New York State Energy Research and Development Authority

Mercury Assessment of Saltmarsh Sparrows on Long Island, New York, 2010–2011

Final Report

June 2012

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Mercury Assessment of Saltmarsh Sparrows on Long Island, New York, 2010–2011

Final Report

Prepared for the

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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 and four additional sites in 2011. Results indicate that Hg exposure represents a significant stressor for populations of breeding birds on Long Island salt marshes including The Nature Conservancy (TNC) Preserves. The Hg concentrations from most of the sampled Long Island salt marshes (Pine Neck Preserve, Accabonac Harbor and the three islands off Hempstead) are amongst the highest concentrations observed in Saltmarsh Sparrows from across the Northeast. Blood Hg concentrations in adult individuals ranged from 0.236 µg/g (ww) in Scallop Pond, Southampton to 2.3 µg/g (ww) from North Cinder Island in Hempstead. Blood Hg concentrations in sparrows from Wading River Preserve in Wading River on the North Shore of Long Island facing the Long Island Sound and Scallop Pond in Southampton were lower than other marshes sampled. One hundred percent of Saltmarsh and Seaside Sparrows from Crow and North Cinder Islands in Hempstead and 59% of Saltmarsh Sparrows sampled from Pine Neck TNC Preserve in East Quogue exceeded the 1.2 µg/g blood Hg songbird effect level considered to cause a 20% reduction in reproductive success, based on Jackson et al. 2011.

We also analyzed mercury concentrations in wing and tail feathers of the Saltmarsh Sparrows to examine differences in Hg exposure on breeding versus wintering grounds. Saltmarsh Sparrows undergo a complete feather molt at the end of summer on the breeding grounds (i.e., salt marshes in the Northeastern U.S.) and tail feathers are replaced again in the winter/spring. Therefore wing feathers reflect a bird's mercury exposure during the previous breeding season. Conversely, because tail feathers are grown during the winter they 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 indicating that the majority of mercury exposure occurs on the breeding grounds in the Northeast. Mean primary feather (P1) Hg concentrations ranged from 6.2 ±0.75 µg/g fresh weight (fw) at Scallop Pond to 25.3+/-14.97 µg/g at Crow Island, the site with the highest individual P1 Hg concentration reaching 45.1 µg/g.

Sampling of invertebrate prey items targeted spiders and amphipods as well as opportunistic sampling of several other taxa (see Appendix 1). Mercury concentrations (and concentrations of its highly toxic form, methylmercury) were highest in spiders. Mercury concentrations in prey items also followed a similar pattern as in sparrows with the highest mean Hg concentrations being observed in the three islands off Hempstead along with Pine Neck Preserve and Accabonac Harbor. 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 forage on prey more enriched in 15N suggesting potential sewage/animal feces pollution. Birds sampled from Scallop Pond and Accabonac Harbor appears to be foraging on less nitrogen enriched prey items than birds sampled from other 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 additional stressor to this already vulnerable species and may also impact other bird 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 have also 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 point sources in the Peconic Bay and the south shore. A previous report has suggested that mercury pollution near Hempstead, NY, may originate from the Hempstead waste incinerator that together with the incinerator in Babylon, NY, released an estimated 55 pounds of Hg in 2009 (NYPIRG 2011). Other potential sources include direct atmospheric deposition (11% of total input in Long Island Sound) and effluent discharge from pollution control facilities (5% of total input for Long Island Sound) (Balcom et al. 2004).

Much of this Hg input is thought to be 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

[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).

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. 2011). The Saltmarsh Sparrow (SALS) is an obligate salt marsh species, utilizing 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 restricted breeding range and the potential for hybridization with other sparrow species, current habitat losses associated with rapid coastal development, and projected habitat losses associated with climate change and sea-level rise.

Here we present results from a study of Hg exposure in Saltmarsh Sparrows from seven different sites across Long Island, New York. The objectives of this study were to: (1) examine Hg exposure in Saltmarsh Sparrows at multiple marshes on Long Island; (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 four different salt marsh complexes in the Hamptons Region in Suffolk County, and three salt marsh islands in the Town of Hempstead, Nassau County (Fig. 1). Scallop Pond is located in Southampton, Accabonac Harbor is in Easthampton, Pine Neck is in East Quogue, and Wading River Marsh is in Wading River, all serve as The Nature Conservancy Preserves. North Cinder, Crow and North Greensedge Islands are located off Oceanside in the town of Hempstead and are part of Marine Nature Study Area of Hempstead (Fig. 1).

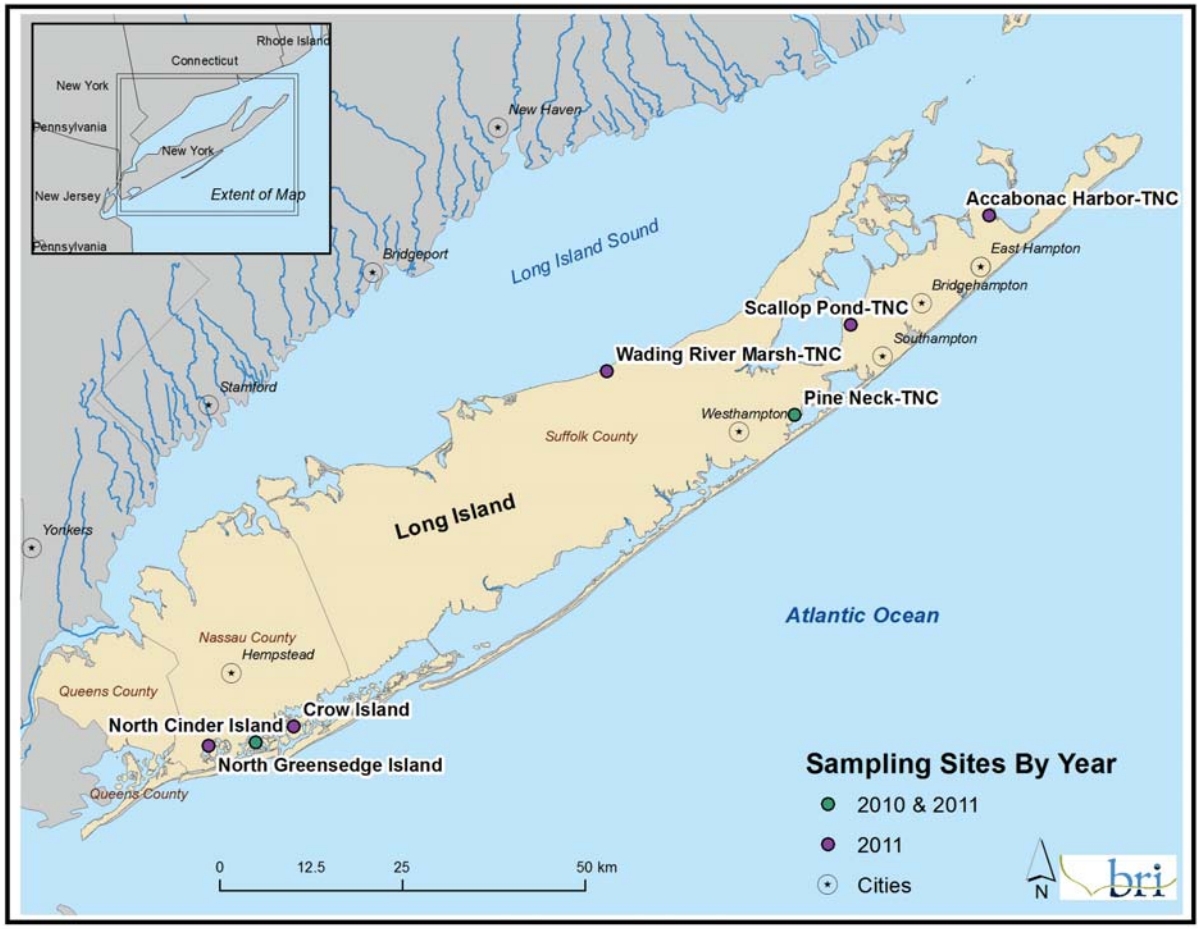

Figure 1. Saltmarsh sparrow sampling locations, Long Island, New York, 2010-2011.

METHODS

Bird Capture and Tissue Sampling

Bird capture and blood sampling occurred in July of 2010 and 2011. We used three to four, 12-m mist nets with 30 mm mesh. We flushed birds from the vegetation into the nets and banded them with a USGS aluminum band. We used a beach umbrella 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. We processed females 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 them last. We released all birds 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 whole 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. We placed feathers in labeled, clean plastic bags, 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. Invertebrate collection methods followed protocols outlined in Buck and Duron (2010) and included hand searching and opportunistic capture with aspirators. Fiddler crabs were captured by hand. 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 measured using an analytical balance and then all samples were stored frozen prior to being transported to BRI's Wildlife Mercury Research Laboratory (WMRL) 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/MeHg 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, Edmonds et al. 2011). 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 WMRL 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 utilized a blank and two calibration standards (DORM-3 and DOLT-4) one for 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.

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 ($\delta^{13}C$ and $\delta^{15}N$) 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:

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

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. For all data analyses and summary statistics, we used a JMP 9.0 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 nonparametric Wilcoxon Method to examine pairwise 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 relationships between blood and feather Hg. Intra-specific variation in stable isotope concentrations ($\delta^{13}C$ and δ15N) across marsh sites were analyzed using a one-way ANOVA followed by a post-hoc Tukey HSD test. Pearson's Product Moment correlations were used to explore relationships between stable isotope and Hg concentrations in after-hatch year birds.

RESULTS

Avian Mercury Exposure

We compared Hg concentrations in male vs. female Saltmarsh Sparrows and found no statistically significant difference in blood or feather Hg (blood: F=2.74, DF=88, p=0.101; First primary (P1): F=0.186, DF=92, p=0.667; Tail: F=2.72, DF=80, p=0.103). The data met normality assumptions. Consequently we combined Hg data from both sexes for further statistical analyses. We also compared Hg data from sites sampled in two different years and found no significant difference between 2010 and 2011 within each site (N. Cinder Is.: F=0.273, DF=18, p=0.608; Pine Neck: F=0.025, DF=21, p=0.875), therefore we pooled data for analysis.

Blood Hg Concentrations

During two years of sampling on Long Island we banded a total of 125 birds: 46 birds in 2010 and 79 birds in 2011 including individuals from three other species (Table 1). Blood samples were collected from adult birds only. Mean blood Hg concentrations in adult SALS varied significantly among sites. Mean SALS blood Hg concentrations were lowest at Scallop Pond (0.35 ± 0.10 µg/g, ww) and North Cinder Island had the highest blood Hg concentration of all sites (1.91 ± 0.22 µg/g, ww) (Fig. 3).

Table 1. Summary table of species captured by site and age on Long Island, NY in July of 2010 and 2011 (AHY=after hatch year=adult; HY=hatch year=juvenile).

Year	Site	Species	Age	Count
2010	North Cinder Island	Saltmarsh Sparrow	AHY	13
			HY	2
		Seaside Sparrow	AHY	2
			HY	1
	Total			*18*
	Pine Neck	Saltmarsh Sparrow	AHY	16
			HY	2
	Total			*18*
	Scallop Pond	Saltmarsh Sparrow	AHY	5
			HY	4
		Song Sparrow	AHY	1
	Total			*10*
2010 Total				**46**
2011	Accabonac Harbor	Saltmarsh Sparrow	AHY	14
			HY	1
	Total			*15*
	Crow Island	Saltmarsh Sparrow	AHY	13
		Seaside Sparrow	AHY	3
	Total			16
	North Cinder Island	Common Tern	AHY	1
		Saltmarsh Sparrow	AHY	6
		Seaside Sparrow	AHY	10
	Total			17
	North Greensedge Island	Saltmarsh Sparrow	AHY	10
		Seaside Sparrow	AHY	5
	Total			15
	Pine Neck Total	Saltmarsh Sparrow	AHY	7
	Wading River Marsh Total	Saltmarsh Sparrow	AHY	9
2011 Total				**79**
Grand Total	**2010 and 2011**			**125**

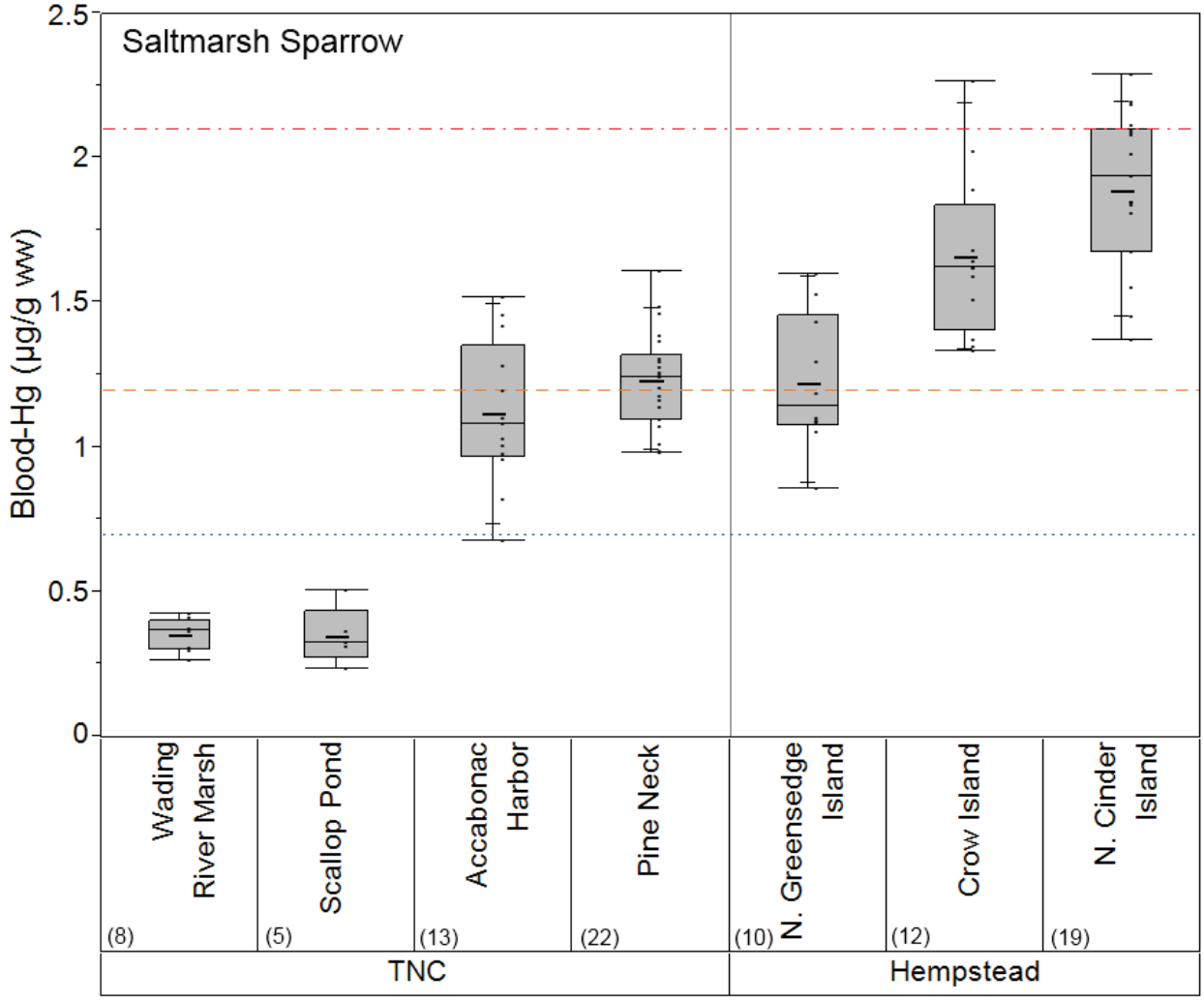

Figure 3. Quantile boxplots of Saltmarsh Sparrow blood-Hg (µg/g ww) from Long Island NY, 2010-2011 (TNC=The Nature Conservancy) where central line of box marks median, edges of boxes are 25th and 75th percentile, and whiskers represent minimum and maximum values. Mean marked as thick dash, 95% confidence interval as the inner whisker. Colored dotted and dashed lines are estimated effect levels for reductions in nesting success of songbirds based on Jackson et al. 2011 where lines represent blood-Hg: lower dotted blue line (0.7 ug) a 10% reduction in nest success; dashed orange line (1.2 µg/g) a 20% reduction; dot-dash red line (2.1 µg/g) a 40% reduction.

We also analyzed samples from a few other species captured on Long Island salt marshes and found that Saltmarsh Sparrows had higher blood Hg concentrations than other species. Saltmarsh had slightly higher Hg concentrations than the Seaside Sparrows from Hempstead Islands (Table 2). These findings are consistent with our sampling at other salt marshes in New England where SALS consistently have the highest Hg concentrations of all bird species sampled per site (Lane et. 2011, BRI unpubl. data).

Table 2. Summary of mean, lowest and highest blood and feather (P1 and R6) mercury concentrations (µg g^{-1}) in adult birds by year, site, and species (SD=standard deviation, (n)=sample size).

Species	Site	Year	Blood-Hg (µg/g ww) Mean ± SD; Min, Max (n)	Primary-Hg (µg/g fw) Mean ± SD; Min, Max (n)	Rectrices-Hg (µg/g fw) Mean ± SD; Min, Max (n)
Common Tern	N. Cinder Is.	2011	0.69 (1)	—	1.26 (1)
Saltmarsh Sparrow	Accabonac Harbor	2011	1.11 ± 0.24; 0.68, 1.52 (13)	20.3 ± 12.1; 3.52, 41.7 (14)	3.54 ± 2.18; 1.04, 8.03 (12)
			—	—	3.89 (1)
	Crow Island	2011	1.65 ± 0.28; 1.33, 2.26 (12)	25.3 ± 14.9; 3.42, 45.1 (13)	3.83 ± 1.85; 1.23, 6.75 (13)
	N. Cinder Is.	2010	1.91 ± 0.22; 1.37, 2.19 (13)	18.0 ± 8.26; 2.44, 28.0 (12)	4.53 ± 4.31; 1.50, 14.2 (9)
		2011	1.84 ± 0.36; 1.45, 2.29 (6)	24.8 ± 10.5; 6.49, 37.5 (6)	1.79 ± 0.80; 1.01, 2.82 (6)
	N. Greensedge Is.	2011	1.22 ± 0.23; 0.86, 1.6 (10)	18.9 ± 8.73; 1.87, 27.6 (10)	2.11 ± 1.52; 0.82, 4.96 (10)
	Pine Neck	2010	1.23 ± 0.11; 1.00, 1.46 (16)	16.7 ± 5.68; 4.13, 27.0 (16)	2.07 ± 0.85; 1.08, 4.14 (14)
		2011	1.24 ± 0.26; 0.98, 1.60 (6)	17.5 ± 5.53; 7.16, 24.3 (7)	1.55 ± 0.55; 1.05, 2.31 (4)
	Scallop Pond	2010	0.35 ± 0.10; 0.23, 0.50 (5)	6.19 ± 0.74; 5.69, 7.46 (5)	1.85 ± 0.95; 1.32, 3.53 (5)
	Wading River	2011	0.35 ± 0.05; 0.26, 0.42 (8)	6.93 ± 3.09; 1.75, 10.0 (9)	1.38 ± 0.37; 0.55, 1.71 (8)
Seaside Sparrow	Crow Island	2011	1.44 ± 0.29; 1.23, 1.65 (2)	7.91 ± 7.51; 1.21, 16.0 (3)	1.33 ± 0.51; 0.78, 1.80 (3)
	N. Cinder Is.	2010	1.70 ± 0.32; 1.47, 1.93 (2)	18.0 ± 1.73; 16.8, 19.2 (2)	3.10 ± 0.74; 2.58, 3.63 (2)
		2011	1.70 ± 0.40; 1.15, 2.18 (8)	8.87 ± 8.08; 1.94, 22.1 (10)	1.12 ± 0.51; 0.45, 2.18 (9)
	N. Greensedge Is.	2011	1.07 ± 0.07; 1.00, 1.17 (4)	11.9 ± 1.68; 9.36, 13.5 (5)	3.11 ± 2.63; 0.81, 7.06 (5)
Song Sparrow	Scallop Pond	2010	0.21 (1)	—	0.66 (1)

We found no statistical difference in SALS blood Hg concentrations between Wading River Marsh and Scallop Pond (Table 3), in addition, they were significantly lower than all three sites in Hempstead, and two of the TNC preserves: Accabonac Harbor and Pine Neck. Sparrow blood Hg levels from North Cinder and Crow Islands in Hempstead were significantly higher than all other sites sampled and North Cinder was significantly higher than the rest of the sites sampled (Table 3).

Table 3. Summary of nonparametric comparisons of SALS blood Hg concentrations using Wilcoxon Method, Long Island, New York, 2010-2011. Site pairs with p-values in bold are significantly different, q=1.96.

Level	- Level	Z	p-Value	Hodges-Lehmann	Lower CL	Upper CL
Crow Is.	Accabonac Harbor	3.672	**0.0002**	0.5345	0.306	0.745
N. Cinder Is.	Accabonac Harbor	4.528	**<.0001**	0.8	0.566	0.998
N. Cinder Is.	Crow Is.	2.089	**0.037**	0.2565	0.025	0.487
N. Greensedge Is.	Accabonac Harbor	1.147	0.251	0.0945	-0.123	0.351
N. Greensedge Is.	Crow Is.	-3.132	**0.002**	-0.439	-0.652	-0.186
N. Greensedge Is.	N. Cinder Is.	-4.015	**<.0001**	-0.691	-0.916	-0.45
Pine Neck	Accabonac Harbor	1.519	0.129	0.127	-0.034	0.28
Pine Neck	Crow Is.	-4.163	**<.0001**	-0.3835	-0.572	-0.237
Pine Neck	N. Cinder Is.	-5.216	**<.0001**	-0.687	-0.835	-0.534
Pine Neck	N. Greensedge Is.	0.285	0.776	0.0185	-0.16	0.183
Scallop Pond	Accabonac Harbor	-3.154	**0.002**	-0.744	-1.053	-0.504
Scallop Pond	Crow Is.	-3.110	**0.002**	-1.276	-1.656	-1.022
Scallop Pond	N. Cinder Is.	-3.342	**0.001**	-1.575	-1.786	-1.236
Scallop Pond	N. Greensedge Is.	-3.001	**0.003**	-0.8365	-1.201	-0.593
Scallop Pond	Pine Neck	-3.402	**0.001**	-0.88	-1.039	-0.734
Wading River	Accabonac Harbor	-3.731	**0.0002**	-0.7245	-1.006	-0.592
Wading River	Crow Is.	-3.666	**0.0002**	-1.2555	-1.515	-1.071
Wading River	N. Cinder Is.	-4.010	**<.0001**	-1.563	-1.747	-1.37
Wading River	N. Greensedge Is.	-3.511	**0.0004**	-0.809	-1.129	-0.679
Wading River	Pine Neck	-4.104	**<.0001**	-0.874	-0.99	-0.764
Wading River	Scallop Pond	0.294	0.769	0.0205	-0.132	0.11

Feather Hg Concentrations

Primary=P1 (wing) feather Hg concentrations also varied among sites (Table 4, Fig. 4). Mercury concentrations in the primaries (mean=18.4 µg/g) were significantly higher than in tail feathers (mean= 2.73 µg/g) at each site or combined (t-ratio= -13.4; df=80; p<0.0001). Primary feathers molt at the end of the breeding season and therefore Hg concentrations reflect previous year's exposure. We found Scallop Pond and Wading River to be significantly lower than all Hempstead sites (Table 4).

Table 4. Summary of nonparametric comparisons of SALS P1 feather Hg concentrations using Wilcoxon Method, Long Island, New York, 2010-2011. Site pairs with p-values in bold are significantly different.

Level	- Level	Z	p-Value	Hodges-Lehmann	Lower CL	Upper CL
Crow Is.	Accabonac Harbor	1.432	0.152	6.1675	-3.392	15.456
N. Cinder Is.	Accabonac Harbor	0.018	0.986	0.2	-5.591	7.612
N. Cinder Is.	Crow Is.	-1.573	0.116	-7.561	-13.482	3.065
N. Greensedge Is.	Accabonac Harbor	-0.498	0.619	-1.7035	-10.912	6.733
N. Greensedge Is.	Crow Is.	-1.581	0.114	-8.9875	-17.497	8.23
N. Greensedge Is.	N. Cinder Is.	-0.574	0.566	-0.9395	-7.839	4.056
Pine Neck	Accabonac Harbor	-1.581	0.114	-5.4905	-9.786	1.283
Pine Neck	N. Cinder Is.	-2.552	**0.011**	-4.17	-8.136	-1.479
Pine Neck	N. Greensedge Is.	-1.508	0.132	-3.861	-7.433	2.257
Scallop Pond	Accabonac Harbor	-1.342	0.180	-17.191	-22.625	2.166
Scallop Pond	Crow Is.	-1.873	0.061	-26.261	-29.491	1.093
Scallop Pond	N. Cinder Is.	-2.559	**0.011**	-16.121	-22.374	-2.335
Scallop Pond	N. Greensedge Is.	-2.143	**0.032**	-15.3575	-20.209	-0.203
Scallop Pond	Pine Neck	-2.759	**0.006**	-11.511	-14.278	-8.725
Wading River	Accabonac Harbor	-2.173	**0.030**	-16.61	-20.88	-1.169
Wading River	Crow Is.	-2.070	**0.038**	-24.543	-29.342	-0.462
Wading River	N. Cinder Is.	-3.001	**0.003**	-14.759	-20.065	-11.362
Wading River	N. Greensedge Is.	-2.490	**0.013**	-14.564	-18.589	-4.899
Wading River	Pine Neck	-3.521	**0.0004**	-10.461	-13.729	-7.367
Wading River	Scallop Pond	1.200	0.230	1.62	-3.756	3.831

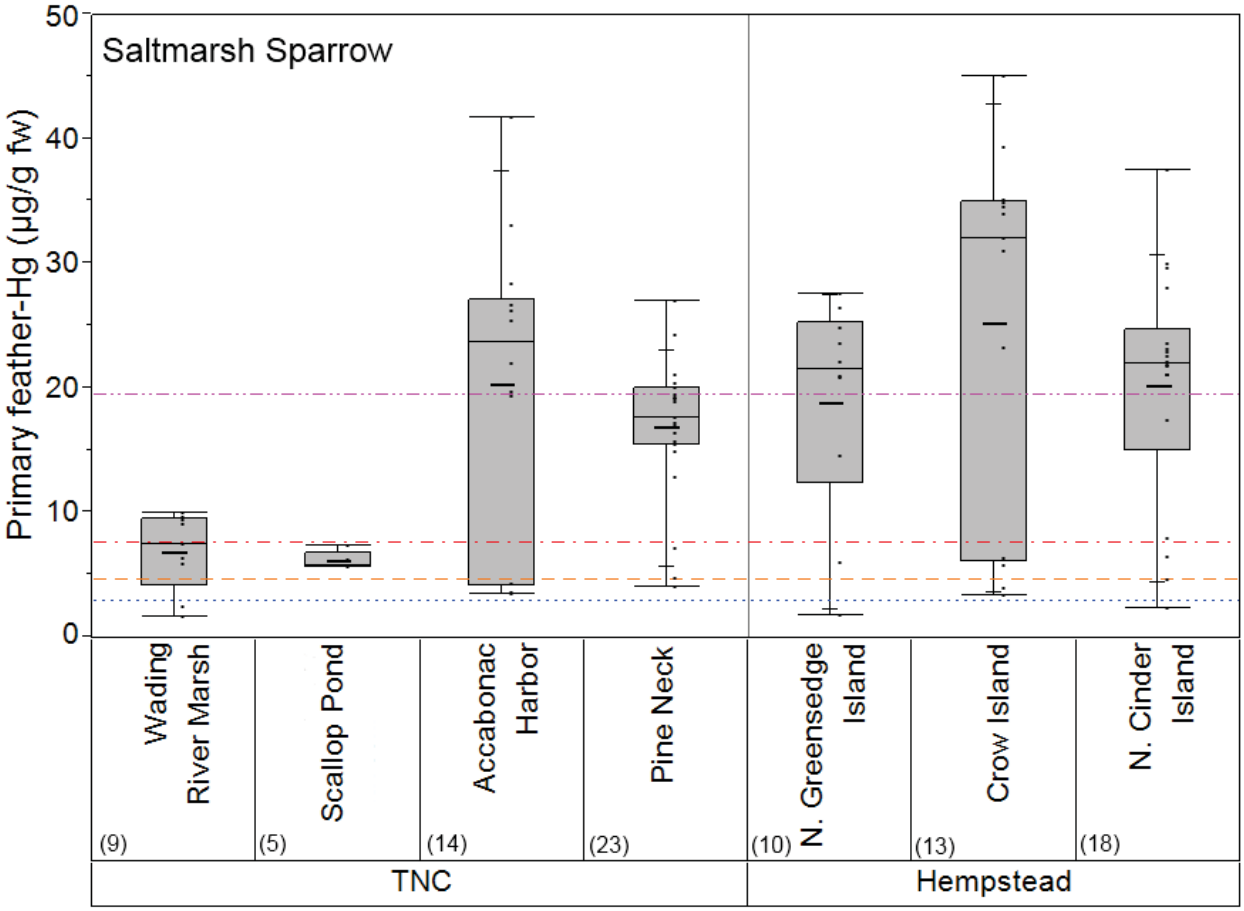

Figure 4. Quantile boxplots of Saltmarsh Sparrow primary feather (P1)-Hg (µg/g ww) from Long Island NY, 2010-2011 (TNC=The Nature Conservancy) where central line of box marks median, edges of boxes are 25th and 75th percentile, and whiskers represent minimum and maximum values. Mean marked as thick dash, 95% confidence interval as the inner whisker, (n)=sample size. Colored lines represent modeled feather-Hg effect levels in songbirds: lower dotted blue line (3 µg/g) a 10% reduction in nest success; dashed orange line (4.7 µg/g) a 20% reduction; dot-dash red line (7.7 µg/g) a 40% reduction and a pink dash line (19.5 µg/g) represents 99% reduction in nest success, based on Jackson et al. 2011.

Blood Hg concentrations between SALS and SESP were similar, the data met normality assumptions therefore a t-test was used (t=-1.23; DF=25; p=0.115); however, feather Hg data were not normally distributed and we used non parametric Welch's test. Mercury concentrations in P1 and tail were significantly lower in SESP (Welch's t-test: P1, t=-4.88; DF=56; p<0.0001; tail, t=-2.35; DF=52; p=0.011; however, sample size of Seaside Sparrows was low (Fig. 4b). Wilcoxon and Chi square tests produced similar outcomes.

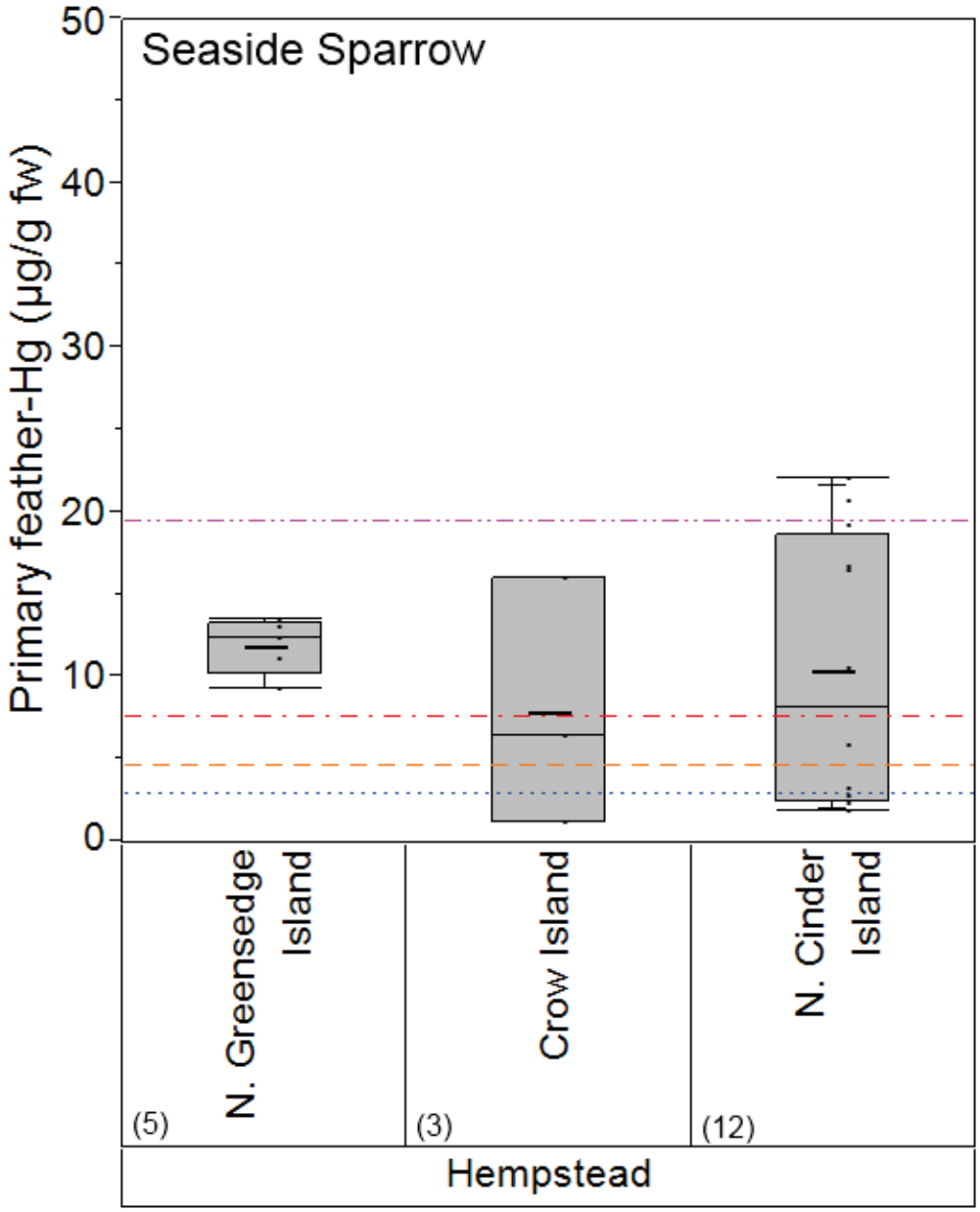

Figure 4b. Quantile boxplots of Seaside Sparrow primary feather (P1)-Hg (µg/g ww) from Long Island NY, 2010-2011 where central line of box marks median, edges of boxes are 25th and 75th percentile, and whiskers represent minimum and maximum values. Mean marked as thick dash, 95% confidence interval as the inner whisker, (n)=sample size. Colored lines represent modeled feather-Hg effect levels in songbirds: lower dotted blue line (3 µg/g) a 10% reduction in nest success; dashed orange line (4.7 µg/g) a 20% reduction; dot-dash red line (7.7 µg/g) a 40% reduction and a pink dash line (19.5 µg/g) 99% reduction in nest success based on Jackson et al. 2011.

Blood – Feather Hg Relationship

We observed a positive relationship between SALS primary (P1) feather and blood Hg concentrations (r^2 = 0.22, Fig. 5). It appears that there are two "populations" of birds: a subset with low P1 Hg levels but high blood Hg, and others that have high blood and high P1 Hg

concentrations. If we exclude that group from the model the r^2 becomes 0.51. These outliers likely represent individuals that did not spend the previous year's breeding season (2009, 2010) at these sites, and their feather Hg concentrations represent the Hg uptake from an unknown breeding territory, or they might have hatched during the previous year. Returning young birds are more likely to disperse and relocate to a new site than the adults (BRI unpublished data).

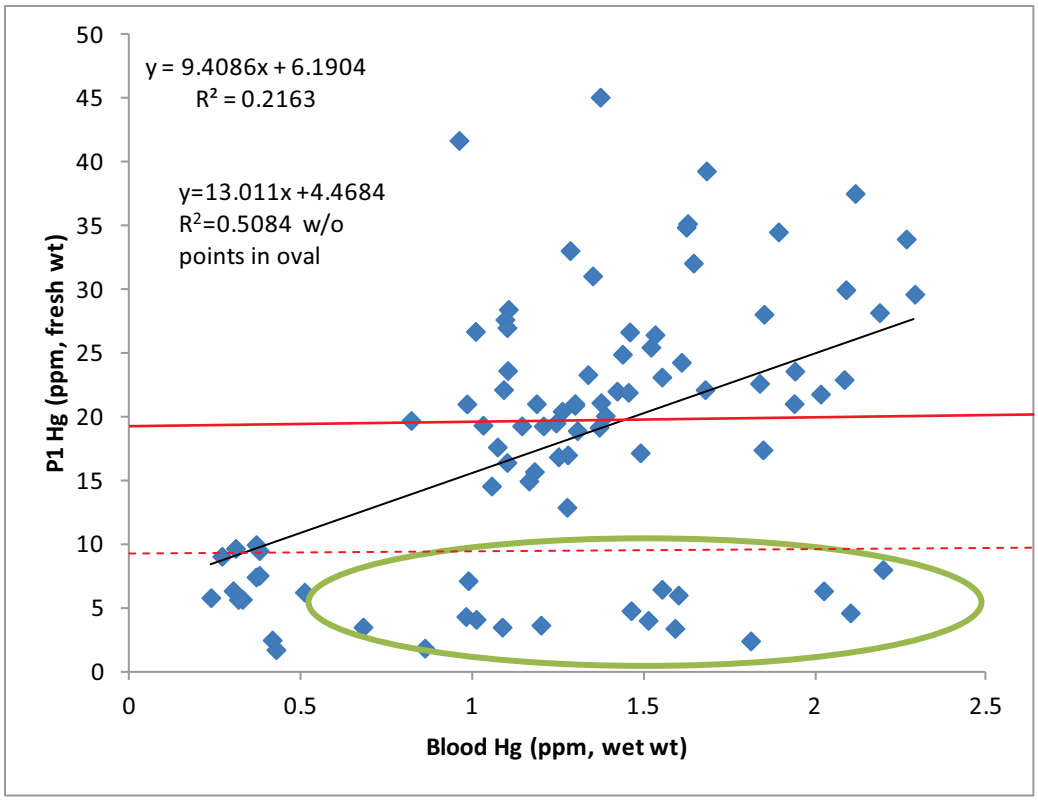

Figure 5. Comparison of P1 Hg versus blood Hg in Saltmarsh Sparrows from Long Island NY. Birds in the green oval likely spend their previous breeding season at a "cleaner" site, possible second year birds were nestlings the previous year at a different site. Red dash line indicates 50% modeled reduction in reproductive success and red solid line represents 99% reduction based on Jackson et al. 2011.

We observed no such trend between tail feather Hg and blood Hg in SALS.

A high proportion of sampled birds exceeded effect levels for reduced reproductive success (Table 5). Most of the birds were from the Hempstead islands and Pine Neck Marsh.

Table 5. Percent of adult SALS sampled in 2010-2011 from the New York study sites that show Hg levels exceeding levels observed by Jackson et al. (2011) to cause reductions in reproductive success (blood-Hg, 1.2 µg/g; feather-Hg, 4.7 µg/g) s. P1=primary 1 feather, R6=outer tail feather.

Site	Species	% adults w/ blood over 1.2 µg/g	%adults w/ P1 over 4.7 µg/g	%adults w/ R6 over 4.7 µg/g
TNC Sites				
Accabonack Harbor	Saltmarsh Sparrow	31	71	23
Pine Neck	Saltmarsh Sparrow	59	96	0
Scallop Pond	Saltmarsh Sparrow	0	100	0
Wading River	Saltmarsh Sparrow	0	78	0
Hempstead Sites				
Crow Is.	Saltmarsh Sparrow	100	85	23
	Seaside Sparrow	100	67	0
N. Cinder Is.	Saltmarsh Sparrow	100	89	21
	Seaside Sparrow	100	58	0
N. Greensedge Is.	Saltmarsh Sparrow	40	90	20
	Seaside Sparrow	0	100	20

In the birds recaptured in 2011 at Pine Neck that were originally sampled in 2010, blood Hg remained about the same, but feather Hg concentration increased by approximately 25% (Table 6).

Table 6. Mercury concentrations in recaptured SALS from Pine Neck Reserve, 2010-2011.

Band #	Sex	2010 blood Hg	2011 blood Hg	2010 P1 Hg	2011 P1 Hg	% blood Hg change	% P1 Hg change
2351-07773	F	1.28	0.987	12.9	7.2*	-22.6	na
2351-07774	F	1.37	1.61	19.2	24.3	17.5	26.5
2351-07781	M	1.28	1.30	17.0	21.1	1.60	23.6

*P1 was missing, P2 was collected and analyzed

Invertebrate Mercury Concentrations

We collected and analyzed composites of spiders (Order Araneae) and amphipods (Order Amphipoda) (Figure 6) from every site. We identified all invertebrates to family. We measured total and methylmercury and calculated percent MeHg in each sample. Small sample sizes did not allow for statistical tests of differences between study marshes. Spiders and amphipods from the three Hempstead islands have higher Hg concentration than at Wading River and Scallop Pond. (Fig. 7). One Lycosid spider composite sample from North Cinder Island

had a relatively low concentration of MeHg (32%) while the majority of spider samples had concentrations above 90% (Appendix 1).

Figure 6. Amphipod from a salt marsh.

We also collected and analyzed 1-2 fiddler crabs per site (order Decapoda) from several marshes to determine Hg exposure to other marsh obligate birds such as Clapper and King Rails and other birds that feed on crabs. Methyl and total Hg concentrations were lower on average than in spiders (Fig. 7) and percent methyl was also lower and ranged between 40 % in Wading River and 85% in Accabonac Harbor (Fig. 8).

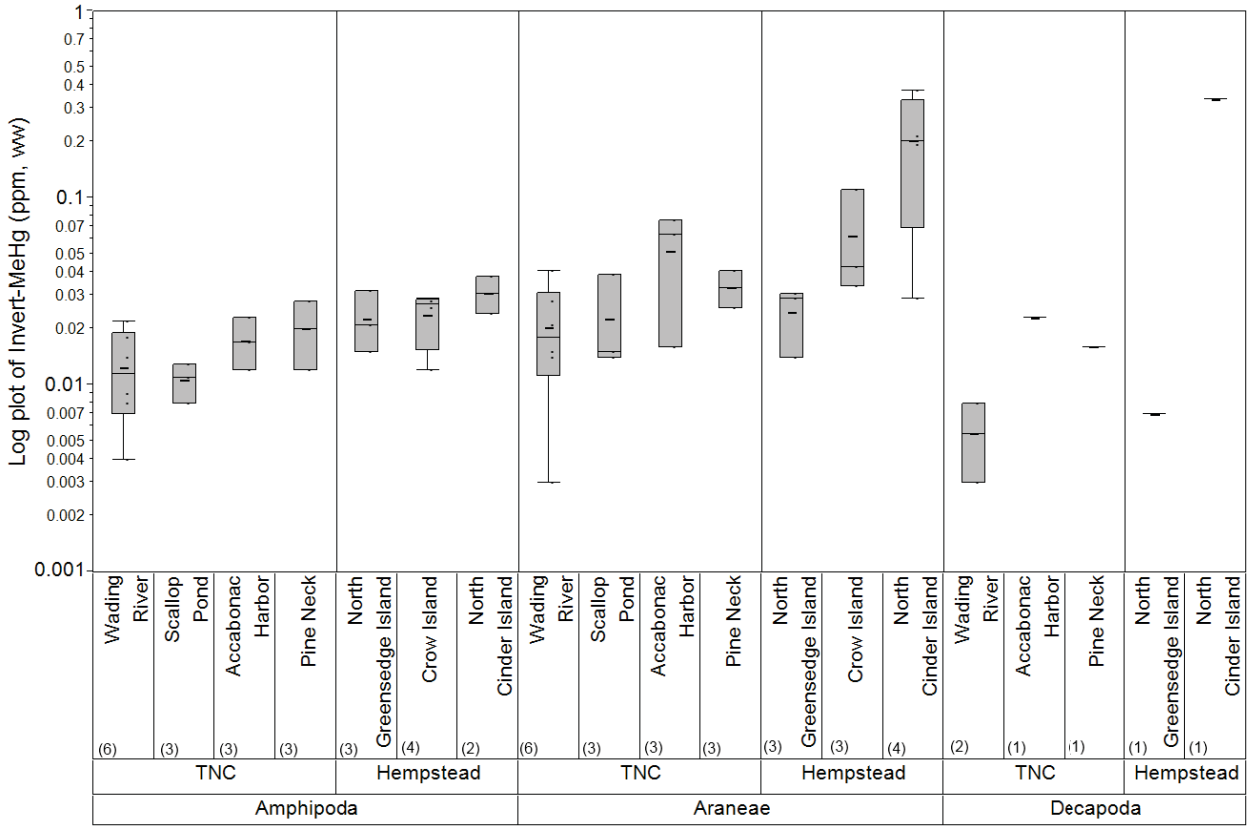

Figure 7. Quantile boxplots of methyl-Hg for invertebrates collected at The Nature Conservancy and Hempstead sites, means of territories indicated by thick line, central line indicates median, edges of boxes indicate 25th and 75th percentile, and whiskers indicate minimum and maximum values.

It is also apparent that spiders have higher MeHg concentrations than amphipods and at several sites higher than in fiddler crabs (Fig. 7). On average, percent MeHg in spiders is also higher than in the amphipods with the exception of N. Greensedge Island (Fig.8).

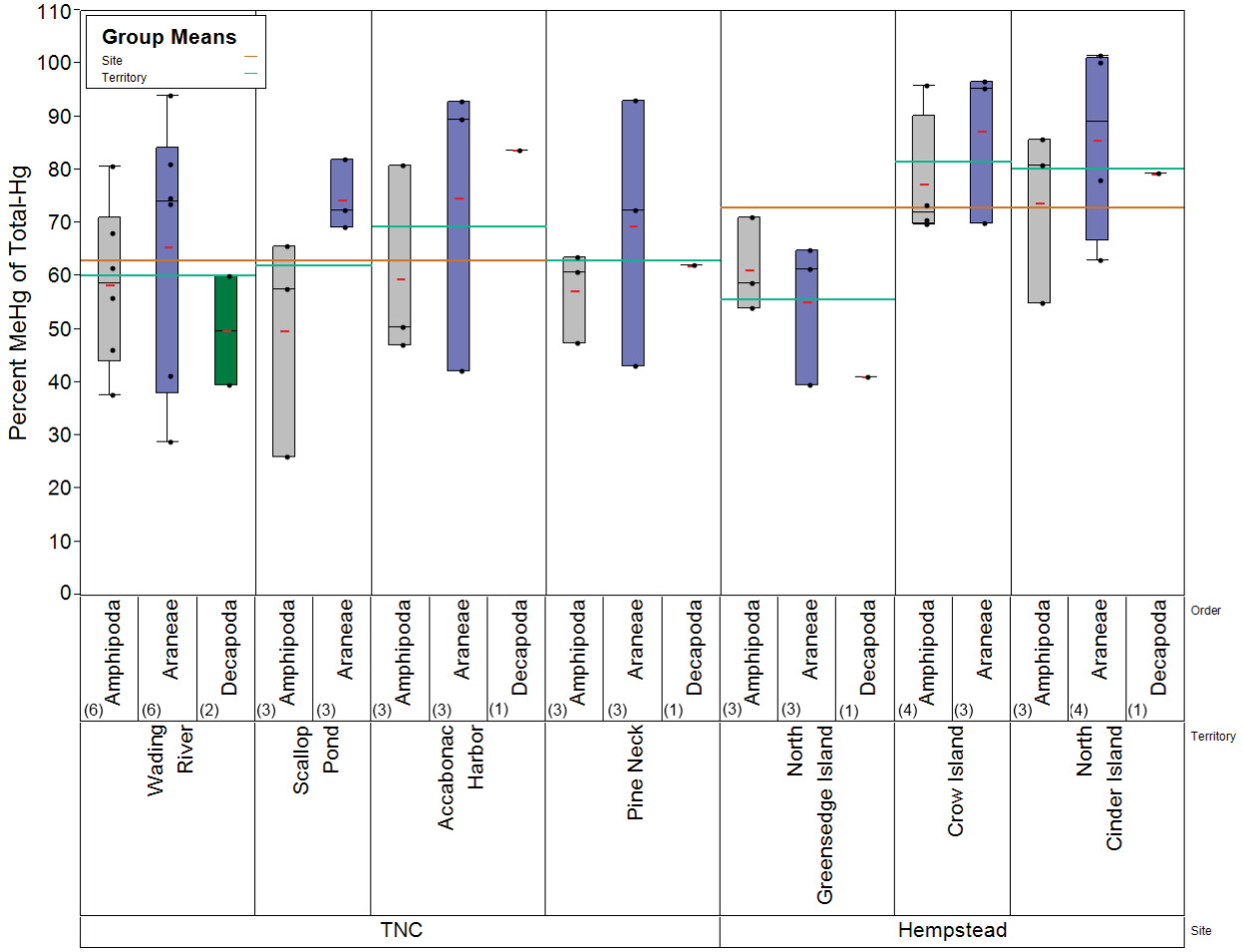

Figure 8. Quantile boxplots of percent methyl-Hg of total-Hg in invertebrates collected at the Nature Conservancy and Hempstead sites, with means of invertebrate orders indicated by thick red line, means of territories indicated by thick green line, and mean of sites indicated by thick brown line. Boxplot central line indicates median, edges of boxes indicate 25th and 75th percentile, and whiskers indicate minimum and maximum values.

In general, percent MeHg appears to be similar among sites with Crow and N. Cinder Islands spiders and amphipods having slightly higher values than the rest of the sites (Fig. 8).

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 7.75 ± 0.41 ‰ on Accabonac Harbor to 12.83 ± 0.46 ‰ on N. Greensedge Island (Figure 9, Table 7). There was a significant difference in SALS $\delta^{15}N$ on Long Island ($F_{(6,63)} = 167.2$; $p < 0.001$) and post hoc comparisons using the Tukey HSD test ($\alpha = 0.05$) revealed intra-specific differences in $\delta^{15}N$ values across marsh sites on Long Island (Table 7). SALS on N. Cinder Island and N. Greensedge Island were enriched in ^{15}N relative to the other sampling sites while SALS sampled on both Scallop Pond and Accabonac Harbor were the most depleted in ^{15}N of all sampling sites. The stable carbon isotope ratios ($\delta^{13}C$) in SALS on Long Island ranged from -16.72 ± 0.52 ‰ on Accabonac Harbor to -13.76 ± 0.37 ‰ on Crow Island (Figure 9, Table 7). There was a significant

difference in SALS $\delta^{13}C$ across sites ($F_{(6,63)} = 51.6$; $p < 0.001$). Post hoc comparisons of $\delta^{13}C$ values in SALS blood revealed that $\delta^{13}C$ values on Accabonac Harbor were significantly more negative (i.e., depleted in ^{13}C) than the other marshes sampled (Table 7).

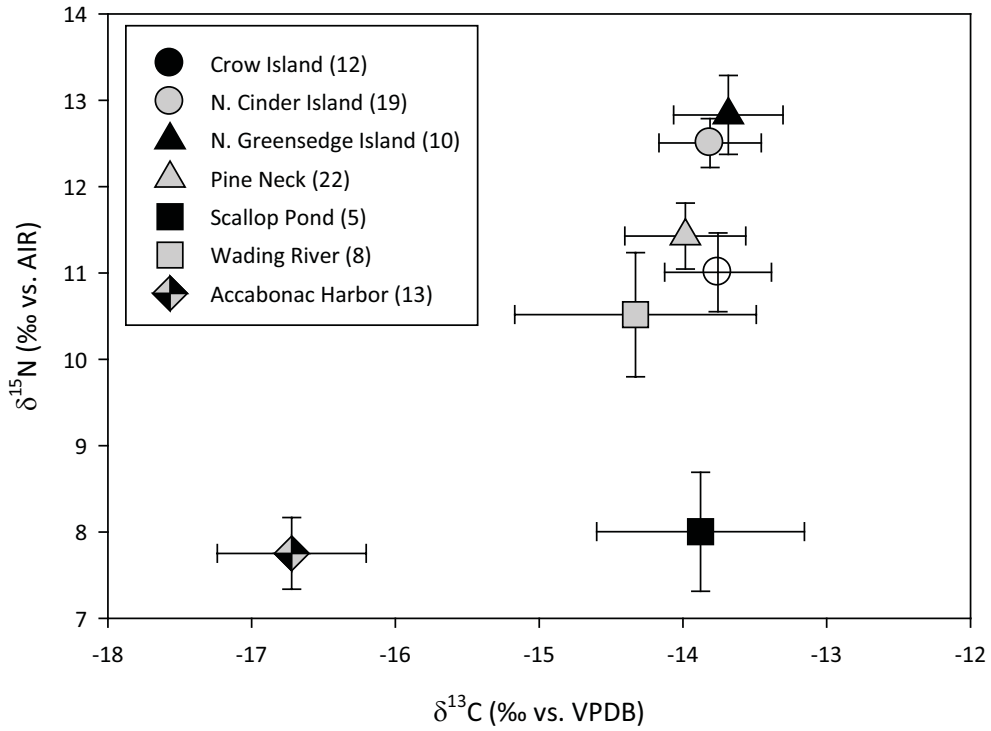

Figure 9. Isotope biplots for SALS on Long Island marshes (2010-2011) showing the distribution of stable carbon ($\delta^{13}C$) and stable nitrogen ($\delta^{15}N$) concentrations in Saltmarsh Sparrows across the seven study marshes.

There is a weak positive correlation between $\delta^{15}N$ and THg in SALS blood (Pearson's Product Correlation r = 0.43) that is stronger when samples from Accabonac Harbor are removed from the correlation matrix (r = 0.56). This correlation suggests a relationship between the bioavailability of THg on salt marshes and nutrient enrichment. Variations in inputs of ammonia, nitrite and nitrate can have a strong influence on $\delta^{15}N$ ratios and strong intra-specific variability in $\delta^{15}N$ in plants (Wigand et al. 2007) and mussels (McKinney et al. 2001) have been shown to correlate with human land use practices within coastal watersheds.

Variations in $\delta^{13}C$ of SALS blood (Figure 9, Table 7) is likely controlled by variations in carbon inputs at the base of the salt marsh food chain. Carbon isotopic ratios are largely controlled by differences in photosynthetic pathways among terrestrial plants. Most grasses

and sedges are considered C4 plants and have $\delta^{13}C$ values of approximately -14‰ (Peterson and Fry 1987). Trees, as well as some wetland plants such as cattail and phragmites, are considered C3 plants and have $\delta^{13}C$ values of approximately -28‰ (Peterson and Fry 1987). While samples of vegetation were not analyzed as part of this project, it is likely that basal carbon sources on Accabonac Harbor are influenced by C3 vegetation while basal carbon sources on the other marsh sites are dominated by C4 vegetation.

Table 7. Stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotope results (mean ± 1 std. dev.) for SALS sampled on Long Island marshes during 2010 and 2011. Sample sizes (n) are shown in parentheses next to sites. Significant differences in mean stable isotope concentrations are indicated by different numerical values following $\delta^{13}C$ results and different letters following $\delta^{15}N$ results.

SITE	$\delta^{13}C$ (‰ vs. VPDB)	$\delta^{15}N$ (‰ vs. AIR)
Crow Island (n = 12)	-13.76 ± 0.37 (1)	11.01 ± 0.46 (B,C)
N. Cinder Island (n = 19)	-13.81 ± 0.36 (1)	12.50 ± 0.28 (A)
N. Greensedge Island (n = 10)	-13.68 ± 0.38 (1)	12.83 ± 0.46 (A)
Pine Neck, East Quogue (n = 22)	-13.98 ± 0.42 (1)	11.43 ± 0.38 (B)
Scallop Pond, South Hampton (n = 5)	-13.88 ± 0.72 (1)	8.00 ± 0.69 (D)
Wading River Marsh (n = 8)	-14.33 ± 0.84 (1)	10.52 ± 0.72 (C)
Accabonac Harbor (n = 13)	-16.72 ± 0.52 (2)	7.75 ± 0.41 (D)

Although sample sizes for prey items were too small to allow for statistical comparisons across trophic levels, the data suggest a relationship between increasing THg and MeHg concentrations and increasing $\delta^{15}N$ (Figure 10). Within the invertebrate – sparrow food web on the salt marshes of Long Island, Hg and MeHg concentrations increase from amphipods $\rightarrow$spiders $\rightarrow$ sparrows (Fig. 11, Appendix 1). Nitrogen isotope ratios increase from amphipods $\rightarrow$ sparrows, with spiders and sparrows occupying a similar trophic position across all sites. The difference in $\delta^{15}N$ between amphipods and spiders and amphipods and sparrows ranges from approximately 4‰ to 6‰, representing 1-2 trophic levels. 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.

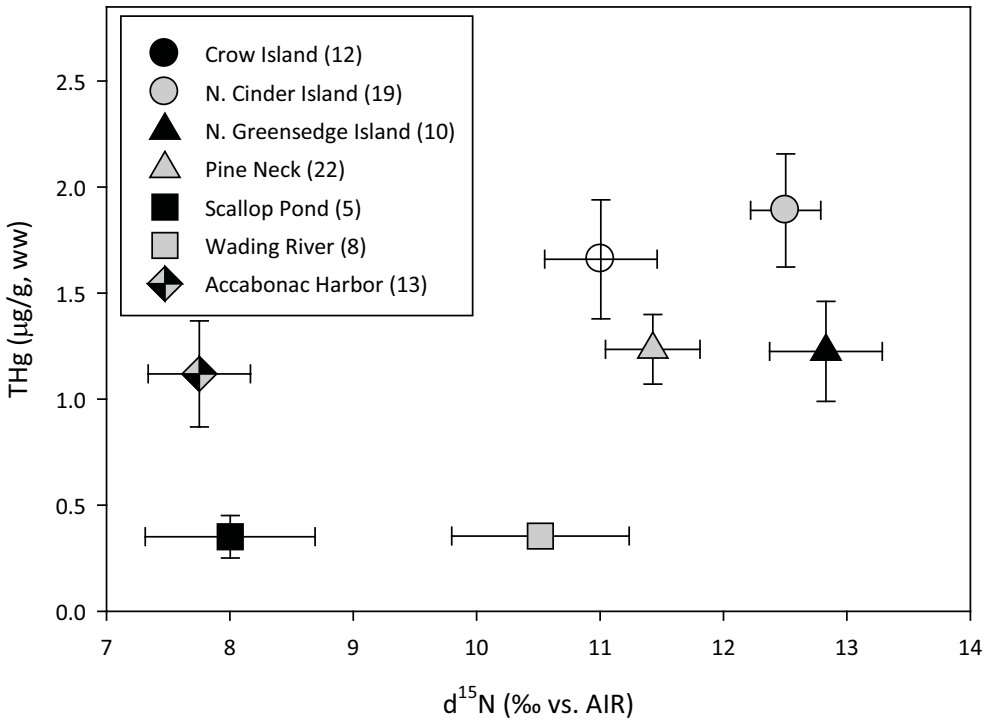

Figure 10. Relationship between bird blood Hg concentrations and δ ^{15}N values in Saltmarsh Sparrows from Long Island, NY.

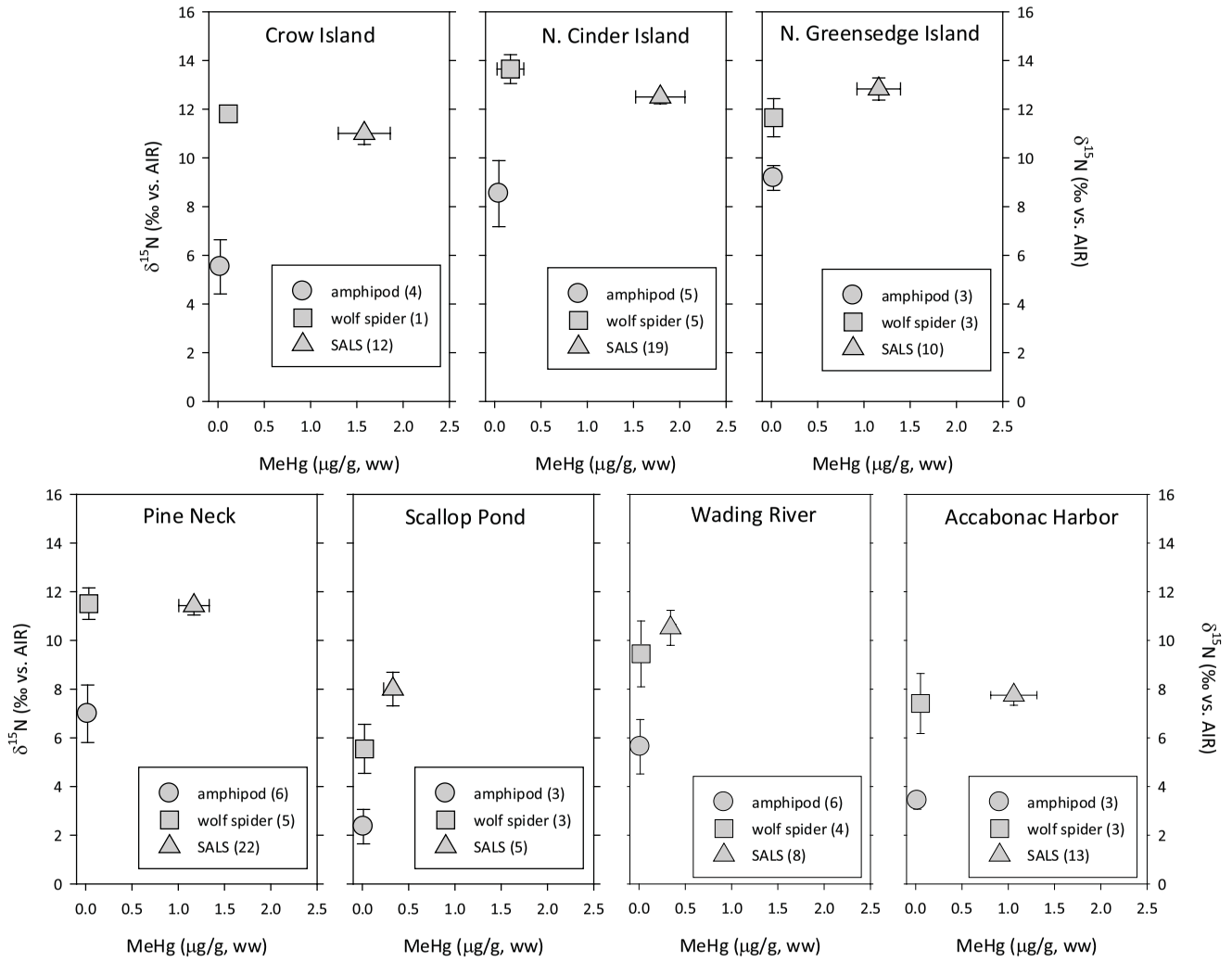

Figure 11. **δ15N vs. methylmercury concentrations in target invertebrate taxa and Saltmarsh Sparrows on Long Island marshes (2010-2011). Methylmercury concentrations in bird blood were assumed to be 95% of total mercury (Rimmer et al. 2005).**

Discussion

Mercury as a Stressor for Saltmarsh Sparrows on Long Island

The Hg concentrations measured in sparrows from the town of Hempstead islands (Crow and North Cinder) on Long Island are amongst the highest observed in marshes throughout New England and the Northeast (Fig. 13), 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}[2]) for songbirds are modeled to be 1.2 µg/g ww based on the Carolina wrens study (Jackson et al. 2011). Many sparrows sampled from Long Island marshes had blood Hg concentrations exceeding 1.2 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.

Saltmarsh Sparrows from Hempstead have the highest average Hg levels in blood of all sites and states sampled in the Northeast (Fig.12), probably as a result of Hg emitted by the Hempstead garbage incinerator.

[2] EC_{20} stands for the effective concentration at which there is a 20% reduction in nest success. The EC_{20} for Hg in songbirds is based on models developed by BRI using field nesting success study on Hg exposure in birds (Jackson et al. 2011).

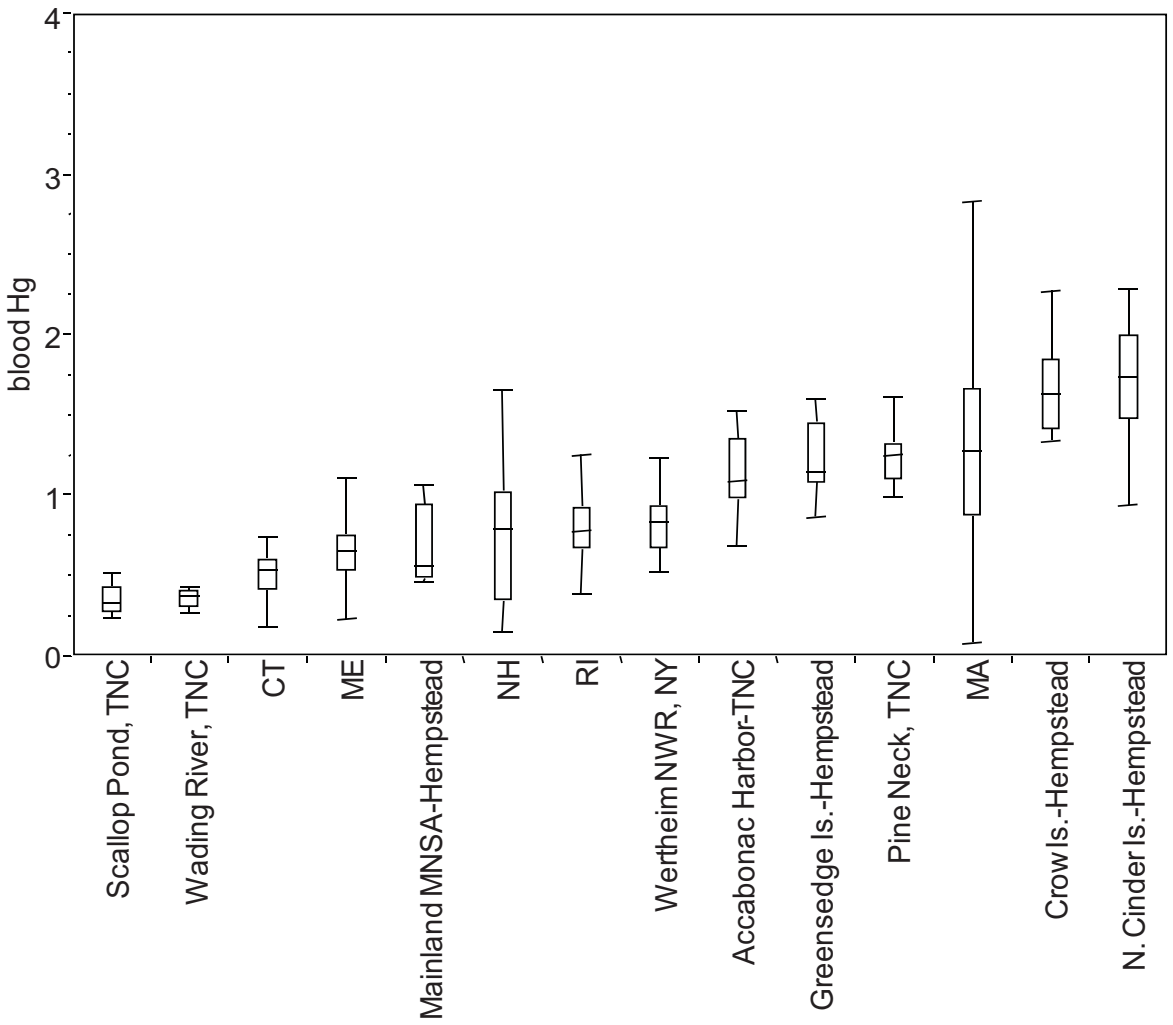

Figure 12. Quantile boxplots of Saltmarsh Sparrows blood Hg (µg/g, wet wt) sampled from all New England states and Long Island Sites. Means indicated by thick line. Boxplot central line indicates median, edges of boxes indicate 25th and 75th percentile, and whiskers indicate minimum and maximum values concentrations. Sample sizes from left to right: 5; 8; 31; 356; 5; 95; 72; 26; 13; 10; 22; 284; 12; 32.

High intra-specific variability in THg and stable isotope ratios observed across the seven sampling sites suggests that a variety of potential mechanisms influencing THg in sparrows. High THg and MeHg concentrations in prey items on certain marshes highlight the role of biomagnification and bioaccumulation in the transfer of contaminants within marsh food webs. In addition, the proximity of North Cinder, North Greensedge and Crow Islands to the municipal solid waste incinerator in Hempstead, NY, that has a history of emissions problems (NYPERG 2011, Hattemer-Frey and Travis 1991), points to the potential legacy effects associated with past and current Hg emissions.

Variations in stable isotope ratios, particularly $\delta^{15}N$, may provide insight on human impacts associated with nutrient enrichment in the estuaries and salt marshes of Long Island as well. These variations could be used to better understand breeding ground fidelity and dispersal of SALS on Long Island. Recent work has shown that variations in $\delta^{15}N$ can be used to monitor site fidelity and habitat use among juvenile fishes in salt marsh habitats (Green et al. 2012). It is generally understood that SALS have high site fidelity and natal philopatry (DiQuinzio et al. 2001; Walsh et al. 2012) and combining stable isotope analysis with mark-and-recapture studies should provide insight into the use of salt marshes by SALS during their breeding grounds use.

BRI has conducted three years of field work during the breeding season on Long Island. These data illustrate the spatial variability in Hg levels observed across Long Island. In addition, these data point to changes in Hg bioaccumulation over time in at least one salt marsh on Long Island. Between 2008 and 2010-2011, mean blood Hg concentrations in sparrows sampled from North Cinder Island (Marine Nature Study Area, Oceanside, NY) increased by 31%. Mechanisms for this increase in Hg concentrations are unknown and should be the focus of future conservation and research efforts.

It is also interesting that despite similar blood Hg concentrations between SALS and SESP, feather Hg concentrations in P1 and tail were significantly lower in SESP. This may or may not be related to different diet or winter range (Fig. 13). Seaside Sparrow is slightly bigger than SALS (average weight 22 g vs 20 g). Tail Hg concentrations reflect winter body burden because the sparrows molt their retrices on the wintering grounds.

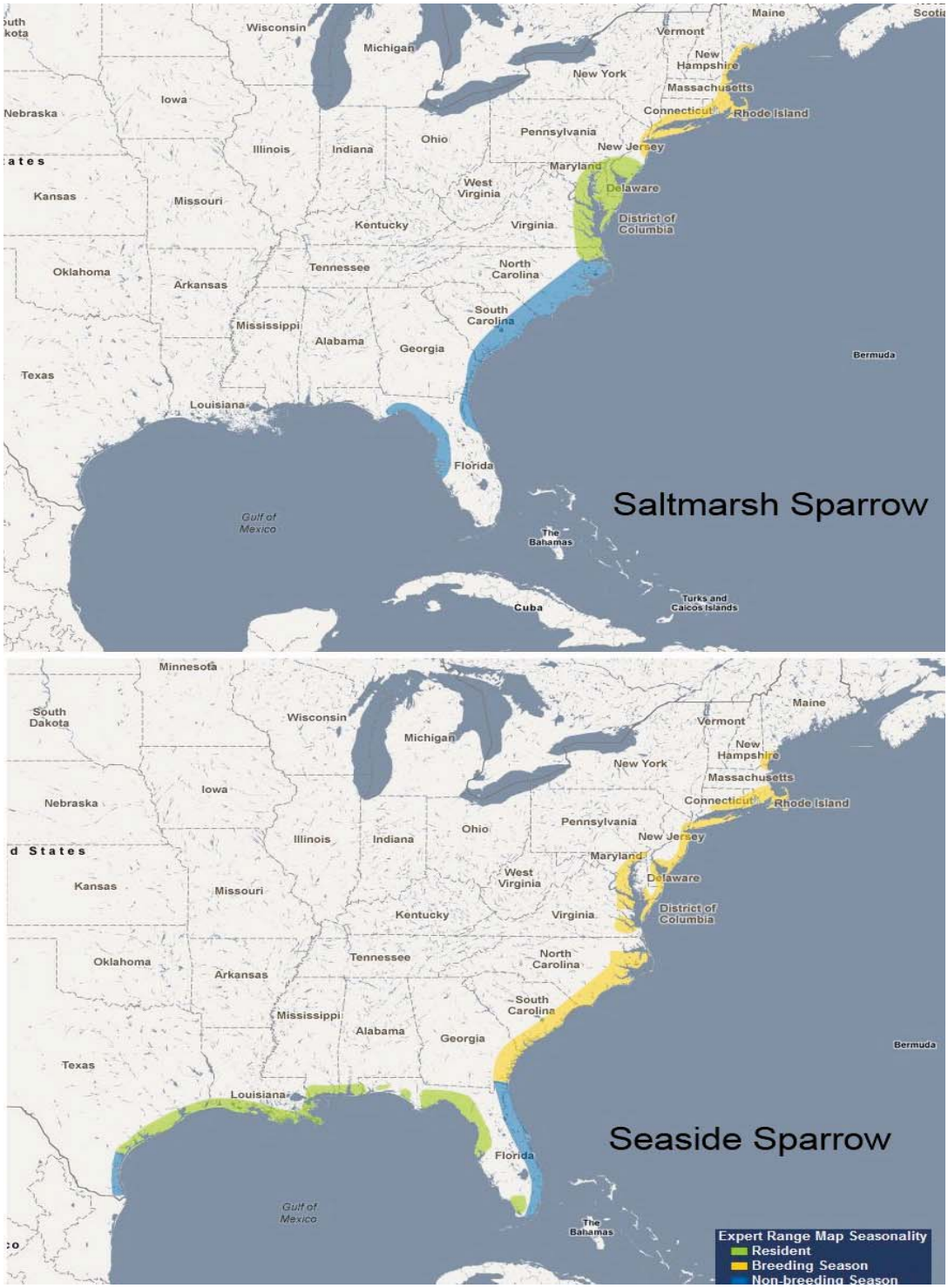

Figure 13. Seasonal distribution maps for Saltmarsh and Seaside Sparrows, (map source, www.mappinglife.org> accessed on May 20, 2012).

Recommendations

Results from this research highlight the risk that Hg contamination poses to Saltmarsh and Seaside Sparrows on Long Island, New York. These species are of high conservation concern and can serve as an important bioindicator of the health 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.
- Conduct mercury isotopic speciation analysis to discover the source of Hg in bird blood.
- Expand future sampling to include sediment and vegetation for THg, MeHg, and stable isotopes.
- 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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Appendix 1. Mean ± SD (n) of invertebrate stable isotopes for Long Island, NY sites in 2011.

Order	Family	Site	δ13C	δ13N
Amphipoda	Talitridae	Crow Island	-14.37 ± 0.84 (4)	5.52 ± 1.11 (4)
		N. Cinder Is.	-13.40 ± 0.46 (3)	8.48 ± 1.06 (3)
		N. Greensedge Is.	-14.51 ± 1.65 (3)	9.17 ± 0.51 (3)
		Pine Neck	-14.28 ± 0.74 (3)	7.61 ± 0.27 (3)
		Scallop Pond	-16.08 ± 0.10 (3)	2.35 ± 0.70 (3)
		Wading River	-15.08 ± 0.60 (6)	5.63 ± 1.11 (6)
	Talitridae Total		-14.67 ± 1.06 (22)	6.30 ± 2.28 (22)
Araneae	Araneidae	Crow Island	-15.69 (1)	8.78 (1)
		Wading River	-14.77 ± 0.22 (2)	9.56 ± 0.82 (2)
	Araneidae Total		-15.07 ± 0.55 (3)	9.3 ± 0.73 (3)
	Clubionidae	Crow Island	-14.67 (1)	8.90 (1)
		Wading River	-15.66 (1)	9.75 (1)
	Clubionidae Total		-15.16 ± 0.70 (2)	9.32 ± 0.60 (2)
	Lycosidae	Crow Island	-15.65 (1)	11.81 (1)
		N. Cinder Is.	-14.15 ± 0.08 (4)	13.7 ± 0.57 (4)
		N. Greensedge Is.	-15.06 ± 0.76 (3)	11.6 ± 0.78 (3)
		Pine Neck	-14.83 ± 0.19 (3)	11.3 ± 0.08 (3)
		Scallop Pond	-18.82 ± 1.04 (3)	5.54 ± 1.00 (3)
		Wading River	-15.25 ± 1.00 (4)	9.44 ± 1.34 (4)
	Lycosidae Total		-15.52 ± 1.69 (18)	10.5 ± 2.85 (18)
Araneae Total			-15.43 ± 1.51 (23)	10.3 ± 2.58 (23)
Decapoda	Ocypodidea	N. Cinder Is.	-12.72 (1)	9.96 (1)
		N. Greensedge Is.	-15.31 (1)	8.80 (1)
		Pine Neck	14.27 (1)	8.75 (1)
		Wading River	-16.54 ± 0.91 (2)	6.81 ± 0.29 (2)
	Ocypodidea Total		-15.07 ± 1.68 (5)	8.22 ± 1.38 (5)
Decapoda Total			-15.07 ± 1.68 (5)	8.22 ± 1.38 (5)
Gastropoda	Ellobiidae*	N. Cinder Is.	-7.12 ± 2.25 (2)	8.08 ± 0.05 (2)

*Very low mass specimens, interpret with caution.

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