New York State Energy Research and Development Authority

Mercury Assessment of Saltmarsh Sparrows on Long Island, New York

Final Report

May 2011

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Mercury Assessment of Saltmarsh Sparrows on Long Island, New York

Final Report

Prepared for the
New York State Energy Research and Development Authority

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Executive Summary

We measured mercury (Hg) concentrations in saltmarsh sparrows (*Ammodramus caudacutus*) from three salt marshes on Long Island, New York during July 2010. Results indicate that Hg exposure represents a significant and emerging stressor for populations of breeding birds on Long Island salt marshes. The Hg concentrations measured in sparrows from two of the Long Island salt marshes (Pine Neck Preserve and North Cinder Island) are among the highest concentrations observed in saltmarsh sparrows from across the Northeast. Mean blood Hg concentrations on Pine Neck Preserve during July 2010 were 1.23 ± 0.12 μg/g, wet weight (ww), while North Cinder blood Hg concentrations were 1.9 ± 0.22 μg/g (ww). Blood Hg concentrations from Scallop Pond were the lowest of the three marshes sampled (0.35 ± 0.10 μg/g, ww).

Mercury concentrations in different feathers of the saltmarsh sparrow were also analyzed to examine differences in Hg exposure on breeding versus wintering grounds. Primary flight feathers in saltmarsh sparrows are grown on the summer breeding grounds (i.e., salt marshes in the Northeastern U.S.) and, as such, reflect a bird's mercury exposure during the breeding season. Conversely, tail feathers are grown during the winter and reflect mercury exposure on the bird's southerly wintering grounds. We found that primary feather mercury concentrations were significantly higher than tail feather mercury concentrations. Mean primary feather Hg concentrations ranged from 6.2 ±0.75 μg/g fresh weight (fw) at Scallop Pond to 18.8 ±8.4 μg/g at North Cinder Island.

We also analyzed Hg concentrations in preferred prey items of saltmarsh sparrows including spiders and amphipods. Mercury concentrations (and concentrations of its highly toxic form, methylmercury) were higher in spiders than in amphipods. Mercury concentrations in prey items also followed a similar pattern as in sparrows with the highest concentrations being observed in North Cinder Island and Pine Neck Preserve (neither spiders nor amphipods were observed on Scallop Pond marsh during the sampling period). To better understand the relationship between prey items and the birds, we also measured the stable carbon and nitrogen isotopic concentrations of bird blood and the prey items. Results show that birds from North Cinder Island occupy a higher trophic level than birds from the other marshes. Birds sampled from Scallop Pond appear to be foraging on lower trophic level prey items than birds sampled from either of the other two salt marshes.

The saltmarsh sparrow is a species of high conservation concern because of its limited breeding range and the loss of coastal habitat associated with human development, sea level rise and climate change. Results from this study suggest that Hg exposure represents an emerging stressor to this already threatened species, and may also impact other songbird populations breeding on Long Island salt marshes. The saltmarsh sparrow can serve as an important bioindicator of the long-term health and well-being of coastal and estuarine ecosystems on Long Island and across the region.

Introduction

The estuaries, coastal zone, and marine ecosystems of Long Island represent one of the world's most productive and utilized water bodies, providing for an active commercial and recreational fishery, as well as numerous other recreational uses for the nearly 16 million people that live in the region (Balcom et al. 2004; Hammerschmidt and Fitzgerald 2006). The waters and near-shore environments also have been heavily impacted by anthropogenic stressors including nutrients, organic chemicals, and heavy metals, particularly mercury. The primary source of mercury (Hg) for the estuaries found on the south shore of Long Island is likely localized discharge from the point sources in the Peconic Bay and the south shore.

Other potential sources include direct atmospheric deposition (11% of total input) and effluent discharge from pollution control facilities (5% of total input) (Balcom et al. 2004).

Much of this Hg input is deposited locally, and the sediments of Long Island Sound and the adjacent salt marshes serve as a repository of the current and historic Hg pollution that has entered the sound (Langer et al. 2001; Fitzgerald and Lamborg 2003). Once deposited, Hg can be transformed via complex, microbially-mediated methylation processes into monomethylmercury (MMHg, MeHg or simply methylmercury) (Benoit et al. 2003). Methylmercury is a highly toxic neurotoxin that can be absorbed by organisms and rapidly bioaccumulates and biomagnifies, impacting ecosystem and human health (Evers and Clair 2005; Scheuhammer et al. 2007).

The salt marshes of Long Island are considered net sources of MeHg, and account for approximately 5.5% of the MeHg input into the sound that are attributable to external sources[1] (Langer et al. 2001; Balcom et al. 2004). The bioavailability of MeHg within the salt marshes of Long Island presents a significant threat to biota, particularly obligate estuarine and salt marsh species. Few studies have focused on the impact of Hg and MeHg on biota in salt marshes, but recent evidence suggests that saltmarsh sparrows (*Ammodramus caudacutus)* can accumulate potentially harmful body burdens of mercury (Shriver et al 2006; Warner et al. 2010; Lane et al. in review). The saltmarsh sparrow (SALS) is an obligate salt marsh species, using salt marshes across New England and the upper mid-Atlantic for their breeding grounds. The salt marshes of Long Island represent the only part of New York State where SALS are found. SALS is considered a bird of high conservation concern (USFWS 2008) and is classified as globally vulnerable to extinction (IUCN 2009) because of significant threats to the species' long-term viability. Factors affecting its high conservation status include a restricted breeding range and the potential for hybridization with other sparrow species, current habitat losses associated with rapid coastal development, and projected habitat

1. Major external sources of MeHg into Long Island Sound include salt marshes (1.5 moles per year); pollution control facilities (1.5 moles per year); atmospheric deposition (3.5 moles per year); watersheds (21 moles per year). Internal production of methylmercury occurs within the sediments of Long Island Sound and greatly exceeds the external sources of MMHg (55 moles per year vs. 27.5 moles per year) (Hammerschmidt et al. 2004; Balcom et al. 2004).

losses associated with climate change and sea-level rise. Mercury exposure represents an emerging stressor for this already vulnerable species.

Here we present results from a study of Hg exposure in saltmarsh sparrows from three different sites across Long Island, NY. The objectives of this study were to: (1) examine Hg exposure in saltmarsh sparrows at three marshes on Long Island, NY; (2) identify potential pathways for Hg bioaccumulation by sampling and analyzing prey items for mercury, methylmercury, and stable isotopes; and (3) identify populations at risk from Hg exposure.

Study Area

The study encompassed three different salt marsh complexes, with two located in the Hamptons region and one in the Town of Hempstead (Fig. 1). Scallop Pond is located in Southampton and Pine Neck is in East Quogue, both are The Nature Conservancy Preserves. North Cinder Island is located off Oceanside in Hempstead (Fig. 1).

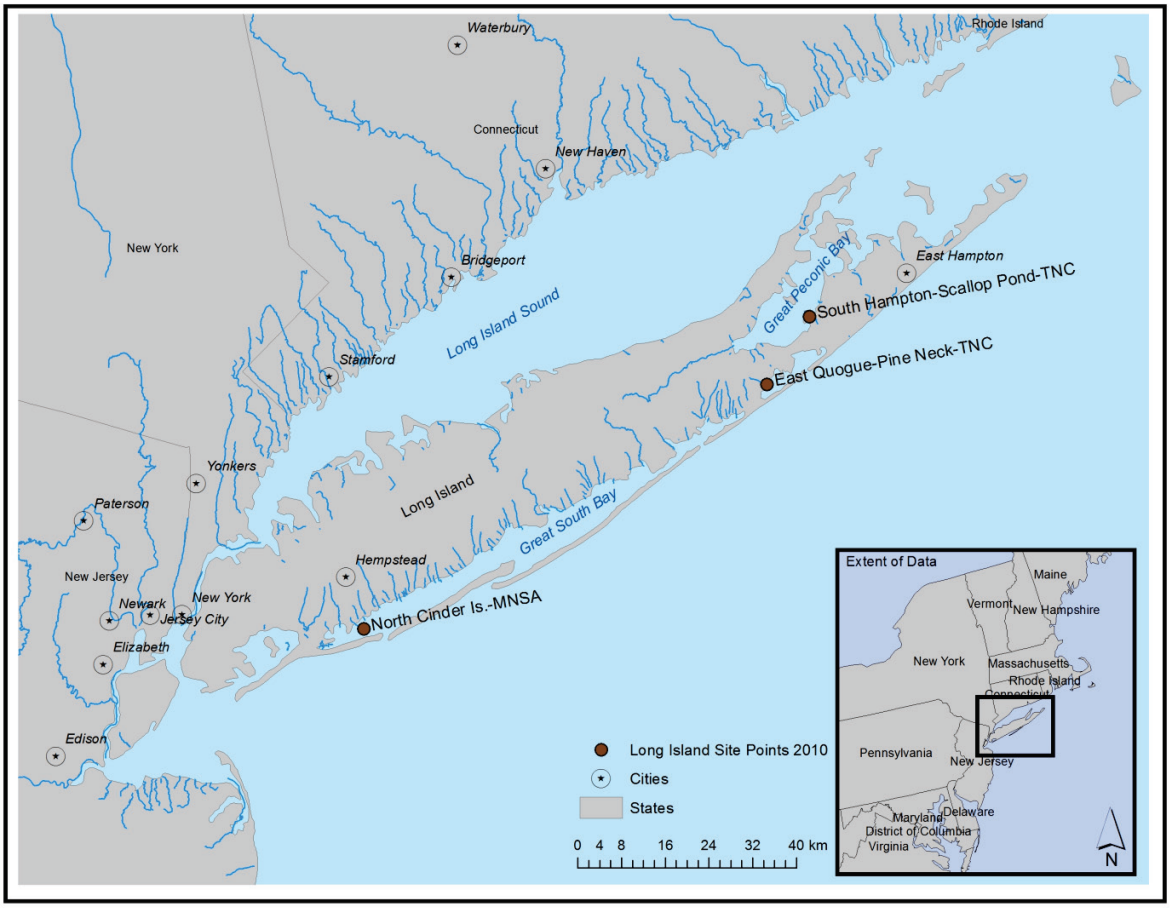

Figure 1. Saltmarsh sparrow sampling locations, Long Island, New York, 2010.

Methods

Bird Capture and Tissue Sampling

Bird capture and blood sampling occurred in July of 2010. We used three-to-four, 12-m mist nets with 30 mm mesh. Birds were flushed from the vegetation into the nets and banded with a USGS aluminum band. A beach umbrella was used to shade the birds during handling. We determined sex, age (adult or hatching year), and breeding status for each bird. Females had a highly developed brood patch and males had an enlarged cloacal protuberance indicating breeding condition. Females were processed first in an effort to minimize adversely impacting their care for offspring; males do not assist in incubation or feeding of nestlings therefore we sampled males after female birds. All birds were released unharmed within 10-25 minutes of capture. Venipuncture of the cutaneous ulnar vein (Fig. 2) with a 27-gauge sterile disposable needle allowed collection of 50-70 μl of blood into heparinized mylar-wrapped tubes for Hg and stable isotope analysis. The capillary tubes were sealed with Critocaps®, stored in plastic vacutainers on ice for up-to-six hours before freezing at -17° Celsius.

Mercury concentrations in blood reflect recent dietary uptake. Samples were collected during the breeding period (July) and therefore reflect a bird's Hg exposure on the marshes where samples were collected. Feather Hg reflects body burden of Hg at the time of molt. Saltmarsh sparrows molt all feathers at the end of breeding season before migrating south. This species undergoes a partial molt in the spring, replacing tail and body feathers but not primary or secondary feathers (Pyle 1997). Consequently, we sampled the first, inner-most primary feathers (also referred to as P1) to assess Hg exposure from the previous year's breeding period. Conversely, the outer-most tail feather, or retrices (also referred to as R6) were sampled to reflect Hg exposure on the wintering grounds. Feathers were placed in clean plastic bags, labeled and refrigerated.

Figure 2: Blood sample collection from a saltmarsh sparrow.

Invertebrate Prey Item Capture

During the summer breeding season, adult SALS feed predominantly on spiders, amphipods and larval insects (Greenlaw and Rising 1994). Our field sampling effort targeted spiders and amphipods exclusively because of their ease of capture and abundance relative to other invertebrates on salt marshes[2]. Invertebrate collection methods followed protocols outlined in Buck and Duron (2010) and included hand searching and opportunistic capture with aspirators. Individual invertebrate samples were stored in snap-cap centrifuge vials (1.5mL), given a unique sample ID, and stored on ice while in the field. Upon returning from the field, sample fresh weights (± 0.0001 g) were calculated using an analytical balance, and then all samples were stored frozen prior to being transported to BRI's Wildlife Mercury Lab for taxonomic identification. All individuals were identified to family level. Samples were then freeze-dried and re-weighed to obtain a dry weight. Dry weight measurements were calculated for each individual. For individuals with a dry weight < 0.002 g, composite samples were made using individuals of the same taxonomic family, collected from the same sample location, and with a similar dry weight. Composited samples were homogenized using acid-rinsed stainless steel spatulas, and sample splits were made for separate analyses (Hg/MMHg and stable isotope).

Lab analysis

Avian tissues mercury analysis

All blood and feather analyses were for total Hg. Methylmercury (MeHg) was not measured because it has been shown that approximately 95% of total Hg in songbird blood is MeHg (Rimmer et al. 2005). Blood was analyzed as whole blood. All blood Hg concentrations are expressed in µg/g, wet weight (ww) and bird feather Hg in µg/g, fresh weight (fw). All blood and feather samples were analyzed at BRI's Wildlife Mercury Research Laboratory in Gorham, Maine, using direct combustion/trapping atomic absorption (AA) method on a Milestone DMA 80. This approach has been incorporated by the U.S. Environmental Protection Agency (EPA) in EPA SW-846 Method 7473. Calibration used a blank and two calibration standards (DORM-3 and DOLT-4) in each of the two detector cells. Instrument response was evaluated immediately following calibration, and thereafter, following every 20 samples, and at the end of each analytical run, by running two certified reference materials and a check blank. Instrument detection limit was 0.05 ng/g.

2. Targeted sampling of spiders and amphipods did not reveal any of these prey items on Scallop Pond. See the Results and Discussion section below for further details.

Invertebrate total and methylmercury analyses

Invertebrates were analyzed for both total Hg and MeHg because the concentration of MeHg can vary substantially in invertebrates (Cristol et al. 2008). Dried samples were weighed accurately (+/- 0.00001 g) into 15-mL vessels and digested with 1.75 mL of 4.57 M nitric acid for 12 h in a 60° C water bath (Hammerschmidt and Fitzgerald 2006). Digestates were analyzed for monomethylmercury (MMHg=MeHg) by derivatization with sodium tetraethylborate and detection with flow-injection gas chromatographic atomic fluorescence spectrometry (Tseng et al. 2004). Analyses were calibrated with MMHg standards taken through the acid digestion procedure. All analyses of two standard reference materials from the National Research Council of Canada (TORT-2 and DORM-3) were within the certified range, indicating little or no bias. Method detection limit for MMHg was about 3 ng/g for a 1-mg sample. Digestates used for MMHg analysis were oxidized with BrCl and analyzed for total Hg. The method is detailed and validated in Hammerschmidt and Fitzgerald (2006). Total Hg was determined after reduction with stannous chloride by dual-Au amalgamation cold-vapor atomic fluorescence spectrometry (Bloom and Fitzgerald 1988). Analyses were calibrated versus aqueous Hg(II) solutions traceable to the U.S. NIST. Method detection limit for total Hg was about 20 ng/g for a 1-mg sample.

Stable isotope analyses

Stable isotope analyses (SI) for carbon and nitrogen ratios (δ13C and δ15N) in bird blood were conducted at Boston University, Boston, Massachusetts. Blood samples were analyzed using automated continuous-flow isotope ratio mass spectrometry (Michener and Lajtha 2007). Using hematocrit tubes, blood was transferred into pre-weighed tin capsules. Assuming a content of 70% water, approximately 1.3 mg of blood (1.3 ml) was added to the capsules. All capsules were oven dried at 60˚C for 24 hours and then reweighed to get the 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 N2 in air) where:

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

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-VPDB 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).

Isotopic analysis for invertebrate samples was conducted at the University of Florida's Stable Isotope Laboratory. Carbon and nitrogen isotopes ($\delta^{13}C$ and $\delta^{15}N$) of invertebrate tissue were measured with a Finnigan-MAT DeltaPlus XL isotope ratio mass spectrometer with a ConFlo III interface linked to a Costech ECS 4010 Elemental Combustion System (elemental analyzer) with Zero Blank autosampler. Approximately 300-400 micrograms of dried invertebrate sample was loaded into tin capsules and placed in the sample carousel on a Costech ECS 4010. After combustion in a quartz column at 1000°C in an oxygen-rich atmosphere, the sample gas was transported in a helium gas carrier stream and passed through a hot reduction column (650°C) consisting of elemental copper to remove oxygen. The effluent stream from the elemental analyzer then passed through a chemical (magnesium perchlorate) trap to remove water. It next passed into a ConFlo III preparation system and into the inlet of a Finnigan-MAT DeltaPlus XL mass spectrometer running in continuous flow mode where the sample gas was measured relative to a laboratory reference gas. All carbon isotopic results are expressed in standard delta notation relative to the Vienna Pee Dee Belemnite (VPDB). All nitrogen isotopic results are expressed in standard delta notation relative to AIR.

Statistical analyses

Only adult (after hatch year) bird blood and feather Hg results were used in statistical analyses. We used raw and log transformed data in the analyses. For all data analyses and summary statistics, we used a JMP 5.0 statistical program along with Microsoft Excel. Factors were considered significant at a probability level of less than 0.05. Data were aggregated by site. We used post-hoc Tukey-Kramer HSD statistic to test for differences between sites. All avian mercury results reflect total Hg concentrations in whole blood and feathers. Invertebrate results are reported as methylmercury and total Hg. Regression analysis was used to examine the relationship between stable isotope results and Hg bioaccumulation in invertebrate prey and after hatch year birds.

Results

Avian Mercury Exposure

Blood Hg Concentrations

In 2010 we banded a total of 46 birds including individuals from three sparrow species on Long Island, New York (Table 1). Blood samples were collected from adult birds only. Mean blood Hg concentrations in adult SALS varied significantly between sites (ANOVA: $F=169$, $df=33$, $p<0.0001$). Mean SALS blood Hg concentrations were lowest at Scallop Pond (0.35 ± 0.10 µg/g, ww). Saltmarsh sparrows at Pine Neck had a mean blood Hg concentration of 1.23 ± 0.12 µg/g, ww, while SALS from North Cinder Island had the highest blood Hg concentration of the three sites (1.91 ± 0.22 µg/g, ww) (Fig. 3). A post-hoc Tukey-Kramer HSD test ($P<0.05$) was used to examine pairwise differences between sites. SALS blood Hg concentrations from North Cinder Island were significantly higher than both Pine Neck and Scallop Pond mean blood Hg concentrations. In addition, SALS blood Hg concentrations from Pine Neck were significantly higher than Scallop Pond.

Table 1. Birds banded and sampled on Long Island, New York in 2010 (HY=hatch year, recently fledged juvenile birds).

Site	Species	# Adults		# HY	% HY
sex		F	M	Unknown	captured
North Cinder Is.-Hempstead	saltmarsh sparrow	10	3	2	13
	seaside sparrow	1	1	1	
Pine Neck-East Quogue	saltmarsh sparrow	8	8	2	11
Scallop Pond-South Hampton	saltmarsh sparrow	1	4	4	44
	song sparrow		1		
Total		**37**		**9**	

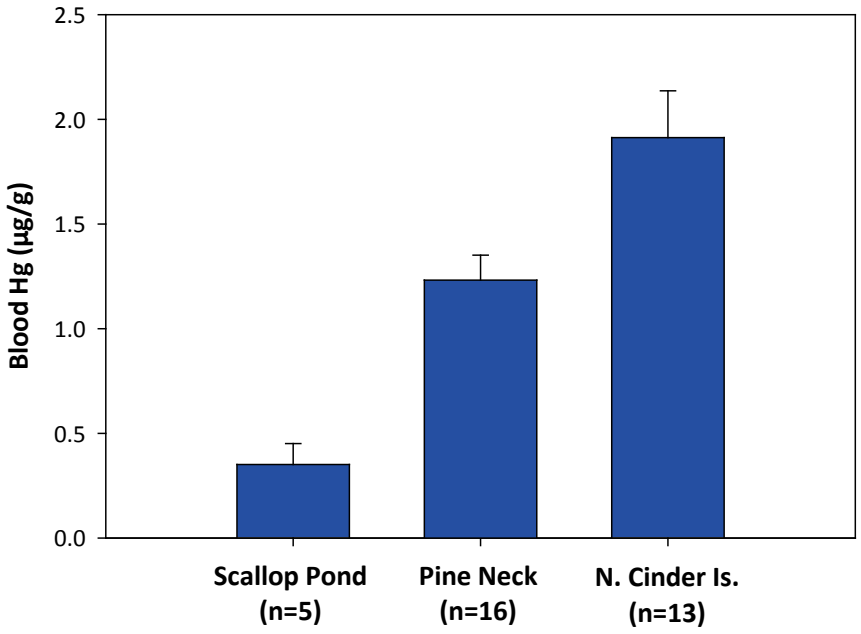

Figure 3. Mean blood Hg concentrations (± std dev) in saltmarsh sparrows from three sites on Long Island NY, 2010.

We also analyzed samples from the two other species of sparrows captured on Long Island salt marshes and found that saltmarsh sparrows had higher blood Hg concentrations than a song sparrow sampled at Scallop Pond and saltmarsh and seaside sparrows from North Cinder Island had similar Hg concentrations (Table 2). These findings are consistent with our sampling at other salt marshes in New England (BRI unpubl. data).

Table 2. Mean, standard deviation (SD), sample size (n) and range for blood Hg (ug/g, ww) concentrations in sparrows sampled on Long Island, New York in 2010.

Site	Species	Mean +/- SD (n)	Range
North Cinder Is.-Hempstead	saltmarsh sparrow	1.9+/-0.2 (13)	1.4 – 2.2
	seaside sparrow	1.7+/-0.3 (2)	1.5 – 1.9
Pine Neck-East Quogue	saltmarsh sparrow	1.2+/-0.1 (16)	1.0 – 1.5
Scallop Pond-Southampton	saltmarsh sparrow	0.35+/-0.1 (5)	0.24 – 0.51
	song sparrow	0.21 (1)	

Feather Hg Concentrations

Primary=P1 (wing) and retrix=R6 (tail) feather Hg concentrations also varied between sites (Fig. 4). Across all sites, Hg concentrations were significantly higher in wing feathers (P1) than tail feathers (R6) (paired t-test: t ratio = -7.79, df=23, $p<0.0001$). Post hoc comparisons using the Tukey HSD test indicated that Mean P1 Hg concentrations from North Cinder Island and from Pine Neck were significantly higher than from Scallop Pond (Fig. 4). We found no significant difference ($F=3.0$, df=27, $p<0.068$) in mean R6 (tail) concentrations among sites.

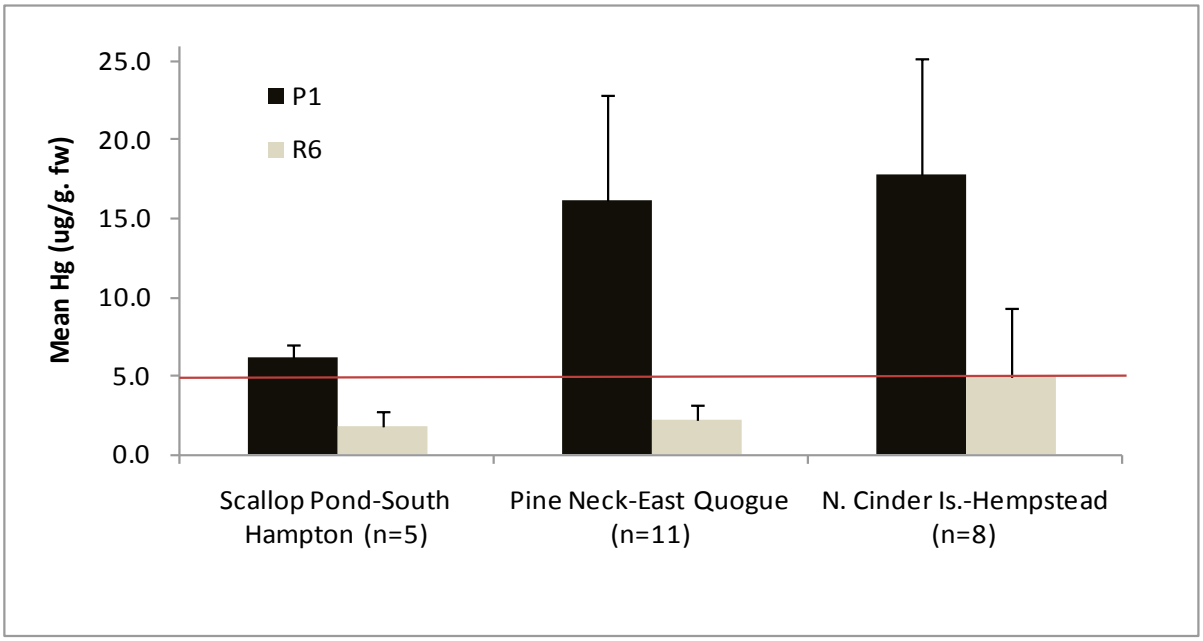

Figure 4. Primary (P1) and tail (R6) feather Hg concentrations in saltmarsh sparrows from Long Island, NY. Red line represents the 5.0 µg/g published effects level concentration for songbird feather Hg (Eisler 1987).

Blood – Feather Hg Comparison

We observed a strong positive relationship between SALS primary (P1) feather and blood Hg concentrations ($r^2 = 0.69$, Fig. 5). Five individuals were considered outliers and were excluded from the model. Three of the outliers were sampled from North Cinder Island and two were sampled from Pine Neck. These outliers likely represent individuals that did not spend the previous year's breeding season (2009) at these sites, and their feather Hg concentrations represent the Hg uptake from an unknown breeding territory. We observed no such trend between tail feather Hg and blood Hg in SALS.

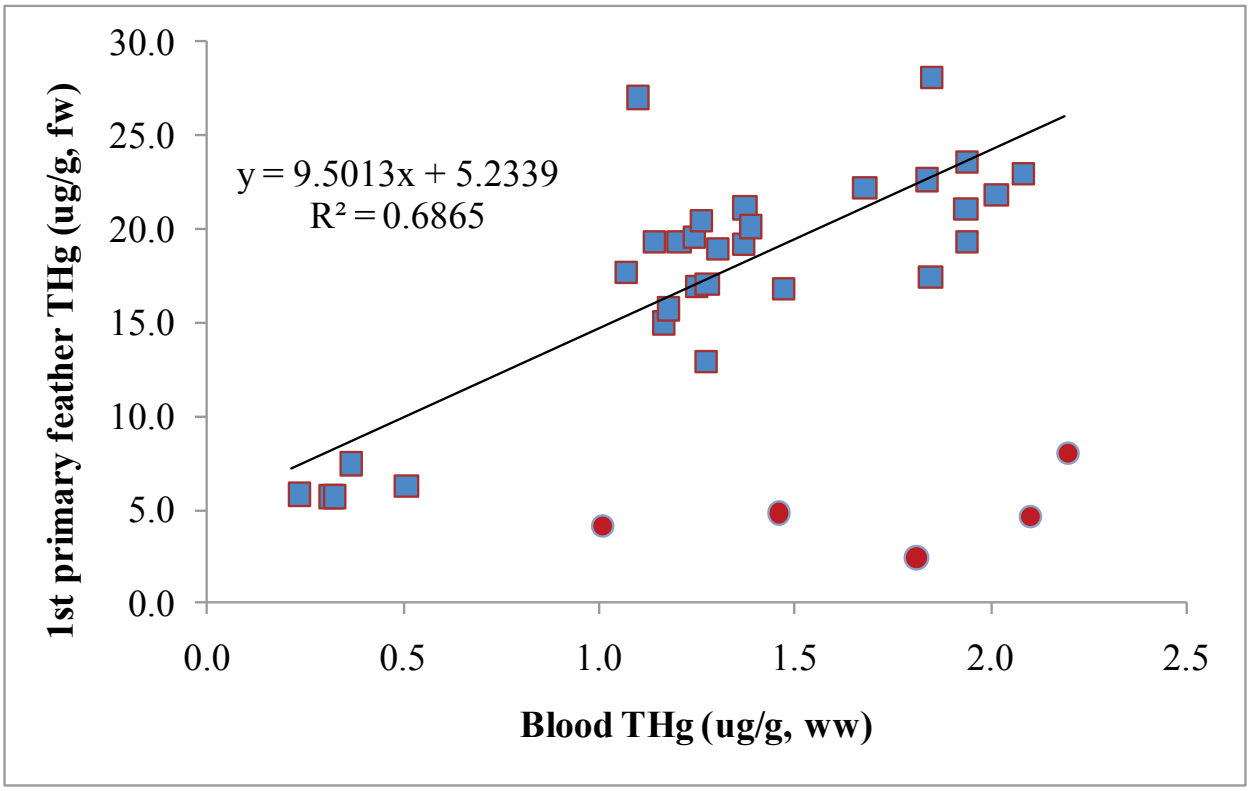

Figure 5. Comparison of P1 Hg versus blood Hg in saltmarsh sparrows from Long Island NY. Outlier samples shown as red circles were not used in model.

Invertebrate Mercury Exposure

We collected a total of 24 invertebrate samples from North Cinder Island, including 17 amphipods (Order Amphipoda) and seven spiders (Order Araneae); 39 samples from Pine Neck Nature Preserve were collected including 22 amphipods and 17 spiders. After invertebrate composites were made, we analyzed a total of 10 invertebrate samples from two sites for total and methylmercury. Small sample sizes did not allow for statistical tests of differences between study marshes. Still, spiders and amphipods from North Cinder Island had higher Hg concentrations than Pine Neck spiders (Table 3; Fig. 6). One Lycosid spider

composite sample from North Cinder Island had a relative low concentration of MeHg (32%) while the other spider samples had concentrations above 90% (Table 3).

Table 3. Mercury and stable isotope data for spiders and amphipods from Long Island, NY.

Site	Order	Family	Hg µg/g ww	Hg µg/g dw	MeHg µg/g ww	MeHg µg/g dw	% MeHg	$\delta^{13}C$	$\delta^{15}N$
N Cinder	Araneae	Lycosidae	0.743	0.110	0.237	0.035	32	-14.82	13.08
	Araneae	Tetragnathidae	0.456	0.129	0.425	0.121	93	-15.08	12.04
	Amphipoda	Talitridae	0.238	0.054	0.215	0.049	90	-13.58	7.21
	Amphipoda	Talitridae	0.207	0.056	0.208	0.056	100	-13.09	10.70
	Amphipoda	Talitridae	0.192	0.058	0.185	0.056	96	-14.62	7.83
Pine Neck	Araneae	Lycosidae	0.143	0.044	0.136	0.042	95	-15.64	11.33
	Araneae	Lycosidae	-	-	-	-	-	-14.04	12.76
	Araneae	Lycosidae	0.097	0.024	0.094	0.023	97	-15.42	10.85
	Amphipoda	Talitridae	0.116	0.033	0.079	0.023	68	-14.36	6.09
	Amphipoda	Talitridae	0.089	0.023	0.041	0.011	46	-13.40	7.96
	Amphipoda	Talitridae	0.128	0.032	0.105	0.026	82	-14.55	5.01

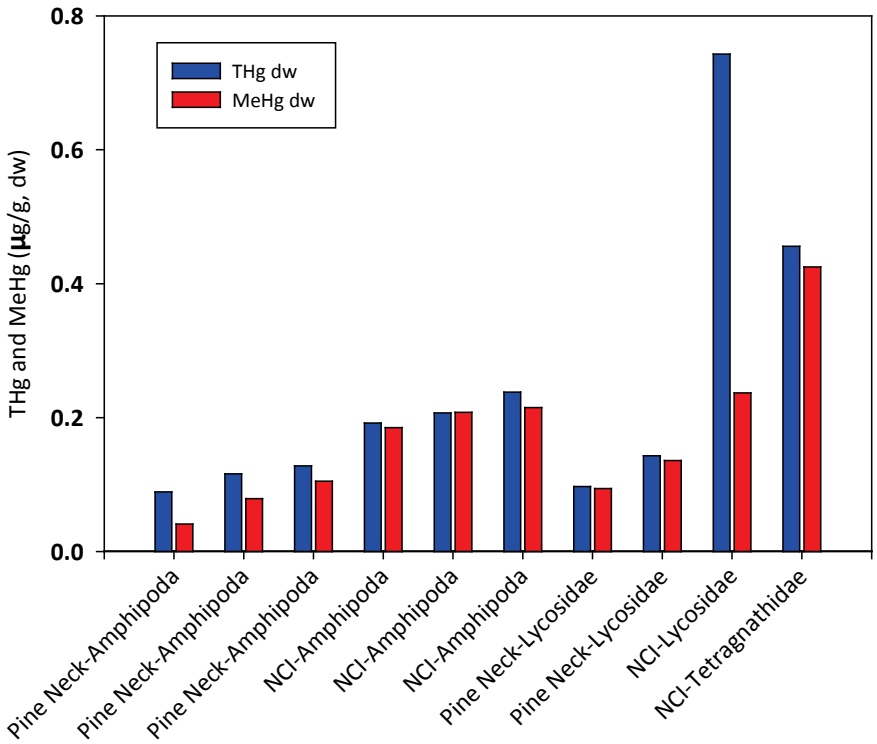

Figure 6. Total and methylmercury in spiders and amphipods collected on Long Island, NY. (NCI = North Cinder Island)

Bioaccumulation of Hg in Saltmarsh Sparrows

Historically, food web studies have relied on labor-intensive gut content analysis to gain an understanding of predator-prey interactions across trophic levels. Such analyses provide a detailed 'snapshot' of the diet of a particular organism at the time of capture but prohibit an understanding of trophic interactions that may vary across time and space. 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 provide an integrated assessment of trophic interactions, and help describe food web pathways leading from the base of the food web up to the top-level consumers (Peterson and Fry 1987).

The combination of nitrogen and carbon isotopic analysis ($\delta^{15}N$ and $\delta^{13}C$, respectively) provides a two-dimensional interpretation of food web dynamics (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 3.5 parts per million (‰), 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).

When stable isotopes are used in conjunction with contaminant analysis, it is possible to examine the bioaccumulation and biomagnification of contaminants. Contaminants that enter food webs are accumulated by organisms at lower trophic levels and then are magnified by consumers at higher levels in the food web. Stable nitrogen isotope values help to confirm the trophic position of organisms, and the relationship between $\delta^{15}N$ and Hg also represents a technique for examining trophic transfer of Hg within and across taxa (Rasmussen and Vander Zanden 2004). Stable carbon isotopes ($\delta^{13}C$) help determine basal carbon sources within particular food webs and potentially identify where contaminants are entering the food web.

In the salt marshes of Long Island, NY, mean $\delta^{15}N$ values in SALS blood ranges from 8.0 ± 0.64 ‰ on Scallop Pond to 12.59 ± 0.18 ‰ on North Cinder Island (Fig. 7). There was a significant difference in $\delta^{15}N$ between the different marshes ($F=152.192$, $df=2$, $P<0.001$). Post hoc comparisons using the Tukey HSD test indicated that the mean $\delta^{15}N$ from North Cinder Island was significantly higher than from SALS $\delta^{15}N$ at both Pine Neck and Scallop Pond. Pine Neck $\delta^{15}N$ was also significantly higher than from Scallop Pond (Fig. 7). No significant difference in $\delta^{13}C$ of SALS blood was detected between the three marsh sites ($F=-.316$, $df=2$, $P=0.733$).

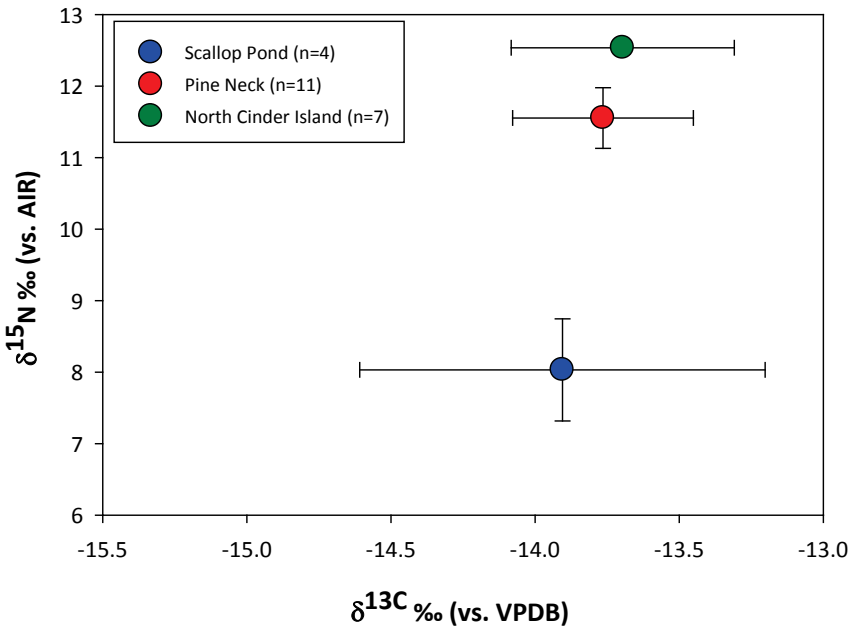

Figure 7. Isotope biplot showing the distribution of stable carbon (δ13C) and stable nitrogen (δ15N) concentrations in saltmarsh sparrows across the three study marshes.

Sparrows captured on Scallop Pond with low $\delta^{15}N$ values (reflecting a diet dependent on lower trophic level prey items) have lower blood Hg concentrations, while SALS from North Cinder Island have higher $\delta^{15}N$ concentrations and higher blood Hg concentrations (Fig. 8). When analyzed together, these data suggest that SALS captured from the three sites on Long Island are accumulating Hg as a function of increasing food web complexity (Fig. 8). There is a strong positive relationship between $\delta^{15}N$ and blood Hg concentrations (R2 = 0.73, Pearson's Correlation Coefficient r = 0.854).

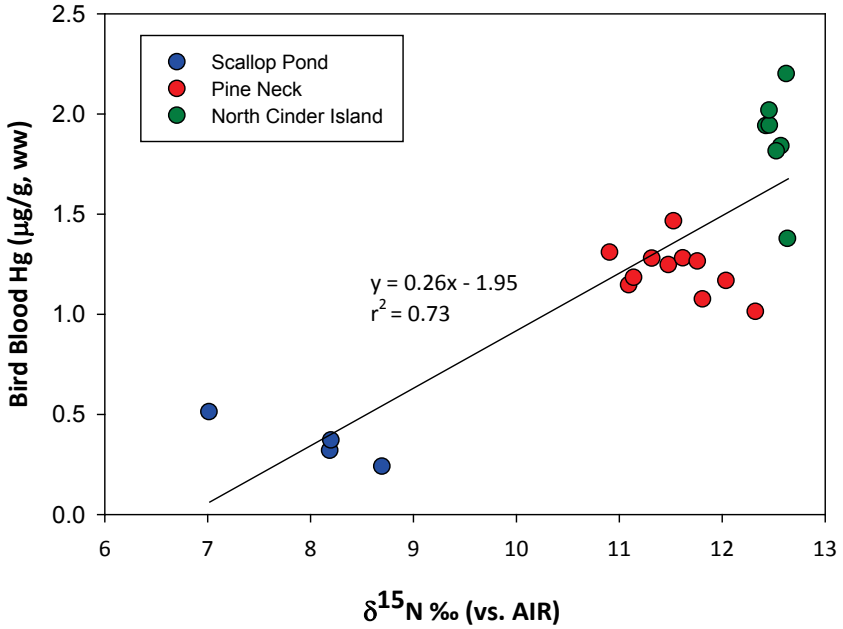

Figure 8. Relationship between bird blood Hg concentrations and δ 15N values in saltmarsh sparrows from Long Island, NY.

Although sample sizes for prey items were too small to allow for statistical comparisons across trophic levels, the data suggest a relationship between increasing Hg concentrations and increasing $\delta^{15}N$ (Fig. 9). Within the invertebrate – sparrow food web on both Pine Neck and North Cinder Island, Hg concentrations and $\delta^{15}N$ increase from amphipods →spiders → sparrows (Fig. 9). The difference in $\delta^{15}N$ between amphipods and spiders is approximately 3.5 ‰, representing an entire trophic level shift. The difference in $\delta^{15}N$ between spiders and SALS is < 1.0 ‰. This suggests that the SALS diet does not rely exclusively on spiders but includes a broad range of lower trophic level prey items.

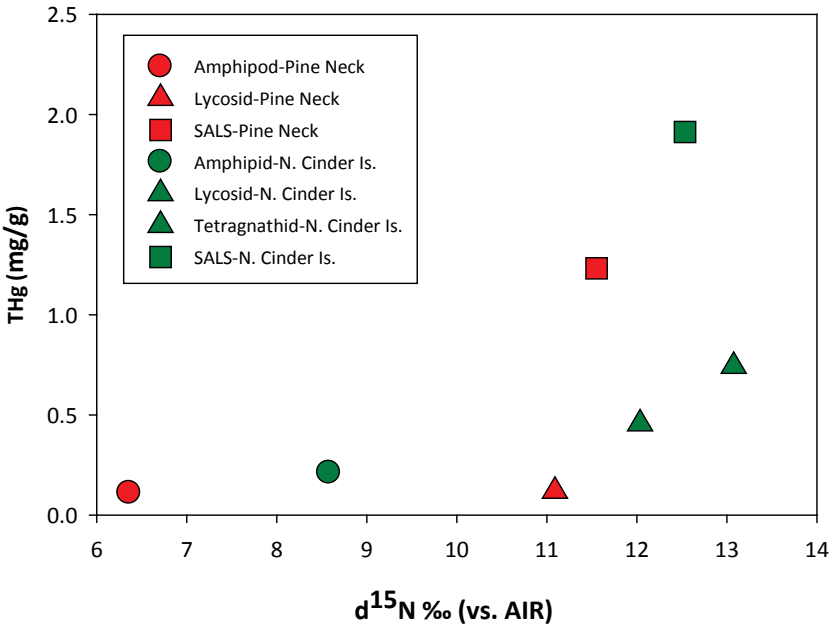

Figure 9. Comparison of trophic position (δ15N) and total Hg concentrations with saltmarsh sparrow food webs on Long Island, NY. (Total Hg concentrations for amphipods and spiders are µg/g (dw) concentrations and total Hg concentrations for SALS represent mean µg/g (ww) concentrations.

Discussion

Mercury as a Stressor for Saltmarsh Sparrows on Long Island

The Hg concentrations measured in sparrows from the two Long Island salt marshes are among the highest observed in marshes throughout New England and the Northeast (Fig. 10), and indicate that saltmarsh sparrows breeding at Pine Neck Reserve in East Quogue and on North Cinder Island in Hempstead are exposed to elevated Hg levels. Current estimates of Hg effects concentration levels resulting in impairment of 20% of the population (EC_{20})[3] for songbirds range from 0.63 µg/g, ww in tree swallow blood (Jackson 2011) to 1.3 µg/g, ww in Carolina wrens (Jackson et al. in review). All sparrows sampled from North Cinder Island and Pine Neck Preserve had blood Hg concentrations greater than 0.63 µg/g, with several sparrows from North Cinder Island having concentrations as high as 2.2 µg/g,ww. Potential risks associated with high Hg exposure in songbirds include: reduced survival (Hallinger et al. 2011), impaired reproduction (Brasso and Cristol 2008), depressed immune competence (Hawley et al. 2009), altered behavior (Hallinger et al. 2010) and disrupted endocrine function (Wada et al. 2009, Franceschini et al. 2009). Combined effects of climate change and Hg exposure as demonstrated in a tree swallow study (Hallinger and Cristol 2011) can potentially have more severe consequences on the reproductive success of the species.

3. EC_{20} stands for the effective concentration at which 20% of a wildlife population is adversely affected by a contaminant. The EC_{20} for Hg in songbirds is based on models developed by BRI using laboratory data on Hg exposure in birds (Heinz et al. 2009).

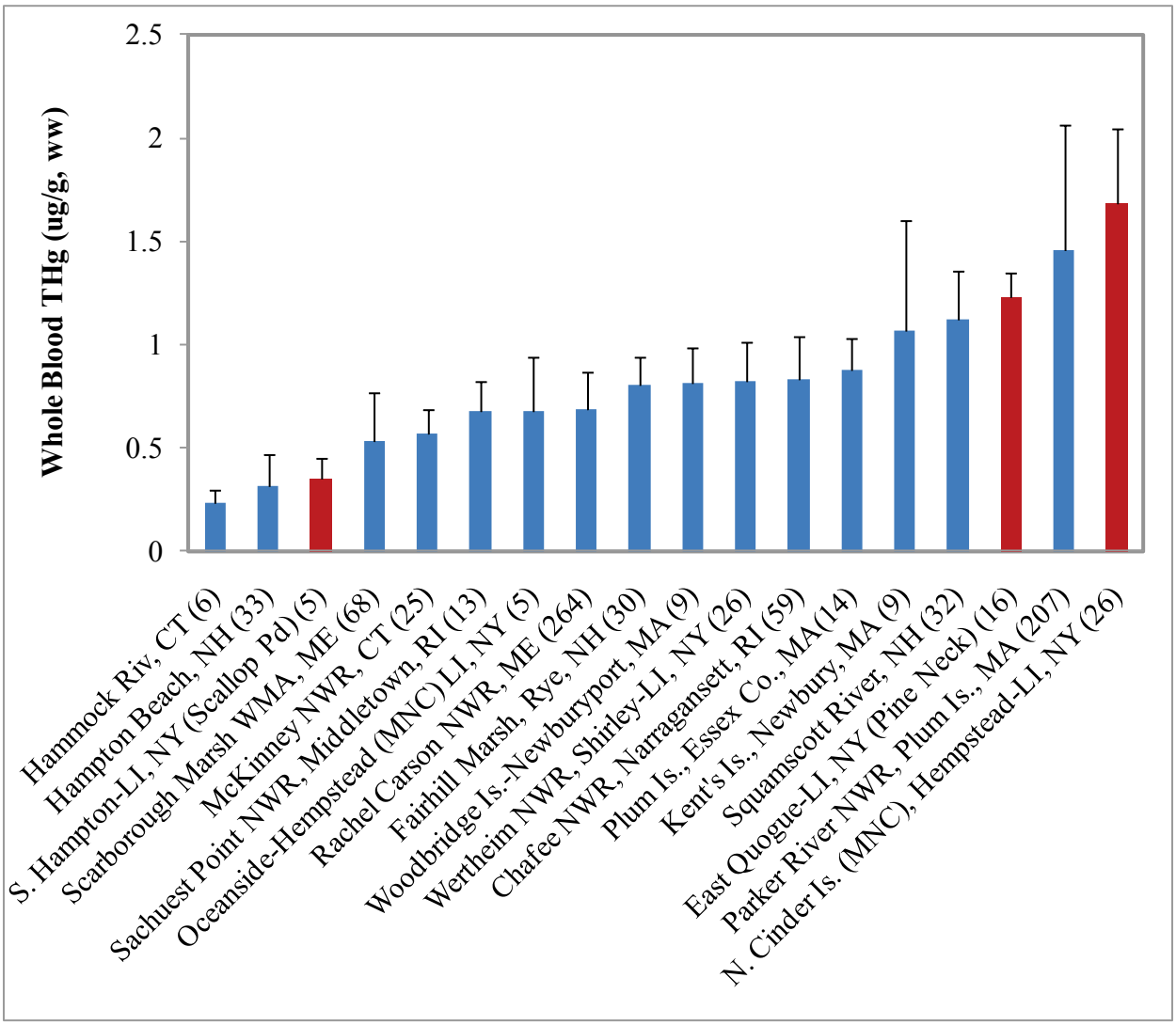

Figure 10. Bird blood Hg concentrations (mean ±stdev) for saltmarsh sparrows sampled from 18 salt marsh habitats across New England and the Northeastern U.S. (Red bars are the Long Island marshes sampled during 2010).

The differences observed across the three sampling sites suggest that a variety of potential mechanisms are affecting the bioavailability and bioaccumulation of Hg in sparrows. On Scallop Pond, the fact that no spiders or amphipods were observed suggests that food web structure may be affecting the bioavailability of Hg and MeHg. North Cinder Island is located proximate to a municipal solid waste incinerator in Hempstead, NY, that has a history of emissions problems (Hattemer-Frey and Travis 1991), and the salt marshes in Hempstead's Marine Nature Study Area may exhibit legacy effects associated with past emissions.

BRI has conducted three years of field work during the breeding season on Long Island. These data illustrate the spatial variability observed across Long Island (Fig. 11). In addition, these data point to changes in Hg bioaccumulation over time in at least one salt marsh on Long Island. Between 2008 and 2010, mean blood Hg concentrations in sparrows sampled from North Cinder Island (Marine Nature Study Area, Oceanside, NY) increased by 31% (Fig. 11). Mechanisms for this increase in Hg concentrations are unknown and should be the focus of future conservation and research efforts.

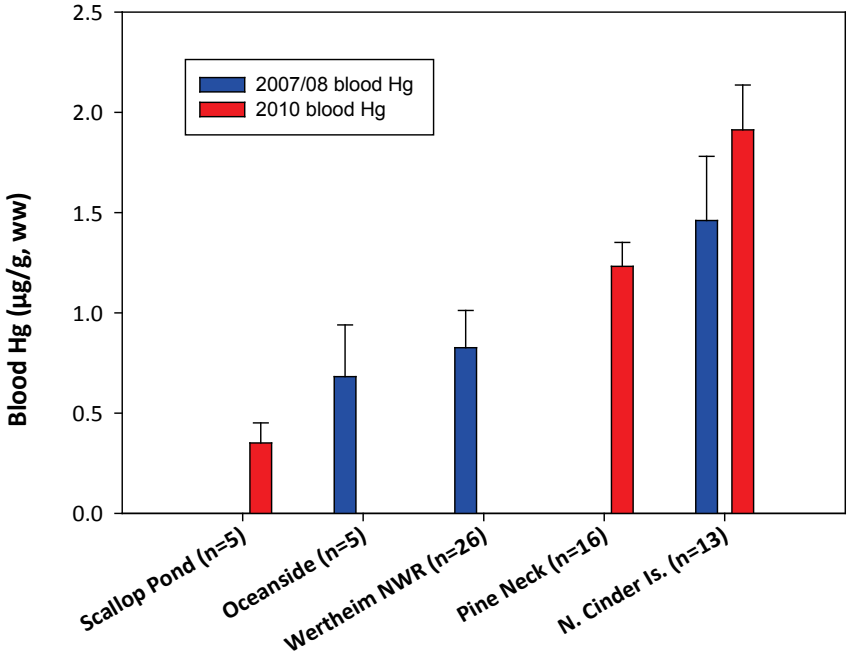

Figure 11. Comparison of bird blood Hg concentrations (mean ±stdev) between 2007/08 and 2010 from salt marshes on Long Island, NY. (N. Cinder Is. Was the only site sampled over two years)

Recommendations

Results from this research highlight the risk that Hg contamination poses to saltmarsh sparrows on Long Island, NY. This species is of high conservation concern and can serve as an important bioindicator of the health and well-being of coastal and estuarine ecosystems across New England and the Northeastern U.S.

- Future research should focus on the spatial and temporal variability of Hg in saltmarsh sparrows and their preferred prey items through an expanded survey of other marsh habitats on Long Island while maintaining a sampling regime at the previously sampled marshes. It is important to understand the mechanisms that are influencing the observed variability and how to incorporate that information into current and future management plans for The Nature Conservancy's reserve land and Hempstead's Marine Nature Study Area.
- Hg monitoring on Long Island would benefit from further integration into regional and national efforts designed to better understand the fate and transport of Hg in terrestrial and aquatic ecosystems. Currently Long Island, NY has been proposed as one of 20 long-term, intensive Hg monitoring sites for the U.S. EPA sponsored National Mercury Monitoring Network (Merc-Net). This network will greatly improve our understanding of Hg deposition in New York and across the country.

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