal matter. In non-agricultural habitats, approximately 84% of the male diet and 79% of the female diet may be comprised of insects (McNicol et al. 1982). In the marshes of Manitoba, 100% of the diet may be animal matter (Bird and Smith 1964).
- **Song sparrows (SOSP):** SOSP are ubiquitous throughout their range and are common along the shoreline of Onondaga Lake and adjacent uplands. The species breeds in a range of forest, shrub, and riparian habitats (Arcese et al. 2002). The males are highly territorial and are often among the first migratory species to return to the breeding grounds. Individuals often have high site fidelity between years. Song sparrows feed primarily on insects and other invertebrates and some seeds and fruit (Aldrich 1984). In the Northeastern United States, the diet consists mostly of plant material in the winter (86%), but is generally over 50% animal based in the summer. The SOSP is a generalist and will feed on a variety of insects, including those from the orders Coleoptera, Hemiptera, Lepidoptera, Diptera, Odonata, and Ephemeroptera (Arcese et al. 2002).

- **Spotted sandpiper (SPSA):** The SPSA breeds and forages along the shore of Onondaga Lake, Ninemile Creek, and the Seneca River. The SPSA diet is invertebrate-based, dominated by copepods, Diptera larvae, and other aquatic invertebrates (Oring et al. 1997). The high trophic position, along with foraging habitat in and along the Onondaga Lake shoreline, and high sediment ingestion rates associated with sandpipers (7-30% of diet per Beyer et al. 1995) contribute to high exposure of SPSA to Hg and other contaminants.

Objectives

We assessed Hg exposure to a variety of songbirds at Onondaga Lake through the non-lethal collection of whole blood and feathers. Blood Hg levels in birds generally represent recent dietary uptake (Evers et al. 2005, Hobson and Clark 1993, 1994, Bearhop et al. 2000) and should, therefore, reflect Hg accumulated by birds feeding at or near their capture location. Feather concentrations indicate a bird's body burden of Hg at the time of feather growth, roughly indicating a body's accumulation of Hg over time (Burger 1993, Evers et al. 2005). Eggs were collected for Hg analysis to assess embryo exposure to Hg. The following objectives were outlined to evaluate avian exposure to Hg:

1. Determine Hg concentrations in bird blood and eggs to identify:
    a. Hg exposure in target species and
    b. Geographic extent and variation of Hg contamination in target species.
2. Model female blood-Hg to egg-Hg relationship in TRES to compare with an existing predictive model.
3. Collect, analyze, and/or archive feather samples for Hg analysis to assess body burden.
4. Determine nitrogen ($\delta^{15}N$) and carbon ($\delta^{13}C$) stable isotope concentrations in bird blood to understand complexity (food chain length) and origin (terrestrial vs. aquatic) of avian food webs.

Study area

Seven locations were chosen for bird sampling on Onondaga Lake. An eighth site located on Oneida Lake was used as a reference for regional baseline mercury exposure. Study sites were selected based on results from the 2008 sampling (Lane et al. 2011) and categorized into one of four general Study Areas, as detailed below (Figure 1):

Figure 1. Study sites on Onondaga Lake 2009.

1) Study Area 1: Onondaga Lake
   a) Beach
   b) Maple Bay
   c) Harbor Brook
   d) Ley Creek
   e) White Cliffs
2) Study Area 2: Ninemile Creek
3) Study Area 3: Seneca River
   a) Canal (only sampled in 2008)
   b) Wetzel Road (only sampled in 2009), located downstream from Onondaga Lake and replaced Canal from 2008
4) Study Area 4 (Reference): Oneida Lake at Shackelton Point

Beach, Onondaga Lake

(43.086750, –76.217493)

Beach is located along the southern edge of Onondaga Lake approximately halfway between the mouth of Onondaga Creek and the lake's outlet to the Seneca River. The upland habitat is a sparsely vegetated area with patches of *Phragmites* sp. The soil composition includes waste soda ash from the Solvay Plant. The lake sediment is also composed of the waste soda ash from the Solvay process with hardpan extending beyond 10 m from shore. Zebra mussel shells are abundant in the shoreline littoral zone.

Songbirds and shorebirds were captured along the shoreline and upland area.

Maple Bay, Onondaga Lake

(43.111570, –76.247250)

Maple Bay is located at the northern end of Onondaga Lake. The upland area adjacent to the site includes a town park with paved and dirt walking trails dominated by wet hardwood bottomland and patches of *Phragmites* sp. The outlet of Onondaga Lake to the Seneca River is the northeastern border of the site, with Interstate Highways 90 and 690 nearby. The lake at the site is generally shallow (< 2 m at more than 20 m from shore) with a sandy bottom. The shoreline has limited patches of grass, *Phragmites* sp., and cattail, with dense forest edge.

Ninemile Creek

(43.077886, –76.228796)

Ninemile Creek is located approximately 1.5 km upstream from Onondaga Lake on Ninemile Creek, a tributary to the lake. The upland area is cattail and *Phragmites* sp. dominated with mowed road edge and paved road. The creek bottom is soft sediment.

Ley Creek, Onondaga Lake

(43.081513, –76.183344)

Ley Creek is located at the southern end of Onondaga Lake northeast of the mouth of Onondaga Creek and adjacent to Route 370 and freight train tracks, about 1.6 km (1 mile) north of Destiny USA. The upland habitat is a *Phragmites* sp. dominated wetland, mowed grass, and train tracks with gravel bed. The lake edge is shallow (< 2 m at about 10 m out) with the bottom composed of large cobble and gravel.

Harbor Brook, Onondaga Lake

(43.064727, –76.190021)

Harbor Brook is located on the southern shore of Onondaga Lake, south of the primary inlet of Onondaga Creek and adjacent to Interstate 690. The upland habitat is gravel road, hardwood forest, and small *Phragmites* sp. wetlands, with the lake edge dominated by a larger *Phragmites* dominated wetland. The adjacent area of the lake is shallow (< 2 m at about 10 m from shoreline), with both fine, soft sediment, and hardpan likely resulting from calcium and chloride deposits. High densities of zebra mussel shells are found along the shoreline.

White Cliffs, Onondaga Lake

(43.088580, –76.227820)

White Cliffs, also referred to as Ninemile Creek Outlet in 2008, is located near the outlet of Ninemile Creek. The upland area is dominated primarily by two-acres of cattail and *Phragmites* sp. wetland and sparse vegetation at the base of an eroded cliff of Solvay waste. The lake here is shallow (< 2 m depth out to 10 to 20 m) with the sediment composed of either Solvay waste or fine sediment deposited from Ninemile Creek.

Wetzel Road, Seneca River

(43.164064, –76.255241)

Wetzel Road is located along the Seneca River (Figure 2), approximately 6.3 river km (3.9 miles) downstream from the outlet of Onondaga Lake. The site consists of a cattail dominated wetland bordered by mixed hardwood/red maple bottomland.

Figure 2. Wetzel Road as seen from the Seneca River in 2009.

Oneida Lake-Reference Site

(43.173435, –75.930973)

The reference site is located at the Cornell Biological Field Station at Shackelton Point on Oneida Lake. Oneida Lake is a large lake with a relatively undeveloped shoreline and without known industrial pollution (including Hg), and has a similar composition of avian species as Onondaga Lake. The upland area of the site is dominated by grass meadow surrounded by hardwoods.

Blood and feather samples were collected from all birds captured and eggs were collected from TRES and RWBL only.

Methods

Overview

Bird sampling and egg collection methods were the same as those employed during the pilot assessment of 2008 and are explained in detail in the pilot report (Lane et al. 2011). All field sampling was completed by two to four BRI biological technicians. All bird handling/sample collection was conducted under appropriate state and federal permits and using standard methods of tissue collection from songbirds (Evers 2009). All birds were sampled and released unharmed. Birds were identified to species and sex was determined either by plumage (ex. RWBL), by the presence of brood patch in females or cloacal protuberance in males (ex. SOSP, TRES), or by genetic analysis of blood (ex. SPSA). We determined age based on plumage, presence/absence of molt limits, and feather wear.

Bird and Egg Sampling

Birds were captured using nylon mist nets in conjunction with audio callback to attract target species in the immediate area. All birds were marked with unique U.S. Geological Survey leg bands. Blood was non-lethally collected from birds using heparin-coated capillary tubes and stored in labeled vacutainers; a single tail feather was pulled and stored in labeled plastic or paper envelopes.

Tree swallow nest boxes were erected in 2008 at all four study areas defined above (*n* = 70), and a subset of previously established (by Cornell University) boxes were monitored at the reference site, Oneida Lake. Female TRES were captured on-nest for blood and feather sampling and both sexes were occasionally captured with mist nets while targeting other wetland songbirds. Eggs were collected for mercury following BRI egg collection protocol. Nestlings were banded in 2009 (*n* = 65), but no blood or feather samples were collected. Feather samples from adult tree swallows were archived.

For simplicity throughout this report, Hg implies methylmercury, the dominant species of Hg present in blood and feathers. Methylmercury has a tendency for biomagnification and is a potent toxicant. Blood and feather Hg results are summarized by study area, site, sex, and year in Appendix A.

Eggs were stored in hard cases on cotton with ice in the field and refrigerated within eight hours of collection. Eggs were weighed and measured within one week of collection; eggs were weighed at Syracuse University to 0.1 mg, with maximum length and width measured to 0.1 mm. Egg contents were weighed following transfer to labeled 20 mL I-Chem acid-cleaned borosilicate glass jars. Contents were classified by embryo development stage or as rotten. Following processing, eggs were stored frozen until analysis. Abandoned or inviable eggs were also collected.

Red-winged blackbird eggs were collected from the same sites as TRES – Ley Creek, Maple Bay, Wetzel Road, Ninemile Creek, Harbor Brook, and Oneida Lake. Egg handling and processing was the same as that followed for TRES eggs.

All samples were logged and label-checked following field collection and prior to storage. Freezer temperature remained at less than -15°C based on daily temperature checks.

Invertebrate Sampling (data summarized in a separate report (Buck et al. 2012))

Invertebrates were collected using emergent traps set over water at Beach and on land using sweep nets. Spiders were collected opportunistically using aspirators at Beach, Ley Creek, Ninemile Creek, and Oneida Lake. Emergent traps were checked every morning and evening for two days following placement. All samples were transferred using aspirators into clean vials.

Fresh weights (0.1 mg) of individuals were measured within two days of collection and unique identification numbers were assigned.

Lab methods

Mercury

Methylmercury is the organic and highly toxic form of mercury that crosses through an organism's biological barriers (Boudou et al. 1991) such as the blood-brain barrier and can affect the central nervous system in vertebrates. Inorganic mercury can have toxic effects on organs such as kidneys, but does not pass into the brain. Methylmercury is not readily excreted and will consequently bioaccumulate in tissues. Blood, egg, and feather samples were analyzed for total Hg as this analysis is less expensive and typically 90-100% of total Hg in these tissues is in MeHg form (Rimmer et al. 2005, Edmonds et al. 2010). Mercury analysis followed EPA method 7473 (USEPA 1998) using gold-amalgamation atomic absorption spectroscopy following thermal desorption of the sample by a Milestone DMA-80. Blood and feathers were analyzed for total Hg at the BRI Wildlife Mercury Research Laboratory (WMRL) in Gorham, Maine. Internal lab quality control included initial calibration and continuing verification, blanks, sample replication, and certified reference materials (CRM): DORM-3 (fish protein CRM for trace metals) and DOLT-4 (dogfish liver CRM for trace metals) purchased from the National Research Council of Canada.

Eggs were analyzed for total Hg at Trace Element Research Lab (TERL), Texas A&M, College Station, Texas, following freeze drying and homogenizing with a Retsch ZM200 ultracentrifugal mill. A representative subsample of dried egg was used for Hg analysis. Analysis followed USEPA method 7473 (USEPA 1998), the same as that for blood and feathers. Egg Hg concentrations in this report are converted from dry weight to wet weight.

Stable Isotopes

Blood samples were shipped to the Boston University Stable Isotope Laboratory for analysis. Samples were analyzed using automated continuous-flow isotope ratio mass spectrometry (Michener and Lajtha 2007). Blood was transferred from capillary tubes into pre-weighed tin capsules. Assuming a content of 70% water, approximately 1.3 mg of blood was added to the capsules. All capsules were oven dried at 60˚C for 24 hours and then reweighed for dry mass. The capsules were then folded and compressed prior to analysis. The samples were combusted in a EuroVector Euro EA elemental analyzer. The combustion gases (N_2 and CO_2) were separated on 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 $^{15}N/^{14}N$ are reported as standard delta (δ) notation and are expressed as the relative permil (‰) difference between the samples and international standards (Vienna Pee Dee Belemnite (V-PDB) carbonate and N_2 in air) where:

$$\delta X = (Rsample/ Rstandard-1) \times 1000 \text{ (‰)}$$

Where $X = {}^{13}C$ or ${}^{15}N$ and $R = {}^{13}C/{}^{12}C$ or ${}^{15}N/{}^{14}N$

The sample isotope ratio is compared to a secondary gas standard, the isotope ratio of which was calibrated to international standards. For $^{13}C_{V\text{-}PDB}$ the gas was calibrated against NBS 20 (Solenhofen Limestone). The $^{15}N_{air}$ gas was calibrated against atmospheric N_2 and International Atomic Energy Agency (IAEA) 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, Maryland.

Interlab blood Hg comparison-splits

In 2009, blood and feather samples were analyzed for total Hg at BRI's WMRL in Gorham, Maine. A subsample of remaining blood samples was used as splits to be analyzed by an independent lab, TERL, to verify results from WMRL. Duplicate blood samples were shipped overnight on ice to TERL and analyzed for total Hg on a DMA-80 following USEPA method 7473 (USEPA 1998).

Statistics

Statistical analyses were done in Excel (Microsoft 2010) and JMP 5.0 (SAS 2003). We used non-parametric tests because of small sample sizes. We used a Wilcoxon one-way test to determine significance between sites.

RESULTS

Sampling effort

Blood and feathers

During two years of field work, we banded and sampled 437 birds – 374 birds of 26 species from Onondaga Lake and 63 birds from 13 species from Oneida Lake. In 2008, we collected blood and/or feather samples from 147 birds (137 adults) at Onondaga Lake (including all subsites and the Seneca River), representing 26 species and 25 birds on Oneida. In 2009 we sampled 227 birds of 25 species on Onondaga Lake and 38 birds from 12 species on Oneida Lake.

Eggs

In 2009, we collected and analyzed 18 TRES eggs and 15 RWBL eggs from the Onondaga Lake sites for Hg. In 2009, we collected and analyzed one egg per nest from three TRES nests and the same from RWBL nests at Oneida Lake. We did not collect eggs from Oneida Lake in 2008.

Mercury results

Blood mercury in target songbirds

We found no consistent evidence of among-species differences in blood Hg levels at the eight sampling locations, however, all three target species at sites on Onondaga Lake had greater Hg concentrations than birds sampled at Oneida Lake (Figure 3).

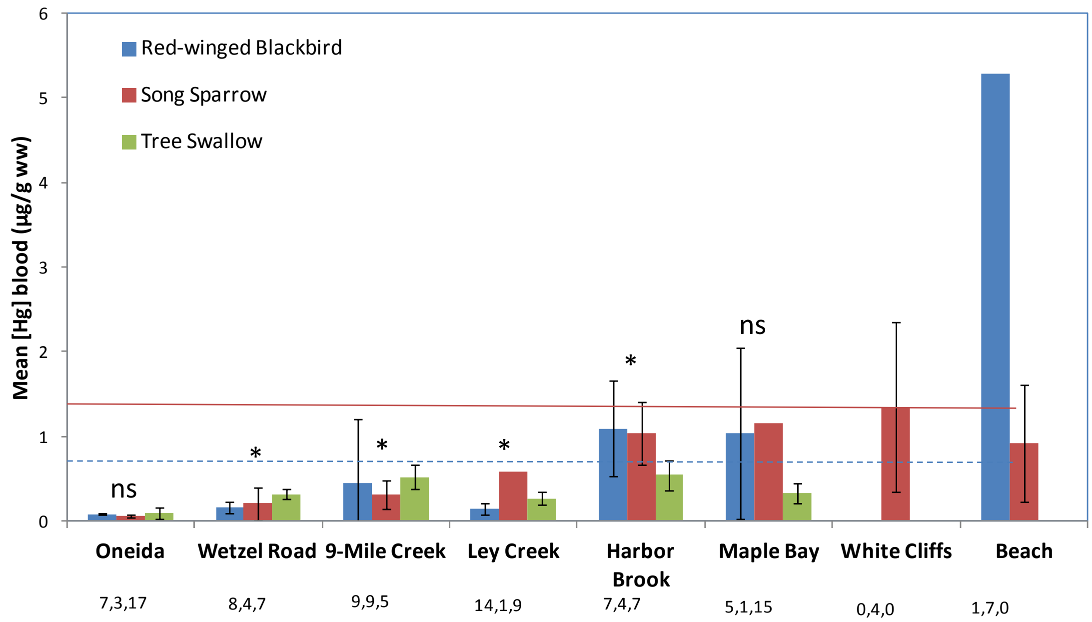

Figure 3. Mean blood Hg concentrations in target songbird species sampled on Onondaga and Oneida Lakes in 2009 (adults only). Error bars represent 1 standard deviation. Where all three species were sampled at a site, significant (α = 0.05) comparisons indicated with asterisks; non-significant comparisons by "ns" (Kruskal-Wallis test). Values shown below location names indicate sample sizes. Blue dash line indicates estimated blood Hg concentration of 0.7 µg/g for a 10% reduction in nest success and the solid red line indicates 1.2 µg/g for a 20% reduction (Jackson et al. 2011).

Egg mercury in tree swallows and red-winged blackbirds

Typically one egg was collected from RWBL nests and one egg was collected from TRES nesting in boxes on Onondaga Lake, Seneca River, Ninemile Creek, and Oneida Lake (Table 1). If more than one egg was collected and analyzed, the concentrations of multiple eggs were averaged per nest for statistical analysis.

Table 1. Number of egg samples analyzed for mercury in 2009, RWBL = red-winged blackbird, TRES = tree swallow.

Site	RWBL	TRES
Maple Bay	0	5
Ninemile Creek	5	3
Ley Creek	4	3
Harbor Brook	4	4

Wetzel Road	2	3
Oneida	3	3

Across all sites, TRES eggs had significantly greater concentrations of Hg than RWBL eggs (Wilcoxon one-way test, chi-square = 12.11, df = 1, $P < 0.001$; Figure 4). Sample sizes were too limited to compare egg-Hg concentrations between sites.

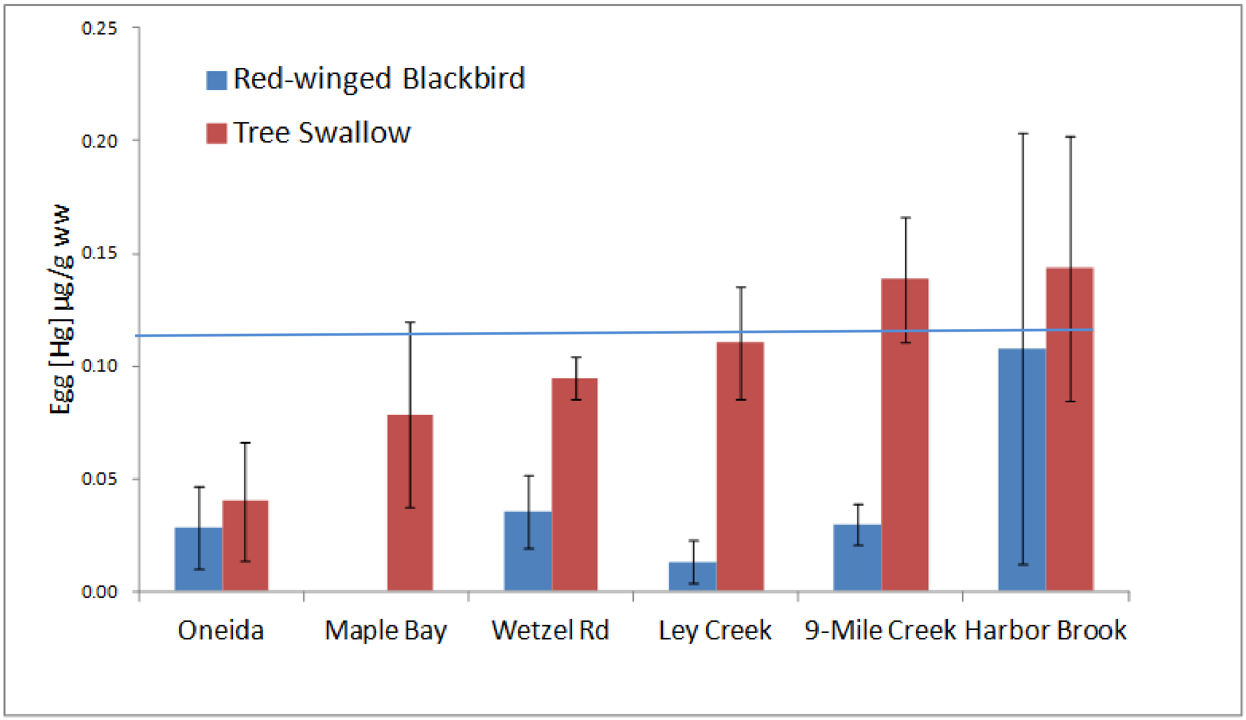

Figure 4. Mean egg Hg concentrations (µg/g ww) in two target songbird species sampled on Onondaga and Oneida Lakes, 2009. Blue line indicates 0.11µg/g - 10% reduction in nest success in Carolina wrens (Jackson et al. 2011).

Tree swallow mercury results

The artificial nest box occupancy rate increased from 2008 to 2009 (Table 2).

Table 2. Summary of tree swallow nest boxes monitored at Onondaga Lake and associated sites in 2008 and 2009. Nest boxes at the reference site on Oneida Lake were not monitored in 2008.

Treatment	Site	Year	# of boxes present	# of boxes with active nests	% Occupancy
Onondaga	Beach	2008	9	3	33%
	Maple Bay	2008	10	6	60%
	Maple Bay	2009	14	14	100%
	Ley Creek	2008	9	4	44%
	Ley Creek	2009	14	13	93%
	Harbor Brook	2008	9	3	33%
	Harbor Brook	2009	15	6	40%
	White Cliffs	2008	9	4	44%
Ninemile Creek		2009	13	4	31%
Seneca River	Canal	2008	9	7	78%
	Wetzel Road	2009	14	10	71%
Reference	Oneida	2008*	*	5	-
		2009	35**	13	-

*only 5 boxes were monitored in 2008.

**over 35 boxes were present but only 35 were monitored.

The greatest concentrations of Hg in TRES blood in 2008 were found at Harbor Brook, followed by Ley Creek and Beach (Table 3). In 2009, blood Hg concentrations were generally lower than in 2008, with the highest blood Hg detected in TRES from Harbor Brook, followed by Ninemile Creek (new site in 2009) and Maple Bay. Thirteen percent of the TRES sampled on Onondaga Lake exceeded the 0.7 µg/g blood Hg concentration associated with a 10% nest success reduction (Jackson et al. 2011) in Carolina wrens (fewer nests fledging at least one nestling); 6% exceeded the 1.2 µg/g blood Hg concentration associated with a 20% Carolina wren nest success reduction threshold (note 0.7 µg/g Hg threshold is similar to 0.63 µg/g reproductive effects threshold for TRES cited in Lane et al. 2011). One of the five TRES sampled at Ninemile Creek exceeded the 10% nest success reduction threshold. None of the samples collected from Seneca River or Oneida Lake exceeded the proposed effect thresholds.

Table 3. Summary of blood-mercury (µg/g) by treatment, sites, year, and sex for tree swallows.

Treatment	Site	Year	Female Mean ± SD [*n*]	Male mean ± SD [*n*]	All adults mean ± SD [*n*]
Onondaga	Beach	2008	0.45 ± 0.04 [2]	—	0.45 ± 0.04 [2]
	Maple Bay	2008	0.37 ± 0.08 [3]	0.45 ± 0.34 [2]	0.41 ± 0.19 [5]
		2009	0.35 ± 0.09 [12]	0.15 ± 0.05 [2]	0.33 ± 0.11 [15]*
	Ley Creek	2008	0.86 ± 0.32 [2]	—	0.88 ± 0.32 [2]
		2009	0.27 ± 0.08 [8]	0.24 [1]	0.26 ± 0.07 [9]
	Harbor Brook	2008	1.49 ± 0.24 [2]	—	1.49 ± 0.24 [2]
		2009	0.57 ± 0.17 [6]	0.37 [1]	0.54 ± 0.17 [7]
	White Cliffs	2008	0.42 ± 0.07 [3]	0.42 [1]	0.42 ± 0.06 [4]
	Onondaga By year	2008	0.67 ± 0.44 [12]	0.44 ± 0.24 [3]	0.62 ± 0.42 [15]
		2009	0.37 ± 0.16 [26]	0.23 ± 0.11 [4]	0.36 ± 0.16 [31]*
Onondaga Overall mean		2008-2009	0.47 ± 0.31 [38]	0.32 ± 0.20 [7]	0.44 ± 0.29 [46]*

Seneca	Canal	2008	0.17 ± 0.03 [6]	—	0.17 ± 0.03 [6]
	Wetzel Rd	2009	0.31 ± 0.06 [7]	—	0.31 ± 0.06 [7]
Seneca Overall mean			0.25 ± 0.09 [13]	—	0.25 ± 0.09 [13]
Ninemile Creek	Ninemile Creek	2009	0.52 ± 0.15 [5]	—	0.52 ± 0.15 [5]
Reference	Oneida	2008	0.08 ± 0.03 [5]	0.08 [1]	0.08 ± 0.03 [6]
		2009	0.09 ± 0.07 [14]	0.12 ± 0.08 [2]	0.09 ± 0.06 [17]*
Overall mean			0.09 ± 0.06 [19]	0.10 ± 0.06 [3]	0.09 ± 0.06 [23]*

*n in the last column reflects the total number of adult birds sampled=males+females+unknown

There was a significant difference in blood Hg levels of adult TRES among the four study areas (Kruskal-Wallis test, chi-square = 53.9, df = 3, $P < 0.0001$; 2008 and 2009 combined). Based on a post-hoc multiple comparison test, Hg levels in TRES at the reference site in 2009 were significantly lower than at Onondaga, Ninemile Creek, and Seneca (Figure). Analyzed by year 2008 and 2009, the differences were still significant (Kruskal-Wallis test, chi-square=20.7, df=2, $P < 0.0001$; and chi-square=35.3, df=3, $P < 0.0001$, respectively). Based on a post-hoc multiple comparison test, Hg levels at the reference site were significantly lower than at Onondaga, Ninemile Creek, and Seneca (Figure 5).

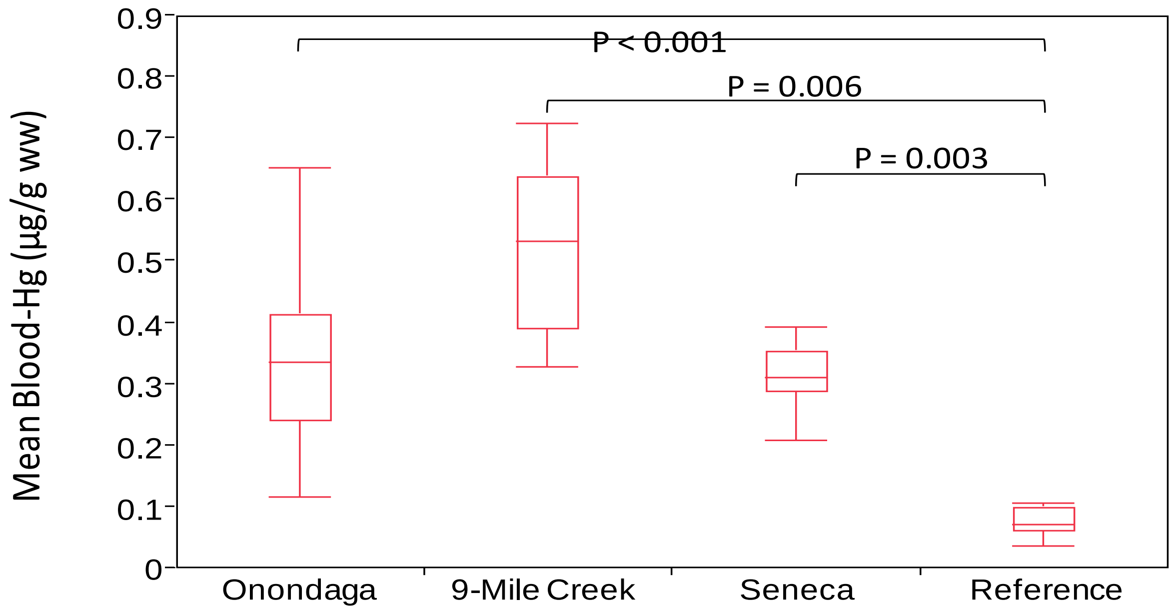

Figure 5. Quantile box plots showing blood-Hg concentrations in adult tree swallows sampled in 2009 in four study areas. Brackets and associated probability values indicate significant differences between pairs based on Steel-Dwass comparison. Sample sizes: Onondaga = 31, Ninemile Creek = 5, Seneca (Wetzel) = 7, Reference (Oneida Lake) = 17.

Tree swallow blood-egg relationship (2008-2009)

We collected and analyzed 27 blood/egg pairs from Onondaga and Oneida Lakes in 2008 and 2009. There was a significant positive correlation between Hg levels found in adult female TRES blood and eggs presumed to have been laid by these individuals (Spearman correlation = 0.791, $P < 0.0001$; Figure 6).

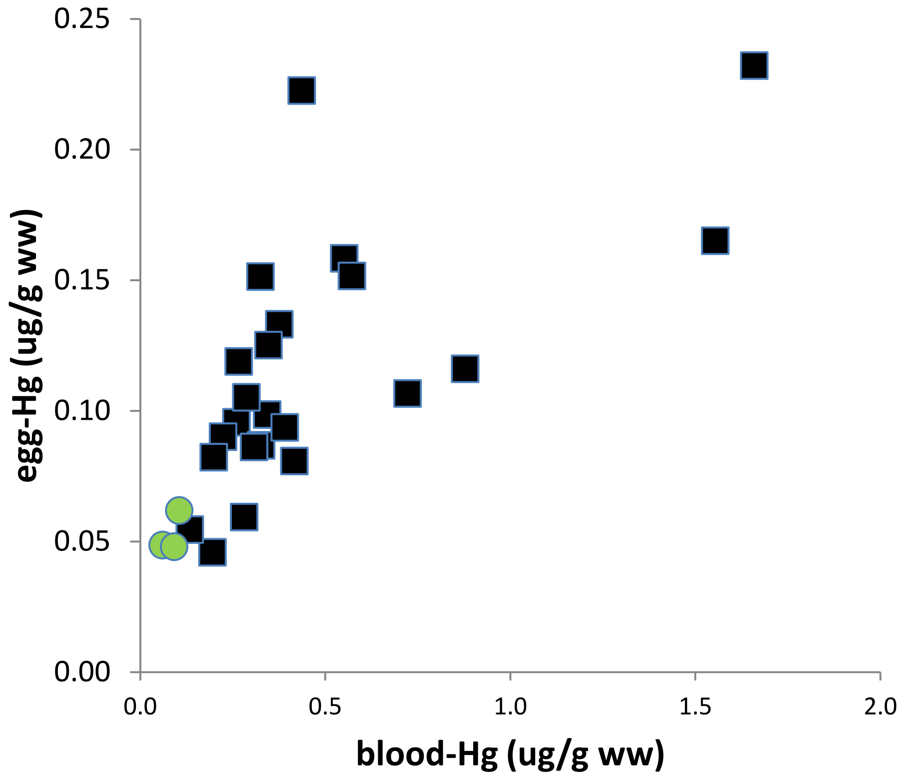

Figure 6. Correlation between Hg concentrations in blood of female tree swallows and their eggs, New York, 2008-2009 (green circles represent Oneida TRES, black squares-Onondaga.

Red-winged blackbird mercury results

We analyzed adult RWBL blood, feathers, and eggs collected in 2008 and 2009 for Hg to assess the species' exposure at four study areas: (1) Onondaga Lake (sites – Beach, Maple Bay, Ley Creek, Harbor Brook, and White Cliffs), (2) Ninemile Creek, (3) Seneca River (sites – Canal and Wetzel Road), and (4) Oneida Lake. Only one hatch-year RWBL was sampled and was subsequently excluded from statistical analyses because there may be a difference in Hg levels between adult and hatch year birds (Condon and Cristol 2009). Condon and Cristol (2009) report that it might take up to three months after fledging for young songbirds to accumulate similar Hg levels as adults because most of the Hg is sequestered into growing feathers.

Fifty-one blood samples were collected from RWBL in 2009. Adult female RWBLs had approximately 6× the blood Hg concentration of adult male RWBLs on Onondaga Lake

(Table 4). Each sex had significantly greater blood Hg concentrations on Onondaga Lake than on Oneida Lake (female, $P < 0.001$, 21× greater; male, $P = 0.001$, 3× greater (Table 4).

Table 4. Red-winged blackbird blood and feather mercury concentrations for 2009. Concentrations in µg/g ww.

Study Area	Sex	Blood Hg, wet wt mean ± SD, (n)	Feather Hg, fresh wt mean ± SD, (n)
Onondaga	Male	0.234 ± 0.269 (16)	0.313 ± 0.321 (16)
	Female	1.49 ± 1.473 (11)	0.427 ± 0.241 (11)
Ninemile Creek	Male	0.519 ± 0.942 (6)	0.504 ± 0.562 (6)
	Female	0.279 ± 0.199 (3)	0.479 ± 0.454 (3)
Seneca River	Male	0.132 ± 0.053 (5)	0.182 ± 0.085 (5)
	Female	0.204 ± 0.070 (3)	0.146 ± 0.017 (3)
Oneida Lake (Reference)	Male	0.078 ± 0.002 (3)	0.118 ± 0.019 (3)
	Female	0.071 ± 0.011 (4)	0.093 ± 0.021 (4)

Fifty-one feather samples from RWBL captured in 2009 were analyzed for total Hg. No significant difference in feather Hg concentrations between sexes on Onondaga Lake (sites combined) was observed (Wilcoxon one-way test, chi-square = 3.62, df = 1, $P = 0.057$; small sample sizes precluded a comparable analysis at the reference site).

Both sexes of RWBL showed significantly higher feather Hg levels at Onondaga compared to the reference site (females: Wilcoxon one-way test, chi-square = 7.09, $P = 0.008$; males: chi-square = 3.91, $P = 0.05$). The mean feather Hg concentration in RWBL from Onondaga Lake was 3.5× greater than the mean Hg concentration in RWBL feathers from Oneida Lake and the mean feather Hg concentration from Ninemile Creek was 5× greater than the mean feather Hg concentration in RWBL from Oneida Lake.

Song sparrow blood and feather mercury

Thirty-nine song sparrows were sampled on Onondaga and Oneida Lakes in 2009 (Table 5). Two of the three females banded in 2008 were recaptured in 2009. No males banded in 2008 (*n* = 17) were recaptured in 2009. We found no significant difference in blood Hg concentrations between years at Onondaga Lake (Wilcoxon one-way test, chi-square = 0.53, df = 1, P = 0.47); samples at other locations (Ninemile Creek, Wetzel Road [Seneca River]) and the reference site at Oneida Lake were too small to permit analysis of between-year differences. We observed no significant difference in blood Hg concentration between adult and hatch-year SOSP at Onondaga Lake (Wilcoxon one-way test, chi-square = 0.02, df = 1, P = 0.89). Blood Hg concentrations for both age groups were pooled for subsequent statistical analyses. Blood Hg concentrations differed significantly among study areas (Kruskal-Wallis one-way test; chi-square = 21.85, df = 3, P < 0.001). A post-hoc multiple comparison test found significant differences in blood Hg between the reference site and both Ninemile Creek and Onondaga, and between Onondaga and both Ninemile Creek and Seneca (Figure 7). Summary statistics for SOSP blood Hg are provided in Table 5.

Table 5. Summary statistics of blood-Hg concentrations (µg/g ww) in song sparrows for adults and hatch-year birds (2009).

Location	mean ± SD (n)
Onondaga	1.05 ± 0.704 (23)
Maple Bay	1.15 (1)
Beach	0.943 ± 0.602 (9)
Harbor Brook	1.08 ± 0.780 (8)
Ley Creek	0.576 (1)
White Cliffs	1.34 ± 1.01 (4)
Ninemile Creek	0.313 ± 0.165 (9)

Wetzel Road	0.200 ± 0.195 (4)
Reference (Oneida)	0.058 ± 0.014 (3)

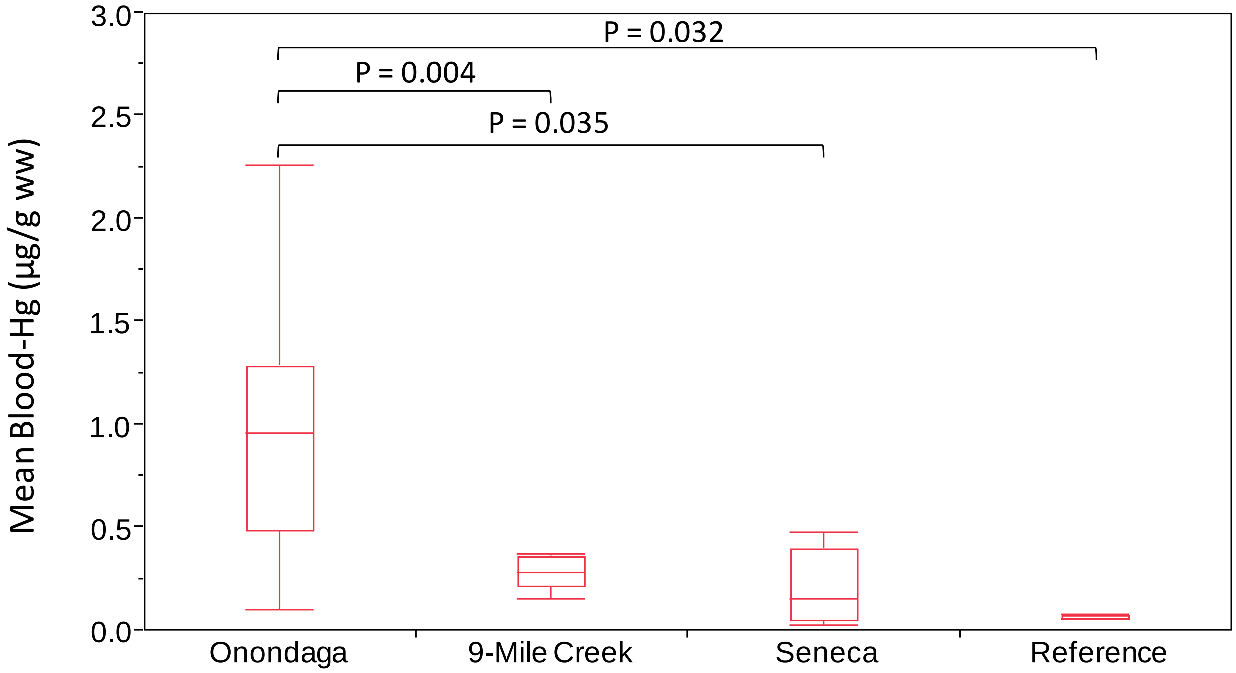

Figure 7. Quantile box plots showing blood-Hg concentrations in song sparrows from four study areas from 2009. Brackets and associated probability values indicate significant differences between pairs based on Steel-Dwass comparison. Sample sizes: Onondaga = 23, Ninemile Creek = 9, Seneca (Wetzel)= 4, Reference (Oneida Lake) = 3.

Song sparrow tail feathers from 2009 (n = 31) were analyzed for total Hg (Table 6). There was a significant difference between adult and hatch year birds (Wilcoxon one-way test, chi-square = 6.40, df = 1, P = 0.01); therefore, we excluded hatch year birds in further analyses. Two of seven hatch-year SOSP tested had extremely high (53.6 and 26.4 µg/g) tail feather Hg concentrations. Feather Hg concentrations differed significantly among the four sampling areas (Kruskal-Wallis one-way test; chi-square = 14.13, df = 3, P = 0.003); a post-hoc multiple comparison test found differences in feather-Hg concentrations only between Onondaga and Oneida Lakes; all other comparisons were similar (Figure 8).

Table 6. Summary statistics of adult song sparrow feather-Hg concentrations (µg/g fw) 2009.

Location	n	mean ± SD	LCL	UCL
Onondaga Lake	17	4.454 ± 3.613	2.597	6.312
Beach	7	2.337 ± 0.832	1.568	3.107
Maple Bay	1	10.475	—	—
Ley Creek	1	1.369	—	—
Harbor Brook	4	4.217 ± 3.533	–1.404	9.839
White Cliffs	4	7.661 ± 4.031	1.247	14.075
Ninemile Creek	7	1.674 ± 0.918	0.968	2.380
Wetzel Road, Seneca	4	1.107 ± 0.720	–0.038	2.252
Reference (Oneida)	3	0.300 ± 0.122	–0.004	0.604

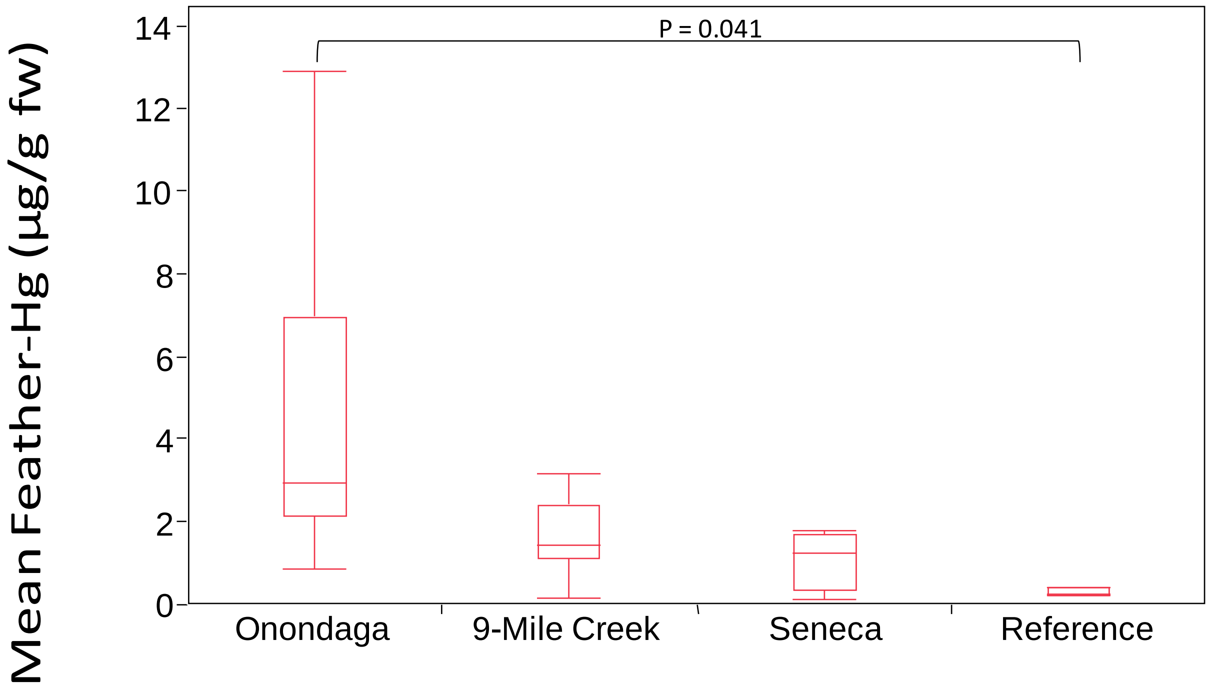

Figure 8. Quantile box plots showing feather Hg concentrations in adult song sparrows in four study areas 2009. Brackets and associated probability values indicate significant differences between pairs based on Steel-Dwass comparison. Sample sizes: Onondaga = 17, Ninemile Creek = 9, Seneca (Wetzel) = 4, Reference (Oneida Lake) = 3.

In 2009, 64% of adult SOSP sampled on Onondaga Lake had blood Hg concentrations that exceeded the 0.7 µg/g blood Hg levels considered by Jackson et al. (2011) to cause a 10% reduction in nest success in Carolina wrens. Twenty-four percent of SOSP had blood Hg concentrations that exceeded the 1.2 µg/g Hg threshold associated with 20% reduction in nest success in Carolina wrens (Table 7).

Table 7. Summary of estimated percent of sampled birds that exceed published effect levels on Onondaga Lake, 2008-2009. Blood and feather threshhold values are based on Jackson et al. 2011 study with adult Carolina wrens.

Species	Study Area	Year	Blood			Tail Feather	
			%> 0.63 µg/g	%> 0.70 µg/g	% > 1.2 µg/g	%> 3.0 µg/g	%> 4.7 µg/g
TRES	Onondaga	2008	33%	20%	13%	—	—
		2009	5.5%	2.7%		—	—
		Overall	15%	8.6%	4.3%	—	—
	Ninemile Creek	2009	20%	20%	0%	—	—
RWBL	Onondaga	2008	41%	41%	26%	0%	0%
		2009	37%	37%	19%	0%	0%
		Overall	39%	39%	22%	0%	0%
	Ninemile Creek	2009	1.1%	1.1%	1.1%	0%	0%
SOSP	Onondaga	2008	79%	68%	47%	—	—
		2009	71%	64%	24%	47%	29%
		Overall	75%	67%	36%	47%	29%
	Ninemile Creek	2009	11%	11%	0%	11%	0%
SPSA	Onondaga & Ninemile Creek	2008	100%	100%	100%	—	—
		2009	88%	88%	63%	6.3%	6.3%
		Overall	89%	89%	68%	6.3%	6.3%

Species	Study Area	Year	Blood			Tail Feather	
			%> 0.63 µg/g	%> 0.70 µg/g	% > 1.2 µg/g	%> 3.0 µg/g	%> 4.7 µg/g
All other species	Onondaga	2008	24%	22%	10%	0%	0%
		2009	43%	41%	39%	80%	80%
		Overall	32%	30%	23%	50%	50%
	Ninemile Creek	2009	40%	40%	20%	—	—

Spotted sandpipers

Twenty-four SPSA were captured and sampled for blood Hg on Onondaga Lake and Ninemile Creek in 2008 and 2009. Data for 2008 (n = 3) and 2009 (n = 21) were pooled due to sample size considerations.

Blood Hg concentrations in adult SPSA at Onondaga (excluding Ninemile Creek) averaged 2.49 ± 1.72 SD µg/g Hg (*n* = 17), among the highest averages of all species sampled on the lake. Adults at both sites (Onondaga Lake and Ninemile Creek) had higher blood Hg levels than hatch-year birds (Wilcoxon one-way test; Onondaga: chi-square = 4.36, df = 1, P = 0.04; small sample sizes at Ninemile Creek precluded formal hypothesis testing). No differences in blood Hg concentrations were observed among the Beach, Harbor Brook, White Cliffs, and Ninemile Creek in adult sandpipers (Kruskal-Wallis one-way test; chi-square = 3.60, df = 3, 15; P = 0.31). Sandpipers were not captured at Oneida likely because of lack of available habitat. Only two were observed during the study period.

If we apply the effects threshold developed for songbirds by Jackson et al. (2011), nearly 90% of the adult SPSA exceeded the blood Hg threshold of 0.7 µg/g Hg associated with a 10% reduction in nest success, and 68% exceeded the blood-Hg threshold of 1.2 µg/g Hg associated with a 20%

nest reduction. Tail feather Hg concentrations were adults: mean = 2.74 ± 6.17 SD n = 19; and hatch-year: mean = 1.97 ± 0.71 SD, n = 6, but one bird with 25.7 µg/g Hg exceeded the 99% reduction threshold for nest success for Carolina wrens (at 19.5 µg/g Hg in feathers Jackson et al. 2011 modeled a 99% reduction in nesting success). Spotted sandpipers were not sampled on Oneida Lake. We conducted a survey for SPSA on July 9, 2009, to estimate the population size of the species on Onondaga Lake in case this species was to be selected for future Hg risk assessment. Two observers boated the perimeter of Onondaga Lake, into Ninemile Creek, and approximately 8 km downstream on the Seneca River, staying within approximately 30 m of the shoreline. Coordinates for every SPSA were logged on a GPS. Forty-five SPSA were recorded, with 36 observed along the shoreline of Onondaga Lake, eight on Ninemile Creek between the I-690 Bridge and the creek outlet, and one on the Seneca River (Figure 9). The majority of observations (24 of 45) were at sites Beach and White Cliffs.

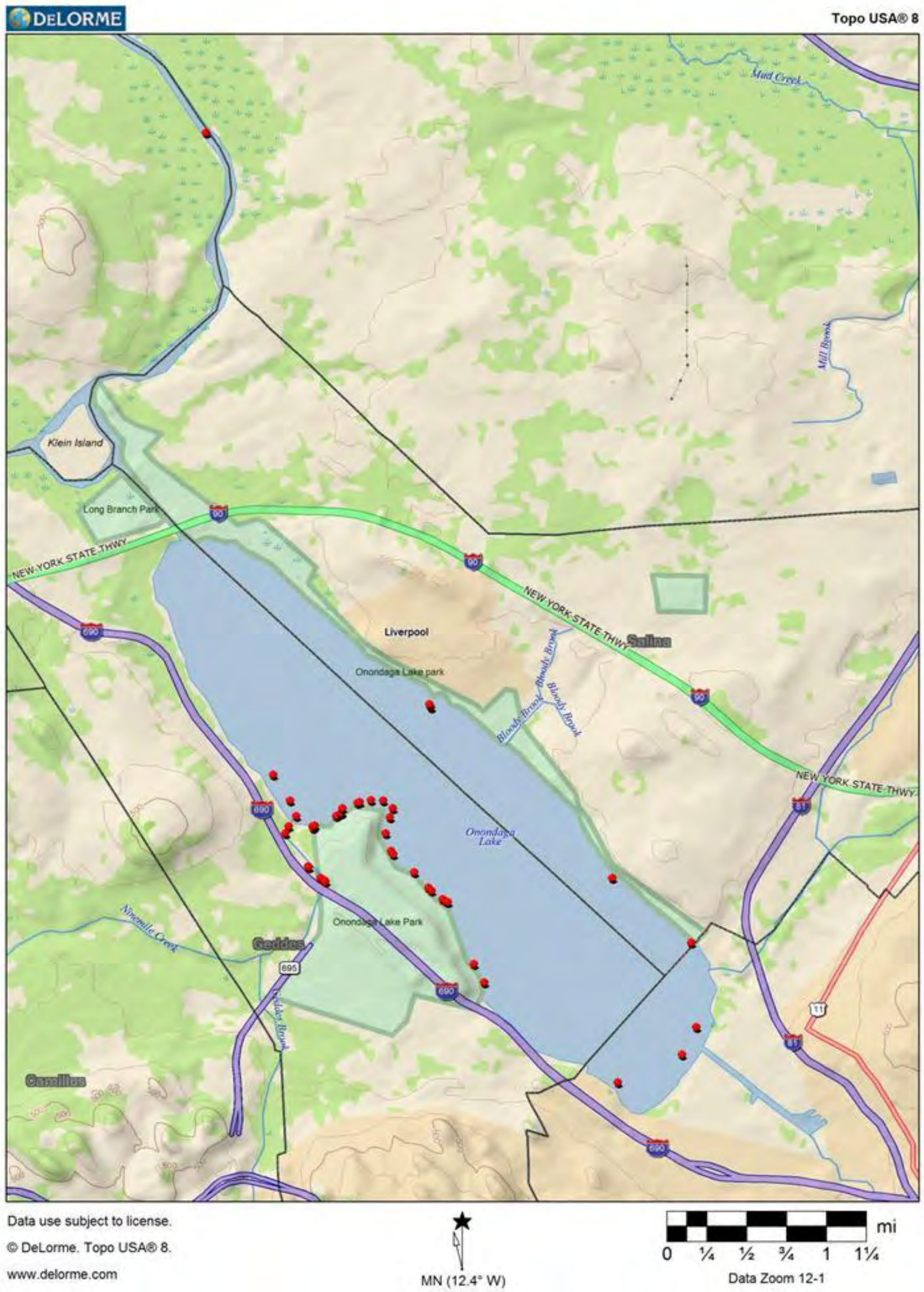

Figure 9. Map of spotted sandpiper sightings on July 9, 2009, on Onondaga Lake and Seneca River.

Blood mercury in non-target species

We sampled 164 non-target birds (including 4 piscivores) and analyzed 164 blood Hg and 14 adult feather Hg samples (from species likely to have high Hg exposure; e.g., invertivores such as American redstart and piscivores such as the belted kingfisher); remaining feathers were archived at BRI's WRML. Blood Hg at the reference site on Oneida Lake ranged from a minimum of 0.025 µg/g in a northern cardinal to a maximum of 0.235 µg/g in a great-crested flycatcher; on the Seneca River sites blood ranged from a minimum of 0.001 µg/g in an American goldfinch to a maximum of 0.140 µg/g in a warbling vireo; on Onondaga Lake from a minimum of 0.001 µg/g in an American goldfinch to a maximum of 7.17 µg/g in a European starling (both birds captured at Ley Creek); and on Ninemile Creek the minimum blood Hg concentration was 0.003 µg/g in an American goldfinch and the maximum was 4.12 µg/g in a gray catbird (Appendix A). The birds from the southwest area of the lake generally had higher blood Hg concentrations.

Onondaga Lake and Ninemile Creek had a number of individuals of non-target species with blood Hg concentrations that exceeded the estimated effect concentrations of 0.70 and 1.2 µg/g (Appendix A). None of the sampled birds at either of the Seneca River sites or at the Oneida Lake site exceeded the effect thresholds. Two non-target invertivore birds exceeded an estimated 99% reduction of nesting success for the Carolina wren based on blood Hg (5.6 µg/g Hg) or tail feather Hg (19.5 µg/g Hg; Jackson et al. 2011), an adult female European starling (7.2 µg/g blood Hg) and an adult female American redstart (6.2 µg/g blood Hg).

We sampled two piscivorous species – three adult belted kingfishers (blood Hg=1.8 – 3.0 µg/g) and one hatch-year green heron (blood Hg=0.3 µg/g) (Appendix A). There are no effect levels published for these species, but (except for one kingfisher with a blood Hg concentration of 3.01 µg/g), they did not exceed the effect levels for piscivorous birds based on common loon studies (3 µg/g in blood; 40 µg/g in feathers; Evers et al. 2008).

Blood mercury in recaptured birds

Of all birds banded and sampled in 2008, eleven were recaptured and sampled in 2009. Six of the recaptured birds were tree swallows and we found a significant increase in blood Hg levels between the two years (Wilcoxon signed-rank, $Z = -3.06$, $P = 0.002$; Table 8), although some of this increase may be attributable to birds nesting at a different, and potentially more contaminated, site in 2009 vs. 2008.

Table 8. Blood mercury concentrations (µg/g ww) in recaptured adult tree swallows from 2008 to 2009.

Site	Band #	Sex	Dates	Hg	% Change
Maple Bay	2311-555-39	F	May 24, 2008	0.417	–24%
Maple Bay			May 21, 2009	0.317	
Maple Bay	2311-555-42	F	May 25, 2008	0.425	–9%
Maple Bay			June 2, 2009	0.388	
Canal	2311-555-43	F	May 25, 2008	0.215	62%
Wetzel Road			June 2, 2009	0.349	
Canal	2311-555-48	F	June 9, 2008	0.134	125%
Maple Bay			June 8, 2009	0.302	
Canal	2311-555-58	F	June 18, 2008	0.199	77%
Maple Bay			June 2, 2009	0.352	
Oneida (ref.)	2311-555-55	F	June 11, 2008	0.058	23%
Oneida (ref.)			May 28, 2009	0.071	

Inter-lab comparison blood Hg-lab splits

There was no difference in total Hg concentrations as determined by TERL and BRI WMRL (Wilcoxon signed rank; $S = -20$, $P = 0.13$). In addition, the average relative percent difference between labs was 13% where the EPA allows 20% (USEPA 1998; Table 9).

Table 9. Blood Hg split results from the same bird, analyzed at TERL and BRI WMRL, 2009. RPD = relative percent difference.

		TERL		BRI WMRL		
Band #	**Species**	**TERL ID**	**Hg µg/g**	**WMRL ID**	**Hg µg/g**	**RPD***
1232-310-78	RWBL	T9087-041	0.190	A9BK0003	0.168	12%
1232-870-07	RWBL	T9087-042	1.11	A9BK0032	1.041	6%
1232-870-14	RWBL	T9087-043	0.152	A9BK0039	0.099	42%
1232-870-15	AMRO	T9087-044	0.134	A9BK0040	0.127	5%
1533-075-53	BEKI	T9087-045	3.30	A9BK0043	3.01	9%
1533-075-53R	BEKI	T9087-046	3.25	A9BK0044	3.35	3%
1573-580-42	BEKI	T9087-047	1.62	A9BK0056	1.77	9%
2301-530-66	GRCA	T9087-048	0.302	A9BK0063	0.302	0%
2301-530-87	BAOR	T9087-049	0.559	A9BK0085	0.529	6%
2301-530-95	RWBL	T9087-050	0.106	A9BK0092	0.096	10%
2351-075-95	TRES	T9087-051	0.37	A9BK0158	0.362	2%
2391-692-17	TRES	T9087-052	0.099	A9BK0179	0.060	49%
Unb-GRHE	GRHE	T9087-054	5.45	A9BK0265	4.97	9%
2510-023-76	AMGO	T9087-053	< DL**	A9BK0235	0.007	—

*RPD=Relative Percent Difference is used to evaluate duplicate samples, these are not true duplicates.

**Below detection limit.

Stable isotopes in blood

Blood from adult birds of selected species sampled in 2009 was analyzed for stable isotopes of nitrogen ($\delta^{15}N$) and carbon ($\delta^{13}C$) to assess the effect of trophic position and foraging habitat on blood Hg concentrations. Statistical analyses were performed on SOSP, TRES, and RWBL data. Blood Hg was significantly predicted by $\delta^{15}N$ ($F = 24.4$, $P < 0.0001$, r^2 adjusted = 0.33) and we found no among-site differences in $\delta^{15}N$ for any of the three species (Table 10). Blood Hg concentrations in birds were not predicted by $\delta^{13}C$ ($F = 2.03$, $P = 0.16$, r^2 adjusted = 0.02). Based on samples collected at Onondaga (i.e., excluding the limited data obtained at the reference site), $\delta^{15}N$ is significantly greater in females than in male RWBL (Wilcoxon one-way test, chi-square = 14.47, df = 1, $P < 0.001$), and $\delta^{13}C$ is significantly greater in males than in females (Wilcoxon one-way test, chi-square = 9.65, df = 1, $P = 0.002$). $\delta^{13}C$ was significantly different among locations for RWBL and TRES.

Table 10. Among-site (Onondaga, Ninemile Creek, Seneca, Reference) comparison of blood-Hg, $\delta^{13}C$ and $\delta^{15}N$ in red-winged blackbird (RWBL), song sparrow (SOSP), and tree swallow (TRES) from 2009. Analyses based on Kruskal-Wallis one-way test.

	Sample sizes						
Analysis -Species	Ninemile Creek	Onondaga	Reference	Seneca	chi-square	df	P
blood Hg - RWBL	9	55	20	10	19.63	3	< 0.001
$\delta^{13}C$ - RWBL	9	28	7	8	14.64	3	0.002
$\delta^{15}N$ - RWBL	9	28	7	8	5.28	3	0.15
blood Hg - SOSP	9	41	6	5	34.78	3	< 0.001
$\delta^{13}C$ - SOSP	9	20	2	4	0.26	3	0.97
$\delta^{15}N$ - SOSP	9	20	2	4	3.96	3	0.27
blood Hg - TRES	5	44	22	12	51.05	3	< 0.001
$\delta^{13}C$ - TRES	3	18	9	7	22.85	3	< 0.001
$\delta^{15}N$ - TRES	3	18	9	7	4.47	3	0.22

Documented physical deformities

We captured six birds with physical deformities on Onondaga Lake and one from Oneida Lake (Table 11, Figure and 11). The cause(s) of these deformities is/are unknown.

Table 11. Documented morphological deformities in birds captured on Onondaga and Oneida Lakes in 2009.

Site	Species	Blood Hg	Deformities
Onondaga Lake			
Maple Bay	Yellow warbler	0.277	legs/feet enlarged from fungus/mites
Ley Creek	Baltimore Oriole	1.39	abscess (infection) on chin/throat,
Ley Creek	Song sparrow	0.679	right leg is bent/odd growth at intertarsal joint
Ley Creek	Yellow warbler	1.37	fungus/mites on feet
Ley Creek	Yellow warbler	1.88	legs/feet enlarged from fungus/mites
Ninemile Creek	American robin	0.248	right leg missing below intertarsal joint
Oneida Lake	Tree swallow	0.313	broken lower mandible, damaged scalp

Figure 10. Baltimore oriole with abnormal throat growth, Onondaga Lake, 2009.

Figure 11. Tree swallow with lower mandible half-missing, Oneida Lake 2009.

DISCUSSION

Mercury exposure in birds

Blood mercury

Based on two years of sampling, we found that Hg concentrations in all sampled species are significantly higher on Onondaga Lake and Ninemile Creek than at the reference site on Oneida Lake. Based on the blood Hg concentrations, breeding SPSA on Onondaga Lake appear to be at the greatest risk from Hg exposure. In 2009, 14 of 16 adult SPSA (88%) sampled exceeded the blood Hg effects threshold of 0.70 µg/g and 63% exceeded 1.2 µg/g (Table 7), (range = 0.865–4.4 µg/g ww). We grouped SPSA from Onondaga and Ninemile Creek study sites because some individuals were documented at both study areas.

Of the three target songbird species sampled, TRES tended to have lower blood Hg concentrations than RWBL and SOSP.

Feather mercury

Twenty-three of 108 invertivore tail feathers (21%) were above 3.0 µg/g Hg, the tail feather Hg concentration associated with 10% reduction in nest success in Carolina wrens (Jackson et al. 2011) and none of 10 feathers analyzed from Oneida Lake exceeded 3 µg/g Hg. Feathers reflect the body burden of Hg at the time of molt. Knowing the time of molt or feather replacement for each species sampled is critical to making meaningful interpretations. All three target songbird species sampled molt their flight feathers once a year on the breeding grounds post-breeding (Pyle 1997). The SPSA molts in September and November, or post-breeding and during migration (Pyle 2008). It is likely that feathers collected from adult birds were post-molt 2008 and pre-molt 2009, i.e. grew during the previous year. Philopatry studies in TRES (Winkler et al. 2004) suggest that TRES are site faithful, with only a small percentage of the breeding population dispersing to a different area.

Egg mercury

Mercury concentrations in TRES eggs were greater than RWBL eggs probably because at the time of egg-laying, female RWBL might be foraging at a lower trophic level and consuming a more terrestrial-based diet than the aquatic-based insectivorous TRES. In 2008, 14 of 36 TRES eggs from 11 nests (39%) were above 0.11 µg/g (ww). In 2009, eight out of 17 eggs (47%) were above 0.11 µg/g. Only two of 15 RWBL eggs (13%) exceeded the 0.11 µg/g concentration. Tree swallow and RWBL eggs collected at Harbor Brook on Onondaga Lake had the highest Hg concentration suggesting that a greater source of Hg contamination might be in that area.

Stable Isotopes and Hg in Bird Blood

Mercury in the form of methylmercury that enters food webs is accumulated by organisms at lower trophic levels and is magnified by consumers at higher levels in the food web. This process of bioaccumulation and biomagnification of contaminants represents a significant health risk for wildlife populations. The ratio of stable isotopes of nitrogen (^{15}N and ^{14}N, reported as $\delta^{15}N$) and carbon (^{13}C and ^{12}C, reported as $\delta^{13}C$) measured in producers and consumers can help describe food web pathways leading from the base of the food web up to the top predators (Peterson and Fry 1987) which helps in understanding trophic interactions that may vary across time and space.

The combination of $\delta^{15}N$ and $\delta^{13}C$ analysis provides a two-dimensional interpretation of food web dynamics and, in conjunction with contaminant chemistry, can provide a detailed assessment of the primary routes of contaminant transfer and biomagnification up to top-level predators (Rasmussen and Vander Zanden 2004). Moving up through a food web, $\delta^{15}N$ values show a consistent enrichment of the heavier nitrogen isotope (^{15}N) because organisms preferentially excrete the lighter nitrogen isotope (^{14}N). This produces a trophic level shift of approximately 3‰, allowing for trophic position of particular components of the food web to be determined quantifiably. By contrast, there is very little enrichment of $\delta^{13}C$ values through a food web (<1.0‰ is generally understood), but instead reflects the dietary preference at each trophic level (Peterson and Fry 1987).

In RWBL, blood Hg was significantly and positively related to $\delta^{15}N$, but not to $\delta^{13}C$, suggesting that trophic position for RWBL is a stronger predictor of blood Hg than habitat or carbon source. The different $\delta^{15}N$ found in female RWBL suggests that they feed (1) at a higher trophic level, and/or (2) on an aquatic invertebrate based diet than male RWBL. The higher trophic position best explains the higher blood Hg concentrations in female RWBL than male RWBL.

In general, neither $\delta^{13}C$ nor $\delta^{15}N$ were significantly different by species between study areas suggesting that both trophic position ($\delta^{15}N$) and foraging habitat ($\delta^{13}C$) were similar between treatments. We, therefore, conclude that the birds sampled from Onondaga Lake have significantly higher Hg concentrations because of higher contamination levels in the lake and not because they are foraging at a higher trophic level on Onondaga vs. Oneida Lakes.

Conclusions

The 2008-2009 study demonstrates that Hg concentrations in all target species are significantly higher on Onondaga Lake than the reference site on Oneida Lake. Many individuals had blood Hg levels exceeding the 10% nest success reduction threshold for the Carolina wren (fewer nests fledging at least one young) of 0.7 µg/g (ww) and a proportion exceeded the 20% threshold of 1.2 µg/g Hg. Female RWBL appear to accumulate greater concentrations of Hg than male RWBL. All but two sampled SPSA had blood Hg levels above 0.7 and the majority of shorebirds sampled had blood Hg levels exceeding 1.2 µg/g (ww). Only a few songbird eggs exceeded the egg LOAEL of 0.2 µg/g. Stable isotope ($\delta^{13}C$ and $\delta^{15}N$) data revealed differences in the foraging behavior between the three target songbirds and also highlighted the importance of understanding both site-specific processes and trophic level interactions that can influence birds' susceptibility to Hg bioaccumulation.

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LITERATURE CITED

Aldrich, J.W. 1984. Ecogeographical variation in size and proportions of Song sparrows (*Melospiza melodia*). Ornithol. Monog. 35: 1-134.

Arcese, P., M.K. Sogge, A.B. Marr, and M.A. Patten. 2002. Song sparrow (*Melospiza melodia*). In The Birds of North America, No. 704 (A. Poole and F. Gill, eds.). The Birds of North America, Inc. Philadelphia, PA.

Bearhop S., G.D. Ruxton, and R.W. Furness. 2000. Dynamics of mercury in blood and feathers of Great Skuas. Environ. Toxicol. and Chem. 19:1638-1643.

Beyer, W.N., E.E. Connor, and S. Gerould. 1995. Estimates of soil ingestion by wildlife. Journal Wildl. Manage. 58(2):375-382.

Bird, R.D. and L.B. Smith. 1964. The food habits of the red-winged blackbird, *Agelaius phoeniceus,* in Manitoba. Canadian Field-Naturalist. 78: 179-186.

Blancher, P.J. and D.K. McNicol. 1991. Tree swallow diet in relation to wetland acidity. Canadian Journal of Zoology. 69:2629-37.

Boudou, A., M. Delnomdedieu, D. Georgescauld, F. Ribeyre, and E. Sauter. 1991. Fundamental roles of biological barriers in mercury accumulation and transfer in freshwater ecosystems (analysis at organism, organ, cell, and molecular levels). Water Air Soil Pollution. 56:807-821.

Buck D.G., K. Regan, T. Divoll, D. Yates and S. de la Sota. 2012. Mercury in the invertivore food web of Onondaga Lake. Submitted to U.S. Fish and Wildlife Service, Cortland, New York, by Biodiversity Research Institute, Gorham, Maine.

Burger, J. 1993. Metals in avian feathers: bioindicators of environmental pollution. Reviews in Environ. Toxicol. 5:203-311.

Burgess, N.M. and M.W. Meyer. 2008. Methylmercury exposure associated with reduced productivity in common loons. Ecotoxicology 17:83-91.

Condon, A. and D. Cristol. 2009. Feather growth influences blood mercury in young songbirds. Environ. Toxicol. Chem. 28:395-401.

Custer, T.W., C.M. Custer, K. Dickerson, K. Allen, M.J. Melancon, and L.J. Schmidt. 2001. Polycyclic aromatic hydrocarbons, aliphatic hydrocarbons, trace elements, and monooxygenase activity in birds nesting on the North Platte River, Casper, Wyoming, USA. Environ. Toxicol. And Chem. 20:624-631.

Custer, T.W., C.M. Custer, K.M. Johnson, and D.J. Hoffman. 2008. Mercury and other element exposure to tree swallows (*Tachycineta bicolor)* nesting on Lostwood National Wildlife Refuge, North Dakota.

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

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

Evers, D.C, N.M. Burgess, L. Champoux, B. Hoskins, A. Major, W. Goodale, R. Taylor, and T. Daigle. 2005. Patterns and interpretation of mercury exposure in freshwater avian communities in Northeastern North America. Ecotoxicology 14:193-222.

Evers, D.C., O. Lane, L. Savoy, and D. Yates. 2006. Summary of wildlife mercury exposure for the Nyanza Superfund Project. BRI report 2003-04. Submitted to Avatar Environmental, West Chester, Pennsylvania.

Evers, D.C., L.J. Savoy, C.R. DeSorbo, D.E. Yates, W. Hanson, K.M. Taylor, L.S. Siegel, J.H. Cooley, Jr., M.S. Bank, A. Major, K. Munney, B.F. Mower, H.S. Vogel, N. Schoch,

M. Pokras, M.W. Goodale, and J. Fair. 2008. Adverse effects from environmental mercury loads on breeding common loons. Ecotoxicology 17:69-81.

Gerrard, P.M. and V.L. St. Louis. 2001. The effects of experimental reservoir creation on the bioaccumulation of methylmercury and reproductive success of tree swallows (*Tachycineta bicolor*). Environ. Science & Technology 35:1329-1338.

Hallinger, K.K., D.J. Zabransky, K.A. Kazmer, and D.A. Cristol. 2010. Birdsong differs between mercury-polluted and reference sites. Auk 127(1):156-161.

Heinz, G., D. Hoffman, J. Klimstra, K. Stebbins, S. Kondrad, and C. Erwin. 2009. Species differences in the sensitivity of avian embryos to methylmercury. Archives of Environ. Contam. and Toxicol. 56:129-38.

Hobson, K.A. and R.G. Clark. 1993. Turnover of ^{13}C in cellular and plasma fractions of blood: implications for nondestructive sampling in avian dietary studies. Auk 110:638-641.

Hobson, K.A. and R.G. Clark. 1994. Assessing avian diets using stable isotopes I: turnover of ^{13}C in tissues. Condor 94:181-188.

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

Lane, O.P., D. Buck, D.C. Evers, S. Edmonds, and A. Jackson. 2011. Pilot assessment of mercury and PCB exposure in birds breeding at Onondaga Lake. Report BRI 2010-12 submitted to U.S. Fish and Wildlife Service, Cortland, New York. Biodiversity Research Institute, Gorham, Maine.

McCarty, J.P. and D.W. Winkler. 1999. Foraging ecology and diet selectivity of tree swallows feeding nestlings. Condor 101: 246-254.

McNicol, D.K., R.J. Robertson, and P.J. Weatherhead. 1982. Seasonal, habitat, and sex-specific food habits of Red-winged blackbirds: implications for agriculture. Can. J. Zool. 60:3282-3289.

Michener, R. and K. Lajtha (eds.). 2007. Stable Isotopes in Ecology and Environmental Science (2nd Edition). Blackwell Publishing, Ltd. Oxford, United Kingdom. 566pp.

Microsoft Excel. 2010. Version 14.0. Microsoft Corporation.

Oring, L.W., E.M. Gray, and J.M. Reed. 1997. Spotted sandpiper (*Actitis macularius*). *In* The Birds of North America, No. 289 (A. Poole, Ed.). Philadelphia: The Academy of Natural Sciences; Washington, DC: The American Ornithologists' Union.

Peterson, B.J. and B. Fry. 1987. Stable isotopes in ecosystem studies. Annual Review of Ecology and Systematics 18: 293-320.

Pyle, P. 1997. Identification guide to North American Birds. Part 1. Slate Creek Press, Bolinas, California. 732pp.

Pyle, P. 2008. Identification guide to North American Birds. Part II. Slate Creek Press, Bolinas, California. 835pp.

Quinney, T.E. and C.D. Ankney. 1985. Prey size selection by Tree swallows. Auk 102:245-250.

Rasmussen J.B. and M.J. Vander Zanden. 2004. The variation of lake food webs across the landscape and its effect on contaminant dynamics. Pp. 169-182 in G.A. Polis, M.E. Power, and G.R. Huxel, eds., Food webs at the landscape scale. The University of Chicago Press, Chicago, Illinois.

Rimmer, C.C., K.P. McFarland, D.C. Evers, E.K. Miller, Y. Aubrey, D. Busby, and R.J. Taylor. 2005. Mercury concentrations in Bicknell's thrush and other insectivorous passerines in montane forests of northeastern North America. Ecotoxicology 14:223-240.

Robertson, R.J., B.J. Stutchbury, and R.R. Cohen. 1992. Tree swallow. *In* The Birds of North America, No. 11 (A. Poole, P. Stettenheim, and F. Gill, Eds.). Philadelphia: The Academy of Natural Sciences; Washington, DC. The American Ornithologists' Union.

SAS. 2003. JMP Version 5.0. SAS Institute, Inc. Cary, North Carolina.

Secord, A.L., J.P. McCarty, K.R. Echols, J.C. Meadows, R.W. Gale, D.E. Tillitt. 1999. Polychlorinated biphenyls and 2,3,7,8-tetrachlorodibenzo-p-dioxin equivalents in tree swallows from the upper Hudson River, New York State, USA. Environ. Toxicol. Chem. 18: 2519-2525.

TAMS and YEC Inc. 2002. Onondaga Lake Baseline Ecological Risk Assessment. Original document prepared by Exponent, Bellevue, Washington, for Honeywell, East Syracuse, New York. Revision prepared by TAMS, New York, New York, and YEC, Valley Cottage, New York, for New York State Department of Environmental Conservation, Albany, New York.

U.S. Environmental Protection Agency. 1998. Mercury in solids and solutions by thermal decomposition, amalgamation, and atomic absorption spectrophotometry. Method 7473. U.S. Environmental Protection Agency, Washington, DC.

U.S. Fish and Wildlife Service. 2005. Natural Resource Damage Preassessment Screen for Onondaga Lake, Onondaga County, New York. Original document prepared by K. Karwowski, U.S. Fish and Wildlife Service, Cortland, New York. 31pp.

Winkler, D.W., P.H. Wrege, P.E. Allen, T.L. Kast, P. Senesac, M.F. Wasson, P.E. Llambías, V. Ferretti, and P.J. Sullivan. 2004. Breeding dispersal and philopatry in the tree swallow. Condor 106:768-776.

Appendix A. Summary of blood and feather mercury data, 2008-2009.

Species	Site	Year	Age	Blood mercury (µg/g ww)				Feather mercury (µg/g fw)			
				n	Mean ± SD	Min., Max.	95% CI	*n*	Mean ± SD	Min., Max.	95% CI
Green heron	Harbor Brook	2009	HY	1	0.303	—	—	—	—	—	—
Killdeer	White Cliffs	2008	Ad.	2	1.250 ± 0.014	1.240, 1.260	1.123, 1.38	—	—	—	—
Spotted sandpiper	Ninemile Creek	2009		7	0.964 ± 0.858	0.245, 2.58	0.171, 1.76	4	0.914 ± 0.40	0.480, 1.448	0.278, 1.55
	Beach	2008	Ad.	1	1.56	—	—	—	—	—	—
		2009	Ad.	8	2.373 ± 1.50	1.082, 4.969	1.12, 3.63	8	4.50 ± 8.61	0.456, 25.703	–2.702, 11.7
		2009	HY	1	0.368	—	—	1	1.466		
	Harbor Brook	2008	Ad.	1	3.610	—	—	—	—	—	—
	White Cliffs	2008	Ad.	1	6.420	—	—	—	—	—	—
		2009	Ad.	4	2.587 ± 1.564	0.581, 4.400	0.098, 5.08	4	1.06 ± 0.71	0.250, 1.660	–0.063, 2.18
		2009	HY	1	1.048	—	—	1	2.473		
	Overall	SPSA		24	2.045 ± 1.66	0.245, 6.420	1.345, 2.746	18	2.66 ± 5.80	0.250, 25.703	–0.228, 5.54

Species	Site	Year	Age	Blood mercury (µg/g ww)				Feather mercury (µg/g fw)			
Belted kingfisher	Ninemile Creek	2009	Ad.	1	1.77	—	—	1	6.264	—	—
	Maple Bay	2008	Ad.	1	1.840	—	—	1	35.742	—	—
		2009	Ad.	2	2.538 ± 0.668	2.065, 3.010	–3.468, 8.54	2	12.22 ± 8.84	5.963, 18.47	–67.3, 91.7
	Overall	BEKI	Ad.	4	2.172 ± 0.573	1.772, 3.010	1.26, 3.083	4	16.6 ± 14.02	5.963, 35.74	–5.704, 38.9
Downy woodpecker	Beach	2009	Ad.	1	0.032	—	—	—	—	—	—
	Maple Bay	2008	Ad.	3	0.170 ± 0.042	0.125, 0.209	0.065, 0.275	—	—	—	—
	Overall	DOWO	Ad.	4	0.135 ± 0.077	0.032, 0.209	0.013, 0.258	—	—	—	—
Trail's flycatcher	Ninemile Creek	2009	Ad.	3	0.949 ± 0.551	0.527, 1.572	–0.420, 2.317	—	—	—	—
	Beach	2008	Ad.	2	0.805 ± 0.054	0.767, 0.843	0.322, 1.288	—	—	—	—
		2009	Ad.	1	2.087	—	—	—	—	—	—
	Harbor Brook	2009	Ad.	2	2.758 ± 1.362	1.795, 3.720	–9.476, 14.991	—	—	—	—
	Overall	TRFL	Ad.	8	1.507 ± 1.059	0.527, 3.720	0.622, 2.393	—	—	—	—
Willow	Ninemile	2009	Ad.	2	0.670 ± 0.207	0.524, 0.817	–1.193, 2.534	—	—	—	—

Species	Site	Year	Age	Blood mercury (µg/g ww)				Feather mercury (µg/g fw)			
flycatcher	Creek										
	Harbor Brook	2009	Ad.	2	1.982 ± 0.298	1.771, 2.193	–0.699, 4.664	—	—	—	—
	Overall	WIFL	Ad.	4	1.326 ± 0.786	0.524, 2.193	0.076, 2.577	—	—	—	—
Flycatchers (Willow and Trail's overall)	Overall		Ad.	12	1.447 ± 0.943	0.524, 3.720	0.848, 2.046	—	—	—	—
Great-crested flycatcher	White Cliffs	2008	Ad.	1	0.652	—	—	—	—	—	—
	Oneida (Ref.)	2009	Ad.	1	0.235	—	—	—	—	—	—
Eastern kingbird	Oneida (Ref.)	2009	Ad.	1	0.130	—	—	—	—	—	—
Red-eye vireo	Canal	2008	Ad.	2	0.113 ± 0.004	0.113, 0.119	0.078, 0.154	—	—	—	—
	Maple Bay	2008	Ad.	1	0.463	—	—	—	—	—	—
	White Cliffs	2008	Ad.	1	0.122	—	—	—	—	—	—
	Overall	REVI	Ad.	4	0.204 ± 0.173	0.113, 0.463	–0.070, 0.479	—	—	—	—
Warbling vireo	Canal	2008	Ad.	1	0.140	—	—	—	—	—	—

Species	Site	Year	Age	Blood mercury (µg/g ww)				Feather mercury (µg/g fw)			
	Maple Bay	2008	Ad.	9	0.278 ± 0.185	0.075, 0.609	0.136, 0.420	—	—	—	—
	Harbor Brook	2009	Ad.	1	0.215	—	—	—	—	—	—
	White Cliffs	2008	Ad.	2	0.279 ± 0.146	0.175, 0.382	–1.037, 1.594	—	—	—	—
	Overall	WAVI	Ad.	13	0.262 ± 0.162	0.075, 0.609	0.165, 0.360	—	—	—	—
Northern rough-winged swallow	White Cliffs	2008	Ad.	2	0.651 ± 0.141	0.552, 0.751	–0.613, 1.916	—	—	—	—
Bank Swallow	White Cliffs	2008	Ad.	1	0.353	—	—	—	—	—	—
Tree swallow	Ninemile Creek	2009	Ad.	5	0.516 ± 0.146	0.326, 0.723	0.335, 0.697	—	—	—	—
	Beach	2008	Ad.	2	0.445 ± 0.040	0.416, 0.473	0.082, 0.807	—	—	—	—
	Canal	2008	Ad.	6	0.172 ± 0.033	0.134, 0.215	0.137, 0.206	—	—	—	—
	Maple Bay	2008	Ad.	5	0.405 ± 0.186	0.209, 0.693	0.174, 0.635	—	—	—	—
		2009	Ad.	15	0.325 ± 0.111	0.115, 0.546	0.264, 0.387	—	—	—	—
	Ley Creek	2008	Ad.	2	0.875 ± 0.319	0.649, 1.100	–1.991, 3.740	—	—	—	—
		2009	Ad.	9	0.263 ± 0.072	0.179, 0.415	0.207, 0.318	—	—	—	—
	Harbor Brook	2008	Ad.	2	1.490 ± 0.240	1.320, 1.660	–0.670, 3.650	—	—	—	—

Species	Site	Year	Age	Blood mercury (µg/g ww)				Feather mercury (µg/g fw)			
		2009	Ad.	7	0.539 ± 0.172	0.344, 0.830	0.380, 0.698	—	—	—	—
	Wetzel Rd.	2009	Ad.	7	0.312 ± 0.060	0.207, 0.391	0.257, 0.368	—	—	—	—
	White Cliffs	2008	Ad.	4	0.417 ± 0.055	0.373, 0.494	0.329, 0.504	—	—	—	—
	Overall	TRES	Ad.	64	0.408 ± 0.266	0.115, 1.660	0.342, 0.475	—	—	—	—
	Oneida (Ref.)	2008	Ad.	6	0.078 ± 0.029	0.058, 0.131	0.048, 0.108	—	—	—	—
		2009	Ad.	17	0.091 ± 0.064	0.035, 0.313	0.059, 0.124	—	—	—	—
	Ref. Overall	TRES	Ad.	23	0.088 ± 0.056	0.035, 0.313	0.064, 0.112	—	—	—	—
Barn Swallow	Ninemile Creek	2009	Ad.	2	0.622 ± 0.122	0.535, 0.708	–0.474, 1.72	—	—	—	—
	Oneida (Ref.)	2009	Ad.	1	0.133	—	—	—	—	—	—
Black-capped chickadee	9-Miile Creek	2009	Ad.	1	0.167	—	—	—	—	—	—
	Maple Bay	2008	Ad.	1	0.369	—	—	—	—	—	—
		2008	HY	1	0.149	—	—	—	—	—	—
		2009	Ad.	1	0.557	—	—	—	—	—	—
	Harbor Brook	2009	Ad.	1	0.466	—	—	—	—	—	—
		2009	HY	1	0.326	—	—	—	—	—	—
	White Cliffs	2009	Ad.	1	0.430	—	—	—	—	—	—

Species	Site	Year	Age	Blood mercury (µg/g ww)				Feather mercury (µg/g fw)			
	Overall	BCCH		7	0.352 ± 0.151	0.149, 0.557	0.212, 0.492	—	—	—	—
House wren	Maple Bay	2008	Ad.	1	0.339	—	—	—	—	—	—
American robin	Ninemile Creek	2009	Ad.	2	0.484 ± 0.334	0.248, 0.720	–2.52, 3.49	—	—	—	—
	Beach	2009	Ad.	1	0.127	—	—	—	—	—	—
	Maple Bay	2008	Ad.	1	0.623	—	—	—	—	—	—
		2009	Ad.	2	0.803 ± 0.673	0.327, 1.280	–5.25, 6.85	—	—	—	—
		2009	HY	1	0.143	—	—	—	—	—	—
	Harbor Brook	2009	Ad.	1	0.577	—	—	—	—	—	—
	White Cliffs	2008	HY	2	0.621 ± 0.833	0.032, 1.210	–6.86, 8.11	—	—	—	—
	Overall	AMRO		10	0.529 ± 0.441	0.032, 1.280	0.213, 0.844	—	—	—	—
	Oneida (Ref.)	2009	Ad.	3	0.110 ± 0.041	0.067, 0.149	0.008, 0.212	—	—	—	—
Wood thrush	Maple Bay	2008	Ad.	1	0.156	—	—	—	—	—	—
	White Cliffs	2008	Ad.	1	0.574	—	—	—	—	—	—
	Overall	WOTH	Ad.	2	0.365 ± 0.296	0.156, 0.574	–2.291, 3.021	—	—	—	—
	Oneida (Ref.)	2008	Ad.	1	0.145	—	—	—	—	—	—
Gray catbird	Ninemile Creek	2009	HY	1	0.017	—	—	—	—	—	—

Species	Site	Year	Age	Blood mercury (µg/g ww)				Feather mercury (µg/g fw)			
		2009	Ad.	4	1.557 ± 1.756	0.266, 4.118	–1.237, 4.351	—	—	—	—
	Ninemile Creek (Overall)	GRCA		5	1.249 ± 1.669	0.017, 4.118	–0.824, 3.322	—	—	—	—
	Beach	2008	Ad.	1	1.110	—	—	—	—	—	—
		2009	Ad.	1	0.227	—	—	—	—	—	—
	Canal	2008	Ad.	1	0.177	—	—	—	—	—	—
	Maple Bay	2008	Ad.	2	0.252 ± 0.151	0.145, 0.358	–1.102, 1.605	—	—	—	—
	Ley Creek	2008	Ad.	1	0.625	—	—	—	—	—	—
		2009	Ad.	1	0.302	—	—	—	—	—	—
	Harbor Brook	2008	Ad.	1	0.616	—	—	—	—	—	—
		2009	Ad.	1	3.610	—	—	—	—	—	—
	White Cliffs	2008	Ad.	1	0.569	—	—	—	—	—	—
		2009		4	0.146 ± 0.053	0.115, 0.225	0.061, 0.230	—	—	—	—
	Overall	GRCA		19	0.767 ± 1.144	0.017, 4.118	0.215, 1.318	—	—	—	—
	Oneida (Ref.)	2009	Ad.	1	0.154	—	—	—	—	—	—
European starling	Ley Creek	2009	Ad.	1	7.167	—	—	—	—	—	—

Species	Site	Year	Age	Blood mercury (µg/g ww)				Feather mercury (µg/g fw)			
		2009	HY	2	1.332 ± 1.029	0.604, 2.059	–7.911, 10.57	—	—	—	—
	Overall	EUST		3	3.277 ± 3.447	0.604, 7.167	–5.285, 11.84	—	—	—	—
Yellow warbler	Ninemile Creek	2009	Ad.	1	0.479	—	—	—	—	—	—
	Beach	2008	Ad.	1	0.809	—	—	—	—	—	—
	Maple Bay	2008	Ad.	1	0.237	—	—	—	—	—	—
		2009	Ad.	1	0.277	—	—	—	—	—	—
	Harbor Brook	2008	Ad.	2	1.975 ± 0.361	1.720, 2.230	–1.265, 5.215	—	—	—	—
		2009	Ad.	7	0.970 ± 0.592	0.379, 1.881	0.423, 1.517	—	—	—	—
	White Cliffs	2009	Ad.	1	1.040	—	—	—	—	—	—
	Overall	YEWA	Ad.	14	0.970 ± 0.653	0.237, 2.230	0.593, 1.347	—	—	—	—
	Oneida (Ref.)	2009	Ad.	1	0.068	—	—	—	—	—	—
American redstart	Maple Bay	2008	Ad.	7	0.395 ± 0.147	0.186, 0.572	0.259, 0.530	—	—	—	—
	Harbor Brook	2008	Ad.	2	2.335 ± 0.247	2.160, 2.510	0.111, 4.559	—	—	—	—
		2009	Ad.	5	3.902 ± 1.739	1.837, 6.155	1.743, 6.060	5	8.292 ±	1.19, 13.55	
	Overall	AMRE	Ad.	14	1.924 ± 1.932	0.186, 6.155	0.809, 3.040	5	8.292 ± 5.24	1.19, 13.55	1.79, 14.8

Species	Site	Year	Age	Blood mercury (µg/g ww)				Feather mercury (µg/g fw)			
Common yellowthroat	Ninemile Creek	2009	Ad.	1	0.250	—	—	—	—	—	—
Northern cardinal	Maple Bay	2008	Ad.	2	0.061 ± 0.15	0.050, 0.071	–0.073, 0.195	—	—	—	—
	Harbor Brook	2009	Ad.	1	0.164	—	—	—	—	—	—
	Overall	NOCA	Ad.	3	0.095 ± 0.061	0.050, 0.164	–0.055, 0.246	—	—	—	—
	Oneida (Ref.)	2009	Ad.	1	0.025			—	—	—	—
Eastern towhee	Ninemile Creek	2009	Ad.	1	1.377	—	—	—	—	—	—
Chipping sparrow	Wetzel Road	2009	Ad.	1	0.047	—	—	—	—	—	—
Swamp sparrow	Harbor Brook	2009	Ad.	1	2.335	—	—	—	—	—	—
	White Cliffs	2009	HY	1	0.218	—	—	—	—	—	—
	Overall	2009		2	1.277 ± 1.497	0.218, 2.335	–12.17, 14.72	—	—	—	—
Song sparrow	Ninemile Creek	2009	Ad.	9	0.313 ± 0.165	0.147, 0.706	0.186, 0.439	7	1.67 ± 0.918	0.152, 3.17	0.968, 2.380
	Beach	2008	Ad.	3	0.769 ± 0.073	0.710, 0.850	0.589, 0.949	—	—	—	—
		2008	HY	1	0.502	—	—	—	—	—	—

Species	Site	Year	Age	Blood mercury (µg/g ww)				Feather mercury (µg/g fw)			
		2009	Ad.	7	0.914 ± 0.690	0.264, 2.257	0.275, 1.552	7	2.34 ± 0.833	0.845, 3.52	1.57, 3.11
		2009	HY	2	1.047 ± 0.101	0.975, 1.119	0.137, 1.957	2	40.0 ± 19.24	26.4, 53.6	–132.9, 212.9
	Canal	2008	Ad.	1	0.057	—	—	—	—	—	—
	Maple Bay	2008	Ad.	6	0.599 ± 0.202	0.307, 0.922	0.387, 0.811	—	—	—	—
		2009	Ad.	1	1.146	—	—	1	10.47	—	—
	Ley Creek	2008	Ad.	2	0.988 ± 0.880	0.366, 1.610	–6.92, 8.89	—	—	—	—
		2009	Ad.	1	0.576	—	—	1	1.37		
	Harbor Brook	2008	Ad.	4	2.067 ± 0.464	1.660, 2.700	1.329, 2.806	—	—	—	—
		2009	Ad.	4	1.037 ± 0.376	0.679, 1.567	0.439	4	4.217 ± 3.533	0.850, 9.146	–1.404, 9.84
		2009	HY	4	1.129 ± 1.127	0.094, 2.504	–0.665, 2.923	4	4.483 ± 2.103	1.395, 5.827	1.137, 7.83
	Wetzel Rd.	2009	Ad.	4	0.200 ± 0.195	0.021, 0.476	–0.110, 0.509	4	1.107 ± 0.720	0.117, 1.801	–0.039, 2.25
	White Cliffs	2008	Ad.	4	2.373 ± 0.666	1.38, 2.81	1.313, 3.432	—	—	—	—
		2009	Ad.	4	1.344 ± 1.009	0.482, 2.793	-0.263, 2.950	4	7.661 ± 4.031	3.776, 12.910	1.247, 14.1

Species	Site	Year	Age	Blood mercury (µg/g ww)				Feather mercury (µg/g fw)			
	Overall	SOSP		57	0.948 ± 0.794	0.021, 2.810	0.738, 1.159	36	5.365 ± 9.580	0.117, 53.606	2.124, 8.61
	Oneida (Ref.)	2008	Ad.	3	0.056 ± 0.015	0.047, 0.074	0.018, 0.094	—	—	—	—
		2009	Ad.	3	0.058 ± 0.013	0.049, 0.074	0.025, 0.091	3	0.300 ± 0.122	0.201, 0.437	–0.004, 0.604
	Ref. Overall		Ad.	6	0.057 ± 0.013	0.047, 0.074	0.044, 0.071	3	0.300 ± 0.122	0.201, 0.437	–0.004, 0.604
Brown-headed cowbird	Maple Bay	2008	Ad.	1	0.130	—	—	—	—	—	—
Red-winged blackbird	Ninemile Creek	2009	Ad.	9	0.439 ± 0.761	0.096, 2.441	–0.147, 1.024	9	0.496 ± 0.499	0.098, 1.617	0.112, 0.879
	Beach	2008	Ad.	5	0.673 ± 0.787	0.070, 1.910	–0.304, 1.651	—	—	—	—
		2009	Ad.	1	5.292	—	—	—	—	—	—
	Canal	2008	Ad.	2	0.234 ± 0.069	0.185, 0.283	–0.389, 0.857	—	—	—	—
	Maple Bay	2008	Ad.	6	1.095 ± 0.897	0.073, 2.210	0.153, 2.037	7	0.358 ± 0.432	0.111, 1.325	–0.042, 0.757
		2009	Ad.	5	1.041 ± 1.011	0.145, 2.614	–0.214, 2.296	5	0.292 ± 0.283	0.068, 0.745	–0.059, 0.644
	Ley Creek	2008	Ad.	7	0.373 ± 0.515	0.023, 1.270	–0.103, 0.850	7	0.299 ±	0.101,	0.057, 0.542

Species	Site	Year	Age	Blood mercury (µg/g ww)				Feather mercury (µg/g fw)			
									0.262	0.864	
		2009	Ad.	14	0.143 ± 0.073	0.064, 0.308	0.101, 0.185	14	0.355 ± 0.335	0.120, 1.420	0.162, 0.548
	Harbor Brook	2008	Ad.	5	0.837 ± 0.928	0.199, 2.410	–0.316, 1.990	—	—	—	—
		2009	Ad.	7	1.089 ± 0.560	0.347, 2.153	0.572, 1.607	8	0.466 ± 0.268	0.133, 0.782	0.242, 0.690
		2009	HY	1	1.310	—	—	—	—	—	—
	Wetzel Rd.	2009	Ad.	8	0.159 ± 0.066	0.044, 0.269	0.104, 0.214	8	0.169 ± 0.067	0.088, 0.314	0.112, 0.225
	White Cliffs	2008	Ad.	4	0.807 ± 1.026	0.126, 2.310	–0.825, 2.440	—	—	—	—
	Overall	RWBL		74	0.636 ± 0.890	0.023, 5.292	0.430, 0.842	59	0.354 ± 0.333	0.068, 1.617	0.267, 0.441
	Oneida (Ref.)	2008	Ad.	13	0.112 ± 0.025	0.076, 0.166	0.097, 0.128	—	—	—	—
		2009	Ad.	7	0.074 ± 0.008	0.061, 0.081	0.066, 0.082	7	0.104 ± 0.023	0.073, 0.141	0.083, 0.125
	Ref. Overall		Ad.	20	0.099 ± 0.028	0.061, 0.166	0.086, 0.112	7	0.104 ± 0.023	0.073, 0.141	0.083, 0.125
Common grackle	Ninemile Creek	2009	Ad.	1	0.164	—	—	—	—	—	—

Species	Site	Year	Age	Blood mercury (µg/g ww)				Feather mercury (µg/g fw)			
	Beach	2009	Ad.	1	0.831	—	—	—	—	—	—
	Maple Bay	2008	Ad.	3	0.197 ± 0.128	0.115, 0.345	–0.121, 0.516	3	0.393 ± 0.206	0.193, 0.605	–0.119, 0.905
		2008	U	1	0.046	—	—	1	0.148	—	—
		2009	HY	1	0.448	—	—	—	—	—	—
	Ley Creek	2009	Ad.	3	0.223 ± 0.105	0.119, 0.330	–0.038, 0.485	—	—	—	—
	Overall	COGR		10	0.275 ± 0.232	0.046, 0.831	0.109, 0.441	4	0.332 ± 0.208	0.148, 0.605	0.000, 0.663
	Oneida (Ref.)	2008	Ad.	1	0.162	—	—	—	—	—	—
		2009	Ad.	1	0.060	—	—	—	—	—	—
	Ref. Overall		Ad.	2	0.111 ± 0.072	0.060, 0.162	–0.540, 0.761	—	—	—	—
Baltimore oriole	Harbor Brook	2008	Ad.	3	0.503 ± 0.258	0.307, 0.795	–0.137, 1.143	—	—	—	—
		2009	Ad.	2	0.959 ± 0.608	0.529, 1.389	–4.504, 6.422	—	—	—	—
	Overall	BAOR	Ad.	5	0.686 ± 0.434	0.307, 1.389	0.147, 1.224	—	—	—	—
	Oneida (Ref.)	2008	Ad.	1	0.046	—	—	—	—	—	—
		2009	Ad.	1	0.058	—	—	—	—	—	—
	Ref. Overall		Ad.	2	0.052 ± 0.009	0.046, 0.058	–0.029, 0.133	—	—	—	—

Species	**Site**	**Year**	**Age**	**Blood mercury (µg/g ww)**				**Feather mercury (µg/g fw)**			
American goldfinch	Ninemile Creek	2009	Ad	2	0.005 ± 0.003	0.003, 0.007	–0.022, 0.032	—	—	—	—
	Canal	2008	Ad.	1	0.003	—	—	—	—	—	—
	Ley Creek	2009	Ad.	1	0.001	—	—	—	—	—	—
	Harbor Brook	2009	Ad.	1	0.005	—	—	—	—	—	—
	Wetzel Rd	2009	Ad.	2	0.001 ± 0.000	0.001, 0.001	–0.002, 0.004	—	—	—	—
	Overall	AMGO	Ad.	7	0.003 ± 0.002	0.001, 0.007	0.001, 0.005	—	—	—	—

Appendix B. Mercury concentrations (μg/g, ww) in eggs of tree swallows and red-winged blackbirds, 2009.

Treatment	Site	RWBL Hg	TRES Hg
		mean ± SD (*n*) min, max	mean ± SD (*n*) min, max
Ninemile Creek	Ninemile Creek	0.030 ± 0.009 (5) 0.020, 0.040	0.139 ± 0.028 (3) 0.107, 0.158
Onondaga Lake	Maple Bay	—	0.080 ± 0.037 (6) 0.012, 0.125
	Ley Creek	0.013 ± 0.009 (4) 0.007, 0.027	0.110 ± 0.025 (3) 0.082, 0.130
	Harbor Brook	0.108 ± 0.096 (4) 0.023, 0.233	0.144 ± 0.059 (4) 0.098, 0.223
	Onondaga (overall)	0.061 ± 0.081 (8) 0.007, 0.233	0.106 ± 0.049 (13) 0.012, 0.223
Seneca River	Wetzel Road	0.036 ± 0.016 (2) 0.024, 0.047	0.095 ± 0.010 (3) 0.086, 0.105
Reference	Oneida Lake	0.028 ± 0.018 (3) 0.014, 0.049	0.040 ± 0.026 (3) 0.011, 0.062

Appendix C. Tree swallows re-sampled within the same season and/or re-captured in 2009.

Site	Band Number	Sample date	Blood-Hg (µg/g)	Retrap date	Blood-Hg (µg/g)	Recap date	Blood-Hg (µg/g)
Canal	2311-55536	5/17/08	0.173	6/18/08	0.220	—	—
Canal *	2311-55543	5/25/08	0.215	—	—	6/2/09	0.349
Canal **	2311-55548	6/9/08	0.134	—	—	6/8/09	0.302
Maple Bay	2311-55537	5/22/08	0.279	6/9/08	0.242	—	—
Maple Bay	2311-55558	6/2/08	0.199	—	—	6/2/09	0.352
Maple Bay	2311-55539	5/24/08	0.417	6/9/08	0.518	5/21/09	0.317
Maple Bay	2311-55542	5/25/08	0.425	6/11/08	0.318	6/2/09	0.388
Maple Bay	2391-69201	5/19/09	na	6/4/09	na	—	—
Ley Creek	2311-55541	5/24/08	1.100	6/24/08	0.658	—	—
Ley Creek	2311-55538	5/22/08	1.320	6/11/08	1.790	—	—
Ley Creek	2391-69202	5/27/09	0.437	6/1/09	na	—	—
Ley Creek	2391-69226	6/1/09	0.573	6/5/09	na	—	—
Oneida	2311-55555	6/11/08	0.058	—	—	5/28/09	0.071
Oneida	2391-69222	5/28/09	0.100	6/4/09	na	—	—

*This bird was recaptured at Wetzel Rd in 2009.

**This bird was recaptured at Maple Bay in 2009.

Appendix D. Summary of blood stable isotope data ($\delta^{13}C$, $\delta^{15}N$) and blood Hg data for all study areas, 2009.

Species	Study Area	*n*	Blood-Hg (µg/g ww) mean ± SD	$\delta^{13}C$	$\delta^{15}N$
American goldfinch	Ninemile Creek	2	0.005 ± 0.002	–25.06 ± 0.056	6.44 ± 0.526
	Onondaga	2	0.003 ± 0.002	–24.64 ± 0.492	5.81± 0.098
	Seneca	2	0.001 ± 0.000	–24.54 ± 0.203	5.986 ± 0.017
	Overall	6	0.003 ± 0.001	–24.75 ± 0.171	6.080 ± 0.182
American redstart	Onondaga	4	3.750 ± 0.984	–25.3 ± 0.208	10.42 ± 0.613
American robin	Ninemile Creek	3	0.484 ± 0.236 (2)	–25.0 ± 0.069	7.694 ± 1.692
	Onondaga	5	0.491 ± 0.213	–24.76 ± 0.095	8.283 ± 0.606
	Reference, Oneida	3	0.110 ± 0.024	–25.0 ± 0.122	8.979 ± 0.611
	Overall	11	0.375 ± 0.121 (10)	–24.89 ± 0.064	8.312 ± 0.516
Baltimore oriole	Onondaga	2	0.959 ± 0.430	–24.8 ± 0.157	8.820 ± 0.070
Barn swallow	Reference, Oneida	1	0.133	–25.50	10.87
Black-capped chickadee	Ninemile Creek	1	0.167	–25.8	11.52
	Onondaga	1	0.430	–25.438	11.126
	Overall	2	0.299 ± 0.132	–25.62 ± 0.18	11.32 ± 0.199
Belted kingfisher	Ninemile Creek	1	1.772	–27.45	17.40
	Onondaga	2	2.538 ± 0.473	–26.29 ± 0.134	17.82 ± 0.082
	Overall	3	2.282 ± 0.374	–26.68 ± 0.394	17.68 ± 0.148
Chipping sparrow	Seneca	1	0.047	–18.60	6.116
Common grackle	Ninemile Creek	1	0.164	–23.68	6.772

	Onondaga	5	0.390 ± 0.123	–21.69 ± 0.571	7.598 ± 0.370
	Reference, Oneida	1	0.060	–20.63	8.074
	Overall	7	0.310 ± 0.264	–21.82 ± 0.523	7.548 ± 0.294
Common yellowthroat	Ninemile Creek	1	0.250	–26.21	9.823
Downy woodpecker	Onondaga	1	0.032	–24.58	6.815
Eastern kingbird	Reference, Oneida	1	0.130	–25.68	9.534
Eastern towhee	Ninemile Creek	1	1.377	–24.39	6.491
European starling	Onondaga	2	3.886 ± 3.281	–24.93 ± 0.772	9.778 ± 1.951
Great-crested flycatcher	Reference, Oneida	1	0.235	–23.83	6.641
Gray catbird	Ninemile Creek	5	1.249 ± 0.747	–24.73 ± 0.168	8.933 ± 1.054
	Onondaga	7	0.675 ± 0.490	–25.31 ± 0.266	9.532 ± 0.727
	Reference, Oneida	1	0.154	–24.56	10.447
	Overall	13	0.855 ± 0.382	–25.03 ± 0.174	9.372 ± 0.547
Green heron	Onondaga	1	0.303	–25.71	10.071
Northern cardinal	Onondaga	1	0.164	–25.33	6.047
	Reference	1	0.025	–24.98	7.861
	Overall	2	0.095 ± 0.069	–25.15 ± 0.172	6.954 ± 0.907
Red-winged blackbird	Ninemile Creek	9	0.439 ± 0.254	–21.03 ± 0.801	8.012 ± 0.350
	Onondaga	28	0.765 ± 0.210	–21.43 ± 0.534	9.060 ± 0.379
	Seneca	8	0.159 ± 0.023	–19.88 ± 0.536	8.256 ± 0.288
	Reference, Oneida	7	0.074 ± 0.003	–25.37 ± 0.319	9.347 ± 0.517
	Overall	52	0.523 ± 0.126	–21.65 ± 0.393	8.793 ± 0.234
Song sparrow	Ninemile Creek	9	0.313 ± 0.055	–25.47 ± 0.118	9.220 ± 0.436
	Onondaga	20	0.964 ± 0.154	–25.56 ± 0.143	9.721 ± 0.340

	Seneca	4	0.200 ± 0.097	–24.79 ± 1.108	9.465 ± 0.830
	Reference, Oneida	2	0.062 ± 0.011	–25.53 ± 0.258	11.31 ± 0.499
	Overall	35	0.658 ± 0.108	–25.45 ± 0.147	9.654 ± 0.249
Spotted Sandpiper	Ninemile Creek	7	0.964 ± 0.324	–25.13 ± 0.411	12.04 ± 1.215
	Onondaga	9	1.916 ± 0.469	–24.88 ± 0.207	11.42 ± 0.713
	Overall	16	1.500 ± 0.315	–24.99 ± 0.208	11.69 ± 0.646
Swamp sparrow	Onondaga	1	2.335	–25.6	9.140
Tree swallow	Ninemile Creek	3	0.469 ± 0.072	–27.82 ± 0.243	10.15 ± 0.632
	Onondaga	18	0.393 ± 0.038	–28.11 ± 0.227	11.0± 0.228
	Seneca	7	0.312 ± 0.023	–26.24 ± 0.211	10.66 ± 0.125
	Reference, Oneida	9	0.114 ± 0.027	–26.59 ± 0.213	11.38 ± 0.350
	Overall	37	0.316 ± 0.029	–27.36 ± 0.186	10.96 ± 0.155
Trail's flycatcher	Ninemile Creek	4	0.916 ± 0.227	–25.38 ± 0.035	9.46 ± 0.782
	Onondaga	3	2.562 ± 0.592	–24.51 ± 0.215	10.44 ± 0.331
	Overall	7	1.621 ± 0.419	–24.44 ± 0.087	9.876 ± 0.479
Warbling vireo	Onondaga	1	0.215	–24.60	6.790
Yellow warbler	Ninemile Creek	1	0.479	–25.08	10.66
	Onondaga	5	0.708 ± 0.196	–26.05 ± 0.474	9.543 ± 0.871
	Reference, Oneida	1	0.068	–25.18	10.62
	Overall	7	0.584 ± 0.164	–25.79 ± 0.369	9.86 ± 0.634

Appendix E. Mean blood (by sex) and feather (sexes combined) mercury concentrations (µg/g) in adult red-winged blackbirds, 2008-2009.

Study Area	Sub-site	Female Blood-Hg	Male Blood-Hg	Feather-Hg
		n; mean ± SD 95% CI (lower, upper)	*n*; mean ± SD 95% CI (lower, upper)	*n*; mean ± SD 95% CI (lower, upper)
Onondaga	Beach	1; 5.29	5; 0.67 ± 0.79 –0.30, 1.65	1; 0.32
	Maple Bay	8; 1.41 ± 0.82 0.73, 2.10	3; 0.16 ± 0.09 –0.07, 0.39	12; 0.33 ± 0.36 0.10, 0.56
	Ley Creek	3; 0.57 ± 0.61 –0.95, 2.08	18; 0.16 ± 0.21 0.06, 0.27	21; 0.34 ± 0.31 0.20, 0.48
	Harbor Brook	6; 1.38 ± 0.77 0.57, 2.19	6; 0.59 ± 0.36 0.21, 0.97	7; 0.42 ± 0.25 0.19, 0.66
	White Cliffs	1; 0.18	3; 1.02 ± 1.15 –1.83, 3.86	—
	Overall	19; 1.41 ± 1.23 0.812, 2.00	35; 0.38 ± 0.53 0.20, 0.56	41; 0.35 ± 0.31 0.25, 0.45
Seneca River	Canal (2008)		2; 0.23 ± 0.07 –0.39, 0.86	—
	Wetzel Road (2009)	3; 0.20 ± 0.07 0.03, 0.38	5; 0.13 ± 0.05 0.07, 0.20	8; 0.17 ± 0.07 0.11, 0.23
	Overall	3; 0.20 ± 0.07 0.03, 0.38	7; 0.16 ± 0.07 0.10, 0.23	8; 0.17 ± 0.07 0.11, 0.23
Ninemile Creek		3; 0.28 ± 0.20 –0.22, 0.77	6; 0.52 ± 0.94 –0.47, 1.51	9; 0.50 ± 0.0.50 0.11, 0.33
Oneida Lake	Reference	8; 0.10 ± 0.04 0.07, 0.13	12; 0.10 ± 0.02 0.09, 0.11	7; 0.10 ± 0.02 0.08, 0.13