Methylmercury availability in New England estuaries as indicated by Saltmarsh Sharp-tailed Sparrow, 2004-2007

(BRI 2008-11)

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Suggested citation: Lane, O.P., A. Major, K. O'Brien, N. Pau and D. C. Evers. 2008. Methylmercury availability in New England estuaries as indicated by Saltmarsh Sharp-tailed Sparrow, 2004-2007. Report BRI 2008-11. BioDiversity Research Institute, Gorham, Maine.

Methylmercury availability in New England estuaries as indicated by Saltmarsh Sharp-tailed Sparrow, 2004-2007

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Regional ID: 5N39
DEQ ID: 200550006

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June 2, 2008

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LIST OF ACRONIMS/ABBREVIATIONS

ANOVA	Analysis of variance
BRI	BioDiversity Research Institute
cc	cubic centimeters
g	grams
Hg	Mercury
LOAEL	lethal lowest observed adverse effect level
m	meters
mm	millimeters
MeHg	methylmercury
µg/g	micrograms per gram (or ppm)
N	sample size
NWR	National Wildlife Refuge
PCBs	Polychlorinated Biphenyls
ppm	parts per million
SD	standard deviation
SWMA	State Wildlife Management Area
THg	Total Mercury
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
ww	wet weight

1.0 Abstract

As part of an ongoing investigation of Saltmarsh Sharp-tailed Sparrows (*Ammodramus caudacutus*) in the Northeast, we conducted a sparrow mercury (Hg) exposure survey on five selected National Wildlife Refuges in New England. Our goal was to capture the sparrows during their breeding season and to collect a small blood sample to compare Hg exposure across several refuges in New England.

In 2004-2005, we sampled sparrow blood from Rachel Carson National Wildlife Refuge (NWR) in Maine, Parker River NWR in Massachusetts, Ninigret NWR in Rhode Island, and Stewart B. McKinney NWR in Connecticut. In 2006, we limited our sampling to Parker River NWR and Rachel Carson NWR. In 2007, a genetic component was added to the larger study and one additional refuge (Werthheim NWR on Long Island) was sampled. In all years of the study, mercury levels in sparrows from Parker River NWR were higher than those from other refuges.

Because our results from 2004-2005 revealed that sparrows from Parker River NWR had elevated whole blood Hg levels, we initiated a study in 2006 to assess and compare the sparrows' reproductive success between a lower Hg site (Rachel Carson) and a higher Hg site (Parker River). We found Hg concentrations in adult and nestling sparrows at Parker River to be significantly higher ($p<0.0001$) than at Rachel Carson. Based on two years of limited nest monitoring, productivity parameters such as number of eggs hatching and fledging appear to be significantly lower at Parker River than at Rachel Carson.

Three of the plausible explanations why Hg is higher at Parker River are: (1) there are higher levels of Hg in the Parker River NWR system originating from waterborne and/or airborne sources, (2) Hg is methylated at a higher rate in these marshes and (3) sparrows in Parker River may consume different prey. Additional sampling efforts are needed to further document (1) site-specific exposure profiles, (2) origin of Hg input, and (3) Hg effects in sparrows.

KEY WORDS: blood, eggs, mercury, saltmarsh sparrow, New England, Congressional Districts: ME (1), MA (6), RI (2), CT (3) NY (1), DEC ID: 200550006, Regional ID: 5N39, Rachel Carson NWR, Parker River NWR, Ninigret NWR, Stewart B. McKinney NWR, Wertheim NWR.

2.0 Introduction

Exposure to mercury (Hg) can impact bird behavior, physiology, and reproductive success (Thompson 1996, Wolfe and Norman 1998). Extensive studies with Common Loons have documented these impacts in Maine and New Hampshire (Evers et al. 2004, Evers et al. In Press). Previous studies have documented that freshwater wetlands generally serve as areas of high Hg methylation, thus making obligate salt and fresh water marsh birds especially vulnerable to high levels of Hg contamination (Evers et al. 2005). The role of salt marsh habitats in methylating Hg and enhancing its bioavailability, however, is less documented, but is of increasing concern especially in urban areas (Marvin-DiPasquale et al. 2003).

The Saltmarsh Sharp-tailed Sparrow (Saltmarsh Sparrow or sparrow hereafter) has a limited range, occupying estuaries along the Atlantic Coast from Florida up to the southern coast of Maine where it overlaps with the Nelson's Sharp-tailed Sparrow (Hodgman et al. 2002). Its breeding range is even more restricted, occurring only from southern Maine, becoming less frequent in Delaware, while possibly extending into Virginia. Across its range the species is

non-territorial and exhibits a bondless form of polygyny in which males provide no parental care (Greenlaw 1993, Greenlaw and Rising 1994). The diet during the breeding season consists mainly of animal matter: immature and adult insects and other arthropods (Greenlaw and Rising 1994, Merriam 1979). Tidal flooding causes most of nest failures, but usually the birds renest within a short period of time. Young leave the nest 23-27 days after clutch initiation. Nestlings fledge between 8-11 days after hatching (Greenlaw and Rising 1994).

Saltmarsh Sparrows are obligate salt marsh passerines with ≈ 95% of their global population breeding within the Northeast. The U.S. Fish and Wildlife Service (USFWS) considers Saltmarsh Sparrows to be one of the highest priority species in the Northeast region and classifies them as a "bird of conservation concern". This designation results from the sparrow's near endemic status in the region, a lack of population trend data, and threats on their breeding and wintering grounds (Hodgman pers. com.). Spending their entire annual cycle in salt marsh habitats makes Saltmarsh Sparrows excellent indicators of Hg contamination in salt marsh habitats. Preliminary data collected in 2001-2004 documented that sparrow blood samples from five Maine estuaries (including Rachel Carson NWR) contained some of the highest Hg levels in Maine birds (Shriver et al. 2002, Lane and Evers 2006).

Our objectives include:

1. Determine comparative Hg exposure profiles for Saltmarsh Sparrows on five National Wildlife Refuges across New England.
2. Identify areas with lowest and highest exposure for focused efforts to measure potential Hg effects on sparrows from a high-risk population.
3. Determine reproductive success of sparrows on low versus high Hg sites.
4. Assess Hg exposure and its relationship to reproductive output.
5. Assess organochlorine exposure in sparrow eggs in Parker River NWR.

3.0 Methods and Materials

3.1 Study area

The methods and study sites sampled in 2004-2005 are described in Lane and Evers (2006) (Appendix 1-4). The Chafee NWR is a unit of the Ninigret NWR complex; therefore both names are used interchangeably in this report. In 2006-2007 we focused our efforts on determining geographical variation in Hg exposure and reproductive success from a low Hg site (Rachel Carson NWR in Wells, Maine) and compared it with a high Hg site (Parker River NWR in Newburyport, Massachusetts). The focus areas on Rachel Carson included Furbish Road Marsh (Appendix 2). The focus areas on Parker River NWR included Salt Pannes, Area A, and Sub-Headquarters (sub HQ hereafter), as well as the Essex County Greenbelt property (Appendix 3). In 2007 we added a genetic component to the study and sampled two sites in Maine: Rachel Carson NWR in Wells and Scarborough State Wildlife Management Area (SWMA) in Scarborough; four sites at or near the Parker River NWR: Salt Pannes, Lot 2, Area B, and the William Forward SWMA; three sites on the Ninigret NWR complex in Rhode Island; and one site on Werthheim NWR in Shirley, NY (Appendix 5).

3.2 Capture and sampling

All capture and blood sampling occurred from early June to early September 2004-2007. We used two to six 12-m mist nets with 36 mm mesh size. We positioned the nets perpendicular to drainage ditches and tidal creeks, regularly found in many of the estuaries. A team of 5-6 people "swept" the area of approximately 100-200 m^2 "rounding up" the sparrows and coaxing them to fly towards the nets. The birds were extracted from the nets and banded with a USFWS band. A beach umbrella was used for shade to prevent birds from overheating. Sex, age and breeding status were determined for each bird. Venipuncture of the cutaneous ulnar vein with a 27 gauge sterile disposable needle allowed collection of 1-2 capillary tubes of blood into heparinized tubes for Hg analysis. The capillary tubes were sealed with critoseal or Critocaps® and stored in 10 cc plastic vacutainers, labeled with date, site, species, age and sex information. All samples were temporarily stored in a cooler with ice and later transferred to a freezer. All birds were released within 10-20 minutes of capture.

In 2006-2007 we conducted intensive nest searches and followed the nestlings to fledging. Once the eggs hatched we placed two nets in a V formation around the nest to capture the female to collect blood and feather samples. When nestlings reached 5-7 days old, we collected a small blood sample from each one. We collected all unhatched eggs (eggs that stayed in the nest well after the other eggs hatched or after the eggs remained in the nest well beyond the hatch day) and analyzed them for mercury. We opportunistically collected sparrow eggs from nests flooded during the high tide floods. All blood and egg samples were analyzed for total Hg at Texas A&M University, Trace Element Research Lab. Since previous work has documented that 95% of the total Hg is methylmercury (MeHg) in songbird blood (Rimmer et al. 2005), we determined that MeHg analysis was unnecessary. All blood Hg concentrations are expressed in parts per million (ppm or µg/g) wet weight (ww). All egg Hg concentrations are expressed as µg/g wet weight.

3.3 Statistical analyses

All statistical analyses were conducted using JMP 4.0 software with alpha = 0.05. We used one-way Analysis of Variance (ANOVA) and Tukey-Kramer HSD pairwise comparisons tests to determine significant differences among sites and between species. All means are reported as arithmetic means unless otherwise stated. When conditions of normal distribution of data were not met and/or variances were unequal, a non-parametric Welch ANOVA and Wilcoxon/Kruskal-Wallis Tests were used.

4.0 Results and Discussion

Results from 2004-2006 are presented in Lane and Evers (2006, 2007) and briefly summarized below.

4.1 Summary of 2004 Results

The lowest mean whole blood Hg levels were detected in sparrows from Connecticut sites and the highest were from Massachusetts sites (Table 1).

Table 1. Mean whole blood Hg concentrations in adult Saltmarsh Sharp-tailed Sparrows sampled across New England, 2004. (Sites arranged in increasing Hg concentration).

State	Site	Mean Hg (µg/g , ww)	SD	Hg range (µg/g , ww)	N
CT	Hammock River	0.23	0.06	0.18-0.24	6
ME	Rachel Carson NWR - Spurwink Marsh	0.45	0.10	0.26-0.60	10
ME	Scarborough Marsh SWMA	0.47	0.16	0.23-0.82	15
ME	Rachel Carson NWR - Goosefare Brook	0.50	0.12	0.32-0.75	13
CT	Stewart B. McKinney NWR	0.54	0.11	0.39-0.73	15
ME	Rachel Carson NWR - Granite Point	0.54	0.11	0.46-0.66	3
ME	Rachel Carson NWR - Furbish Marsh	0.56	0.09	0.33-0.69	14
RI	Ninigret NWR – Sachuest Marsh	0.72	0.11	0.54-0.87	9
ME	Rachel Carson NWR - Little River	0.74	0.08	0.64-0.84	7
RI	Ninigret NWR - Chafee	1.08	0.22	0.86-1.36	6
MA	Parker River NWR	1.09	0.38	0.67-1.68	10

4.2 Summary of 2005 results

Among the refuges, the lowest Hg concentrations were detected in the sparrows from Stewart B. McKinney NWR and Rachel Carson NWR. The highest concentrations were found at Parker River NWR (Table 2).

Table 2. Mean whole blood Hg concentrations in adult Saltmarsh Sharp-tailed Sparrows sampled across four NWR systems in New England and additional estuaries in Maine, 2005. (Sites arranged in increasing Hg concentration).

State	Site	Mean Hg (µg/g , ww)	SD	Hg range (µg/g , ww)	N
ME	Libby River-Scarborough	0.31	0.06	0.28-0.42	7
ME	Nonesuch River-Scarborough	0.45	0.09	0.39-0.52	2
CT	Stewart B. McKinney NWR-Salt Meadow Unit	0.61	0.14	0.44-0.96	10
ME	Rachel Carson NWR - Spurwink Marsh	0.61	0.14	0.40-0.87	13
ME	Rachel Carson NWR - Furbish Marsh	0.76	0.20	0.47-1.44	21
RI	Ninigret NWR – Chafee Marsh	0.79	0.19	0.41-1.17	15
MA	Parker River NWR	1.24	0.38	0.81-2.22	15

4.3 Summary of 2006 Results

In 2006, we sampled a total of 61 adult, eight hatch year and 56 nestling Saltmarsh Sharp-tailed Sparrows from all sites combined (Table 3). In 2006, we sampled one nest at RCNWR-Spurwink Marsh. Due to the high numbers of Nelson's Sharp-tailed sparrows at that site, we focused our nest study on Furbish Marsh in Wells instead. For data analysis, we combined Spurwink and Furbish Marsh results since there was no significant difference in blood Hg levels between the two sites in Maine. A total of four sites were sampled on or near Parker River NWR. We found that sparrow blood Hg levels at Salt Pannes and Area A were significantly higher than Hg levels at sub HQ and Essex Co. Greenbelt on Plum Island and Furbish Marsh in Wells ($F=42$, $df=59$, $p<0.0001$).

Table 3. Summary of all Saltmarsh Sharp-tailed Sparrow blood-sampling efforts from Maine and Massachusetts, June-September 2006.

Site	Adult		Nestlings	Hatch-year
	F	M		
Rachel Carson NWR				
Spurwink Marsh	1		4	
Furbish Marsh	11	5	25	1
Total for Rachel Carson	*12*	*5*	*29*	*1*
Parker River NWR				
Salt Panne Study Site	13	1	27	
Sub-HQ	1	6	-	1
Area A	3	5	-	3
Essex Co. Green Belt	2	13	-	3
Total for Parker River	*19*	*25*	*27*	*7*
Total for both Sites	**31**	**30**	**56**	**8**

Table 4. Mean whole blood Hg concentrations in adult Saltmarsh Sharp-tailed Sparrows, sampled across two NWR systems in New England and one additional site in Massachusetts, 2006. (Sites arranged in increasing Hg concentration, n= number of birds).

State	Site	Mean Hg (µg/g , ww)	SD	Hg range (µg/g , ww)	n
ME	Rachel Carson NWR - Furbish Marsh	0.73	0.11	0.58-0.95	16
ME	Rachel Carson NWR - Spurwink Marsh *	0.85	-	-	1
MA	Plum Island-Essex Co. Green Belt (adjacent to the refuge)	0.88	0.15	0.62-1.17	14
MA	Parker River NWR – Sub HQ	1.38	0.14	1.18-1.62	7
MA	Parker River NWR – Area A	1.65	0.14	1.47-1.86	8
MA	Parker River NWR – Salt Pannes	1.94	0.67	1.01-3.73	14

*Spurwink results were combined with Furbish Marsh for statistical analyses.

4.4 Summary of 2007

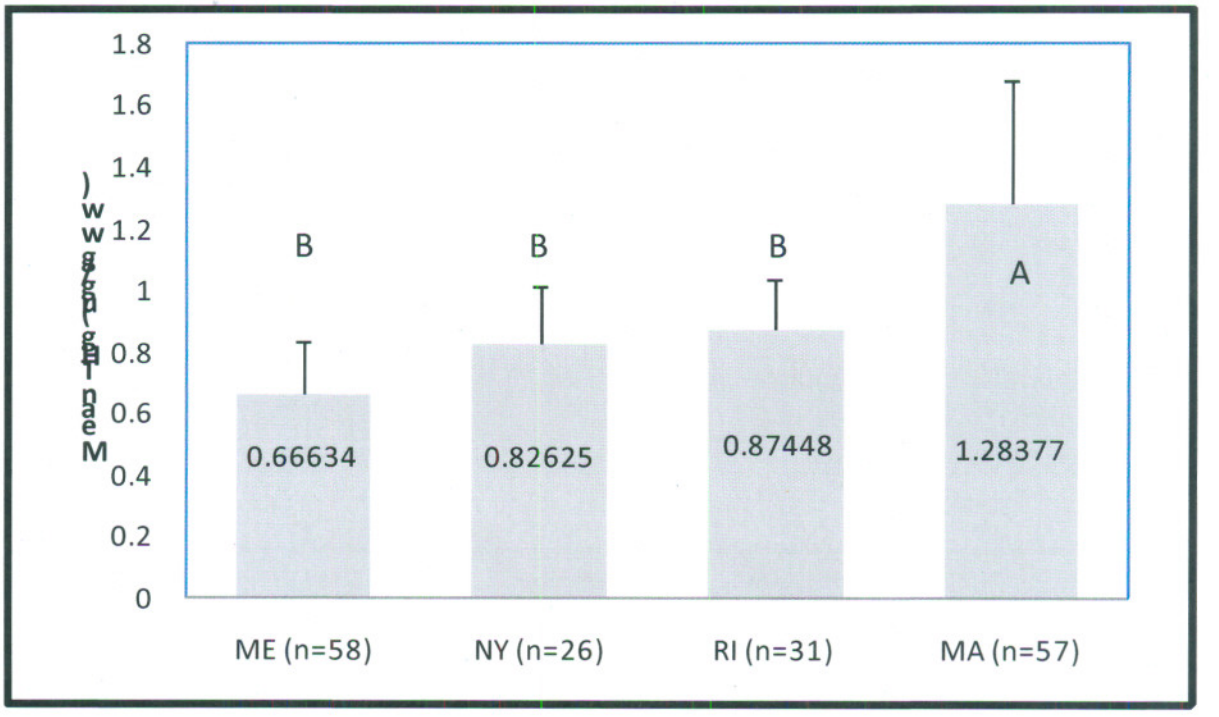
As in previous years mean blood Hg concentrations in sparrows from Parker River NWR in Massachusetts were significantly higher ($p<0.001$) than from the refuges in Maine, Rhode Island and New York (Table 5, Figure 1).

Table **5**. Mean whole blood Hg concentrations in adult Saltmarsh Sharp-tailed Sparrows, sampled across four NWR systems in New England and one additional site in Massachusetts, 2007. (Sites arranged in increasing Hg concentration, n= number of birds).

State	Site	Mean Hg (µg/g , ww)	SD	Hg range (µg/g , ww)	n
ME	Scarborough Marsh	0.53	0.25	0.23-1.12	13
ME	Rachel Carson NWR - Furbish Across road	0.65	0.09	0.56-0.78	9
ME	Rachel Carson NWR-Furbish Middle	0.71	0.12	0.54-0.99	14
ME	Rachel Carson NWR-Furbish East	0.73	0.13	0.53-1.02	22
NY	Wertheim MWR	0.83	0.19	0.52-1.23	26
RI	John Chafee NWRC-Middlebridge	0.77	0.16	0.62-1.04	6
RI	John Chafee NWRC-Stone Wall	0.84	0.20	0.51-1.23	12
RI	John Chafee NWRC-Pettaquamscutt Cove	0.95	0.10	0.75-1.09	13
MA	Parker River NWR – Area B	1.15	0.3	0.65-1.40	5
MA	Parker River NWR – Lot 2	1.18	0.40	0.58-2.20	13
MA	Parker River NWR – Salt Pannes	1.32	0.42	0.52-2.20	36
MA	William Forward WMA	1.53	0.21	1.39-1.77	3

We found blood Hg concentrations in sparrows from Rachel Carson NWR to be lower than from all other sites, followed by Wertheim, Chafee and Parker River NWRs (Figure 1).

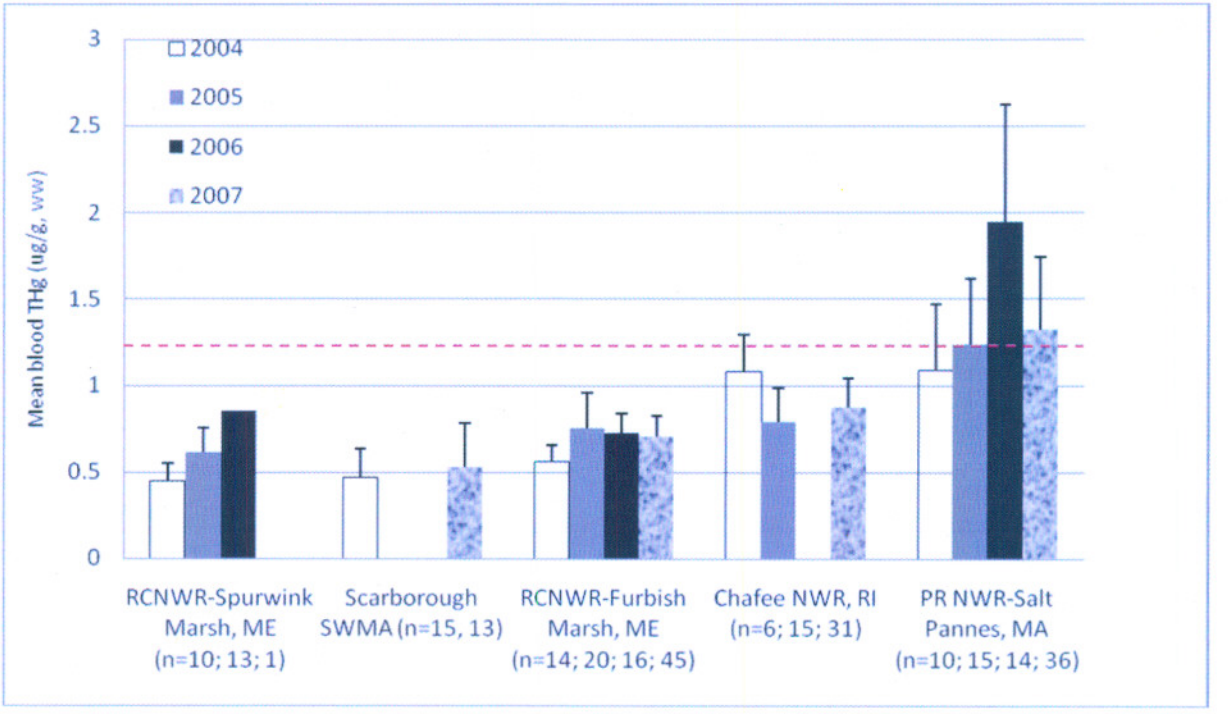
Figure 1. Mean blood THg concentrations in adult Saltmarsh Sharp-tailed Sparrows, 2007, ME=Rachel Carson NWR and Scarborough SWMA; NY=Wertheim NWR, RI=Ninigret NWRC and MA=Parker River NWR.



4.5 Inter-annual variation

We found a general increasing trend in whole blood Hg concentrations between 2004-2006 within a site with the exception of Chafee Marsh in Rhode Island (Figure 2). Sparrows from Chafee Marsh had significantly lower Hg levels in 2005 than in 2004 ($t=3.1$, $df=20$, $p<0.007$). This site was not sampled in 2006 but was sampled in 2007. Sparrows from Spurwink Marsh ($F=7.9$, $df=23$, $p<0.003$) and from Furbish Marsh ($F=7.1$, $df=49$, $p<0.002$) in Maine had significantly higher Hg levels in 2005 and 2006 than in 2004. Mean sparrow blood Hg levels at Parker River were higher (not significantly) in 2005 than in 2004 ($p=0.3$), but in 2006, they were significantly higher than in 2004 and in 2005 ($F=10.6$, $df=38$, $p<0.0002$) (Figure 2). In 2007 blood Hg concentrations were similar or slightly higher than in previous year, with the exception of Parker River (Figure 2). It appears that sparrow blood Hg levels vary on an annual basis reflecting Hg availability in salt marshes. There might be several explanations for the variable Hg levels. Mercury might be increasing in the estuarine environment on an annual basis perhaps from atmospheric and point sources. Secondly, there might be storm events and other processes that occur in the summer that influence Hg methylation processes in the salt marsh.

Figure 2. Mean whole blood Hg concentrations in Saltmarsh Sharp-tailed Sparrows sampled on consecutive years in New England (dashed line indicates adverse effect level of 1.18 µg/g Hg in adult songbird blood, D. Evers, unpublished data).



Because of annual variation in mean blood Hg levels within a site, we did not combine data from multiple years and used data from 2006 only to compare sparrow blood Hg levels among sites. Blood Hg levels were not significantly different between female and male birds therefore we combined the data from both sexes for statistical analyses.

4.6 Female vs. nestling blood Hg 2006

We observed a positive and significant correlation between female blood and average nestling blood (Figure 3), $p<0.0001$. We used a non-parametric test, the Spearman Rho; and found a statistically significant correlation between female and nestling blood ($r=0.91$, $p<0.0001$). It appears the nestling blood is an order of magnitude lower than the adult female blood Hg levels (Figure 4). As nestlings grow, they depurate much of their Hg load into their feathers (Spalding et al. 2000) thereby decreasing their body burden of Hg.

Figure 3. Relationship between female Saltmarsh Sharp-tailed Sparrow and her offspring blood Hg levels in Maine and Massachusetts study sites, 2006.

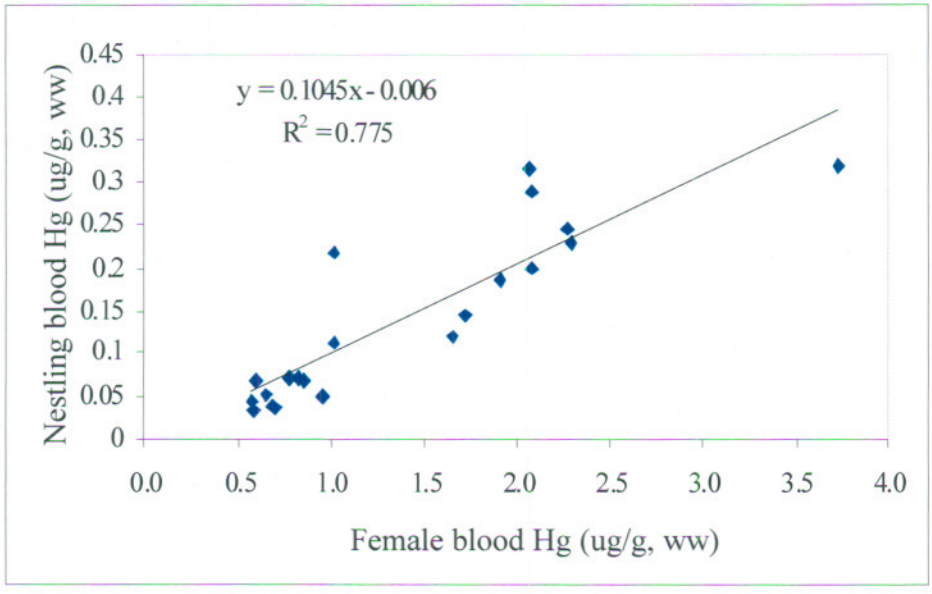
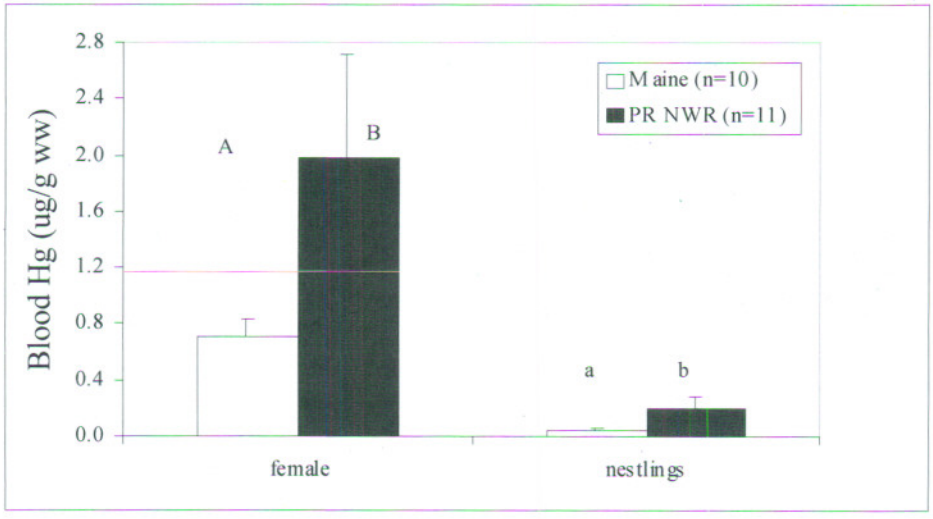


Figure 4. Mean whole blood Hg levels in nesting female Saltmarsh Sharp-tailed Sparrows and their offspring in the Rachel Carson NWR (reference site) in Maine and the Parker River NWR in Massachusetts, 2006 (red line indicates a potential adverse effect level of 1.18 µg/g Hg in adult songbird blood; means with different letters were significantly different, n=number of nests).



On all refuges, we sampled fledged (hatch year) sparrows caught incidentally with the adults. Hatch year blood Hg levels in 2006 ranged from 0.47 μg/g in sparrows from the RCNWR-Furbish Marsh site to 2.3 μg/g at the Parker River-Area A site.

One potential reason for high Hg levels in sparrows from the Parker River NWR is because sampling efforts were concentrated in the salt marsh situated between the Merrimack and Parker Rivers (Appendix 4). Both rivers potentially carry Hg-polluted waters from interior watersheds to the coast. The Merrimack River, flowing through New Hampshire and Massachusetts, is well known as a historical source of Hg. Mercury that has been deposited in the sediment is likely still present and may continue to methylate and enter the aquatic food chain. In addition, the Parker River NWR is located in the northeastern region of the state, a well-known biological hotspot for Hg (Evers et al. 2007).

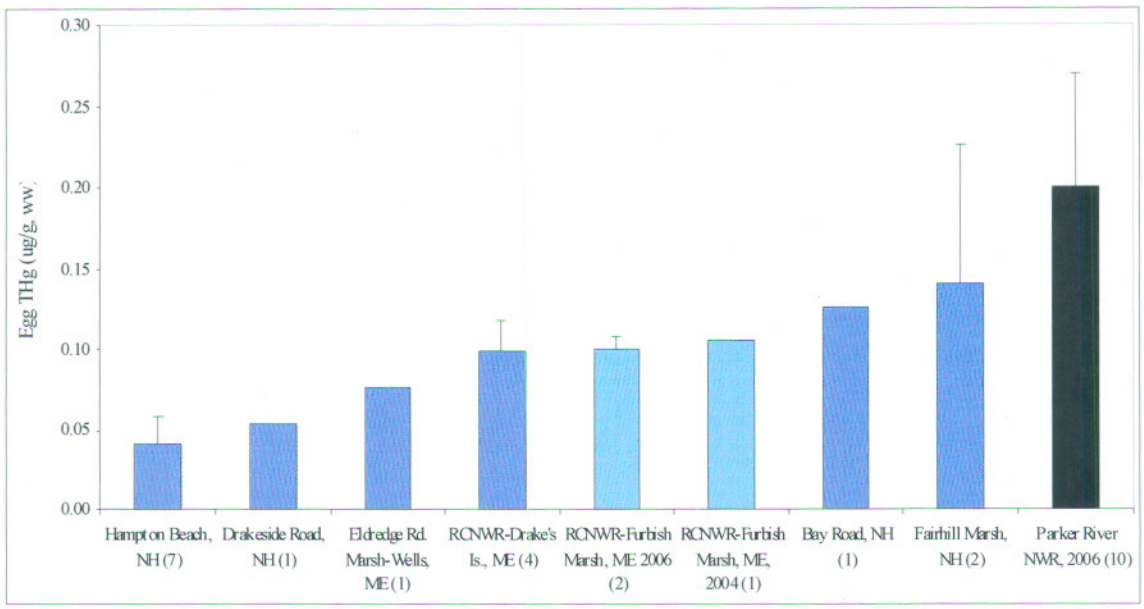
It is most likely that the sparrows' diet influences their body burden of Hg. George et al. (2001) found that amphipods contained higher concentrations of Hg than other organisms found higher on the food chain, such as odonates and crayfish. Contaminants collect in "modern mud" (i.e., mud buildup over the last century), thus bottom-dwelling animals that dwell in mud habitats tend to accumulate contaminants.

Saltmarsh Sparrows forage entirely in the salt marsh (Greenlaw and Rising 1994, Merriam 1979). On Long Island, New York, Merriam (1979) found that the two most common insect orders in Saltmarsh Sharp-tailed Sparrow's diet were Diptera, ranging between 13 % in June to 47% of all items in July (predominantly adults and larvae of Stratiomyidae) and Hemiptera, ranging between 4% in June to 37% in July (nymphs and adults of Miridae). Other invertebrates found in the diet of nestling Sharp-tailed Sparrows were Homoptera (Deplhacidae) ranging between 0 and 34%, the Araneida (spiders), ranging between 3% in July to 56% in June, and amphipods ranging between 5% in the first half of July to 15 % in the second half of the month (Merriam 1979).

4.7 Summary of Egg Contaminants- Mercury (2004-2006)

Twenty-two failed Saltmarsh Sparrow eggs from the Parker River NWR and 17 eggs from seven other estuaries were opportunistically collected and tested for Hg in 2004-2006. We also collected failed Saltmarsh Sharp-tailed Sparrows eggs from various sites in Maine and New Hampshire. In general, Hg levels in the eggs were low (Figure 5). Based on a Hg dosing study conducted on Tree Swallow eggs (Heinz et al. 2008 *In Press*) the lethal lowest observed adverse effect level (LOAEL) in swallow eggs is 0.8 μg/g (ww) and sublethal effects are estimated to occur at 0.4 μg/g (ww). Sublethal effects were also detected at concentrations as low as 0.1 μg/g, but further experiments are necessary to identify the sublethal concentration more accurately. All eggs tested in this study were well below 0.4 μg/g and the lethal LOAEL (Appendix 7).

Figure 5. Mean (+/-SD) egg mercury concentrations from flooded out Saltmarsh Sharp-tailed Sparrow nests collected in Maine, Massachusetts and New Hampshire in 2004 and 2006, (n = egg sample size).



4.8 Organochlorines 2007

We collected 19 failed to hatch eggs from 10 nests and analyzed a total of 16 samples (eggs or egg composites) (Table 6). Concentrations of most organochlorine compounds were low or below instrument detection limit (Appendix VI). Polychlorinated Biphenyls (PCBs) were detected in the highest concentrations, however their concentrations were below the levels reported to have detrimental effects. Kubiak et al. (1989) found Forster's terns nesting on Lake Michigan experienced reproductive failure associated with egg PCB concentrations ranging from 6.2 to 26.0 µg/g (ww). Samples were analyzed at the Mississippi State Chemical Lab in Mississippi State, MS.

It appears that blood is a more appropriate tissue to use when assessing Hg exposure, and eggs are a more suitable indicator tissue for the organochlorine compounds (Lane et al. 2006). Polychlorinated Biphenyls and organochlorine pesticides are lipophilic in nature therefore bioaccumulate more readily in fatty tissues and eggs.

Table 6. Detectable organochlorine concentrations (µg/g, ww) in failed Saltmarsh Sharp-tailed Sparrow eggs collected from Parker River NWR in 2007.

Nest #	#1 ave	#6	#13	#17	# 20 ave	#23	#24	#27 ave	#28	#34
# eggs	3	2	2	1	3	1	1	3	1	2
Composite	N*	Y	Y	N	N*	N	N	N*	N	Y
% Lipid	4.5	5.6	5.3	6.5	4.5	5.5	4.1	4.1	3.4	5.0
% Moisture	83.0	84.1	82.4	80.0	85.9	79.2	84.2	80.8	84.2	79.8
beta BHC	0.008	0.005	0.004	0.005	0.004		0.006	0.005	0.004	0.005
dieldrin	0.008		0.005	0.010			0.010		0.012	0.009
gamma BHC			0.003				0.005		0.008	
gamma chlordane	0.004		0.010	0.007						
heptachlor epoxide	0.004									
mirex	0.028									
oxychlordane	0.009		0.010	0.015	0.011		0.007		0.006	0.007
p,p'-DDE	0.193	0.100	0.120	0.300	0.197	0.044	0.082	0.066	0.071	0.080
PCB-TOTAL	0.493	0.470	0.380	0.710	0.430	0.330	0.340	0.181	0.180	0.280

* eggs were analyzed individually then averaged per nest

4.9 Reproductive Success

A total of 16 nests (13 with eggs and 3 with chicks) were monitored on Rachel Carson NWR in Maine in 2006. Out of 13 nests with eggs, 10 nests hatched (77% hatch rate/nest with eggs) and 8 nests fledged a total of 27 chicks. The three nests initially found with hatchlings fledged an additional 7 chicks, which increased the total number of fledged young to 34 (69% fledge rate/nest). In 2006 we monitored 27 nests containing eggs at Parker River NWR in Massachusetts, 12 of which hatched (44.4 % hatch rate/nest) (32 chicks) and eight of them fledged (29.6 % fledge rate) a total of 22 chicks. Sixteen failed eggs were collected from 6 nests. At Rachel Carson, we found a total of 21 nests including numerous empty nest cups. At Parker River, we found 53 nests including empty cups. At Rachel Carson, 12.5% (2 of 16) of nests failed due to flooding. At Parker River, at least 26 % (7/27) of nests monitored with eggs or chicks failed due to tidal flooding. An additional five nests were found with eggs outside of the cup, thus we assume they were flooded out as well. We evaluated several nesting variables to estimate reproductive success and found that all three were significantly lower at Parker River than Rachel Carson (Table 7).

Table 7. Estimates of reproductive success measured per nesting female at two sites, the Rachel Carson NWR and the Parker River NWR in 2006 (n=number of nests). *Mayfield estimates should be viewed with caution since nests were not visited on a regular schedule.

Reproductive success measures	Rachel Carson NWR	Parker River NWR	t-value, df, p
Per nesting female			
Mean # eggs at hatch time +/-SE (n)	3.8 +/- 0.30 (13)	2.3 +/-0.31 (27)	t=-2.9, df=38, p<0.006
Mean # eggs hatched +/- SE (n)	2.6 +/-0.38 (16)	1.2 +/-0.30 (27)	t=-2.9, df=41, p<0.006
Mean # chicks fledged +/-SE (n)	2.1 +/-0.39 (16)	0.89 +/-0.30 (27)	t=-2.5, df=41, p<0.02
Mayfield estimates per site*			
Probability nest survives incubation	0.75	0.46	
Probability nest survives nestling	0.52	0.78	
Probability egg survives incubation	0.97	0.83	
Hatch rate	0.85	0.53	
Probability egg will produce fledging	0.32	0.16	

In 2007 funding was not available to conduct reproductive studies in Maine. We found 10 nests with eggs at Rachel Carson NWR but most of the nests were not followed through the nesting cycle and consequently the outcome is unknown. At Parker River productivity was higher while blood Hg in nesting females was on average lower in 2007 than in 2006 (Tables 7 and 8). The probably of an individual egg producing a fledging in 2007 (0.30) was almost double the probability in 2006 (0.16).

Table 8. Summary of Saltmarsh Sharp-tailed Sparrow nesting cycles and Mayfield nest success estimates at Parker River National Wildlife Refuge, 2007.

	Cycle 1	Cycle 2	Cycle 3	Cycle 4
Nests Found	14	23	15	1
Nests with Eggs	8 (23 eggs)	14 (46 eggs)	9 (26 eggs)	1 (3 eggs)
Nests Hatched	0	6 (20 chicks)	6 (20 chicks)	1 (3 chicks)
Nests Fledged	0	5 (15 fledglings)	5 (16 chicks)	1 (3 chicks)
Hatching Success (%)	0.00	43.48	74.07	100
Fledgling Success (%)	0.00	75.00	80	100
Productivty	0.00	1.07	1.78	3
Percent Predated	12.50	21.43	10	0
Percent Flooded	87.50	14.29	0	0
Percent Abandoned	0.00	28.57	0	0
Mean Nest Height (n)	8.9 (n=10)	11.0 (n=20)	13.2 (n=12)	20 (n=1)

Mayfield-all cycles	
Probability nest survives incubation	0.43
Probability nest survives nestlng	0.92
Probability egg survives incubation	0.59
Probability chick survives	0.87
Probability nest survives	0.40
Hatch rate	0.76
Probability egg will produce fledgling	0.30

5.0 Conclusions

Based on the results of four years of Saltmarsh Sharp-tailed Sparrow sampling, we conclude that:

1. Bird blood is an appropriate tissue to use to evaluate the Hg exposure to insectivorous birds in salt marshes.
2. Saltmarsh Sharp-tailed Sparrows have elevated blood Hg levels across all sampled sites and are at potential risk of impaired reproductive success at the Parker River NWR in Massachusetts where high number of individuals has blood Hg concentrations exceeding 1.18 µg/g, the level at which adverse effects are expected to occur in insectivorous birds.
3. Many individual birds from most sampled sites have whole blood Hg concentrations approaching 1.18 µg/g Hg.
4. Reproductive success parameters **appear** to be lower at Parker River NWR than Rachel Carson NWR based on the 2006 season and suggest that elevated mercury levels in sparrows may be impacting nesting success although additional data is needed to confirm this conclusion.

5. There appears to be an increasing trend in sparrow blood mercury levels sampled in consecutive years.
6. Mercury levels in sparrow blood sampled in late July-August appear higher than in birds captured in June-early July.
7. Sparrow eggs are not the best indicator tissue to use in assessing Hg.
8. The organochlorine exposure in the salt marshes based on eggs appears to be low.

6.0 Management Recommendations

As a "bird of conservation concern", it is important that biologists investigate all of the variables that influence the reproductive success of Saltmarsh Sharp-tailed Sparrows. In addition to examining the role of contaminants such as mercury have on sparrow reproduction, other factors such as genetics, population biology and climate change need to be investigated in order to formulate management strategies that will ensure the viability of saltmarsh sparrow populations in the Northeast. We have documented that mercury levels at Parker River NWR are potentially high enough to negatively impact sparrow reproduction, so further investigation into Hg sources is warranted. Given this fact, it is important that future research give equal weight to the other factors mentioned above in research funding decisions. Participation in larger, multiple-partner, cooperative research efforts should be continued in order to achieve this goal and leverage project funds. Our specific management recommendations are as follows:

1. Investigate potential point sources of mercury within the Parker River/Plum Island Sound watershed by documenting diet composition, Hg levels in prey, and isotope analysis in addition to collecting blood samples from additional sites within the watershed. Once potential point sources have been identified, USFWS personnel can work with the USEPA-Region 1 and Massachusetts Department of Environmental Protection to enforce existing water quality regulations to eliminate these point sources.

2. Continue to conduct a vigorous nest monitoring program on refuges with high and low mercury levels to confirm the impact of mercury on sparrow productivity.

3. Continue participation in the cooperative research effort on saltmarsh sparrows in the Northeast, emphasizing factors such as genetics to better understand all of the stressors to sparrow populations.

7.0 Acknowledgments

Funding for this project was provided by US Fish and Wildlife Service, Maine Department of Inland Fisheries and Wildlife and Maine Department of Environmental Protection. We are grateful to Kate O'Brien and the staff of Rachel Carson NWR; Nancy Pau, Graham Taylor and other Parker River NWR staff for their logistical support and help in the field. We thank Rachel Carson and Parker River interns for nest searches, productivity monitoring, and collecting failed eggs. We thank Tom Hodgman and Greg Shriver for their expert technical advice. Many thanks to Andrew Major and Steve Mierzykowski for help in the field and with the project. We thank the following individuals for their help and support: Dr. Kim Babbitt, Dr. Adrienne Kovach, Jen Walsh, Megan McElroy, and the field crew from UNH for collecting failed eggs; Sara Williams at Steward B. McKinney NWR and Suzanne Paton at Ninigret NWR; numerous interns from all the refuges for their enthusiastic assistance in the field, Carina

Gjerdrum and Chris Elphick from UCONN for providing sparrow blood from Hammock River site in CT; Alex Chmielewski and the staff at Long Island NWRC for assistance with sampling in New York, and all the volunteers who came out to help catch birds, especially Frank Dehler for his many hours of assistance and valuable help. Many thanks to Dr. Bob Taylor and his team at Texas A&M University for providing lab analysis. BRI biologists Theresa Daigle, Melissa Duron and Wing Goodale were a tremendous help in the field and in the office.

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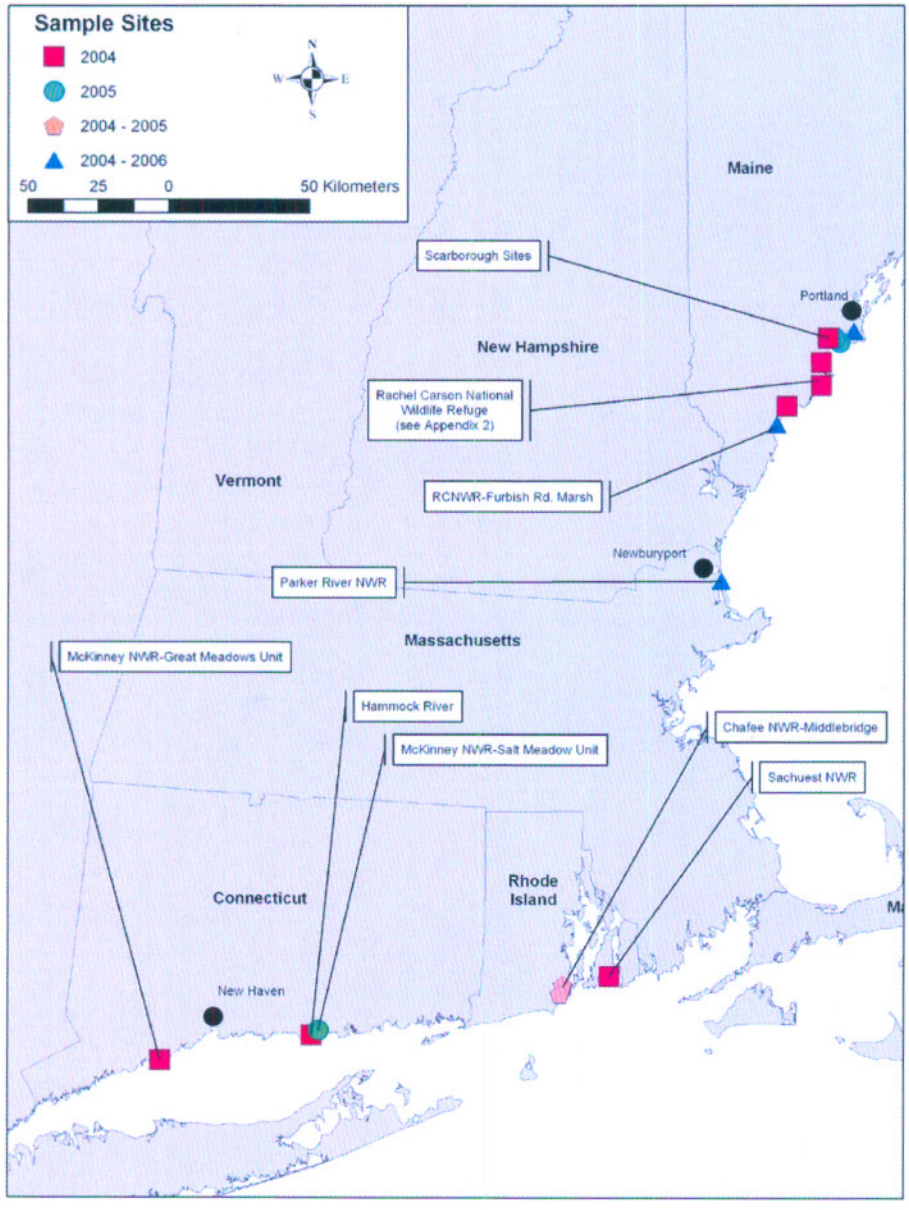
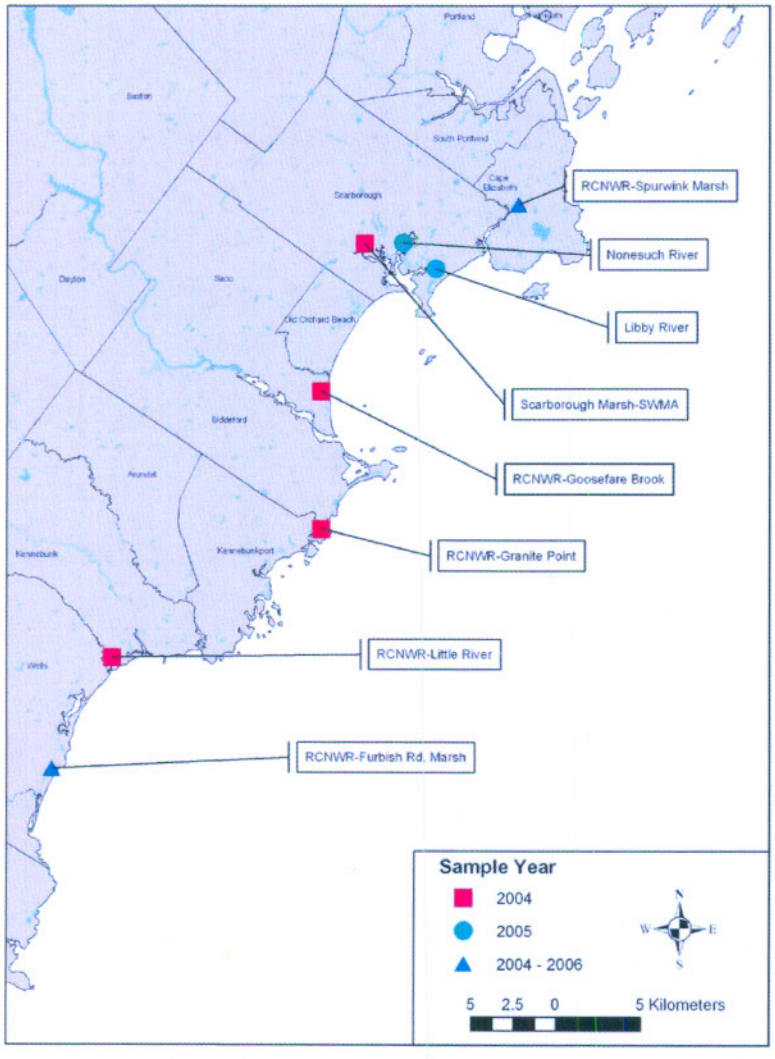
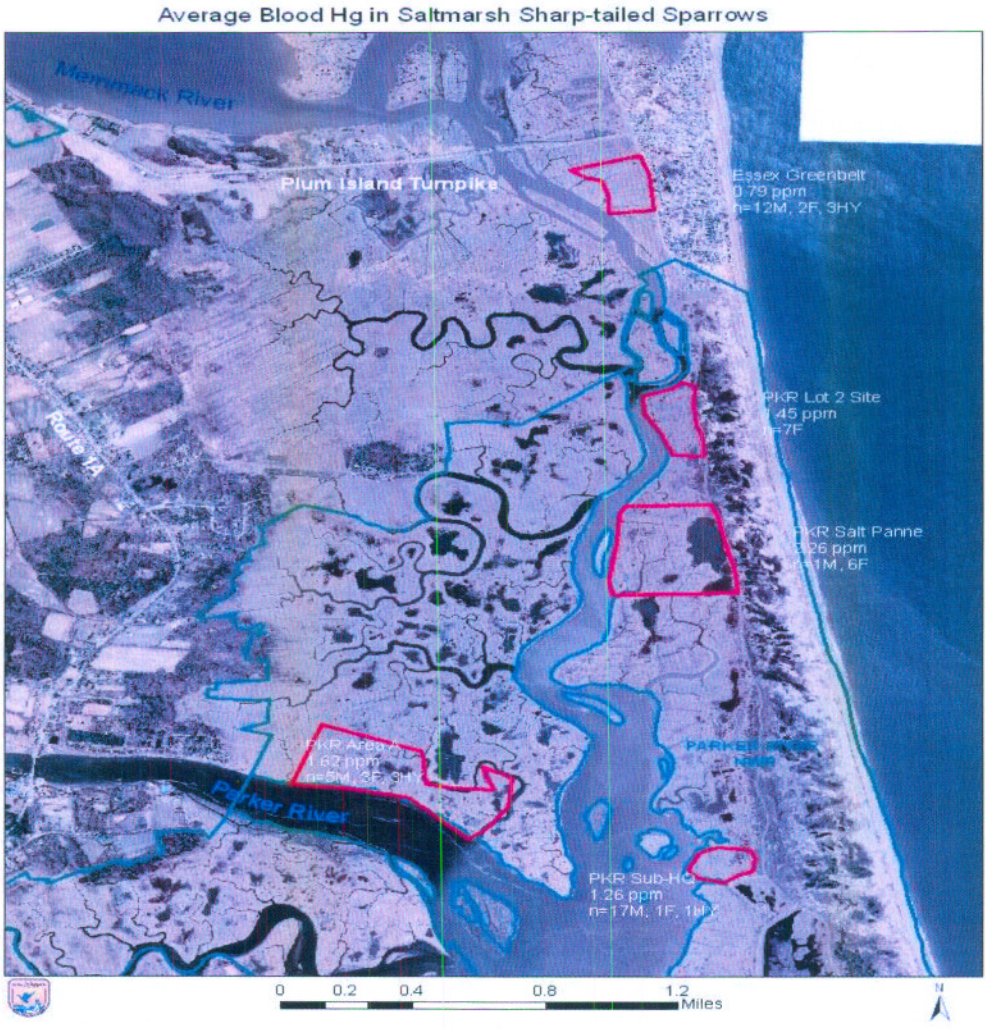
Appendix I. Saltmarsh Sharp-tailed Sparrow sampling locations in New England, 2004- 2006. Rachel Carson NWR in Wells (Furbish Marsh) and Parker River NWR in Newburyport were the only study sites sampled in 2006.



Appendix II. Saltmarsh Sharp-tailed Sparrow sampling locations in the Rachel Carson NWR and other locations in Maine, 2004-2006. Only Furbish Marsh and Scarborough Marsh SWMA were sampled in 2007.

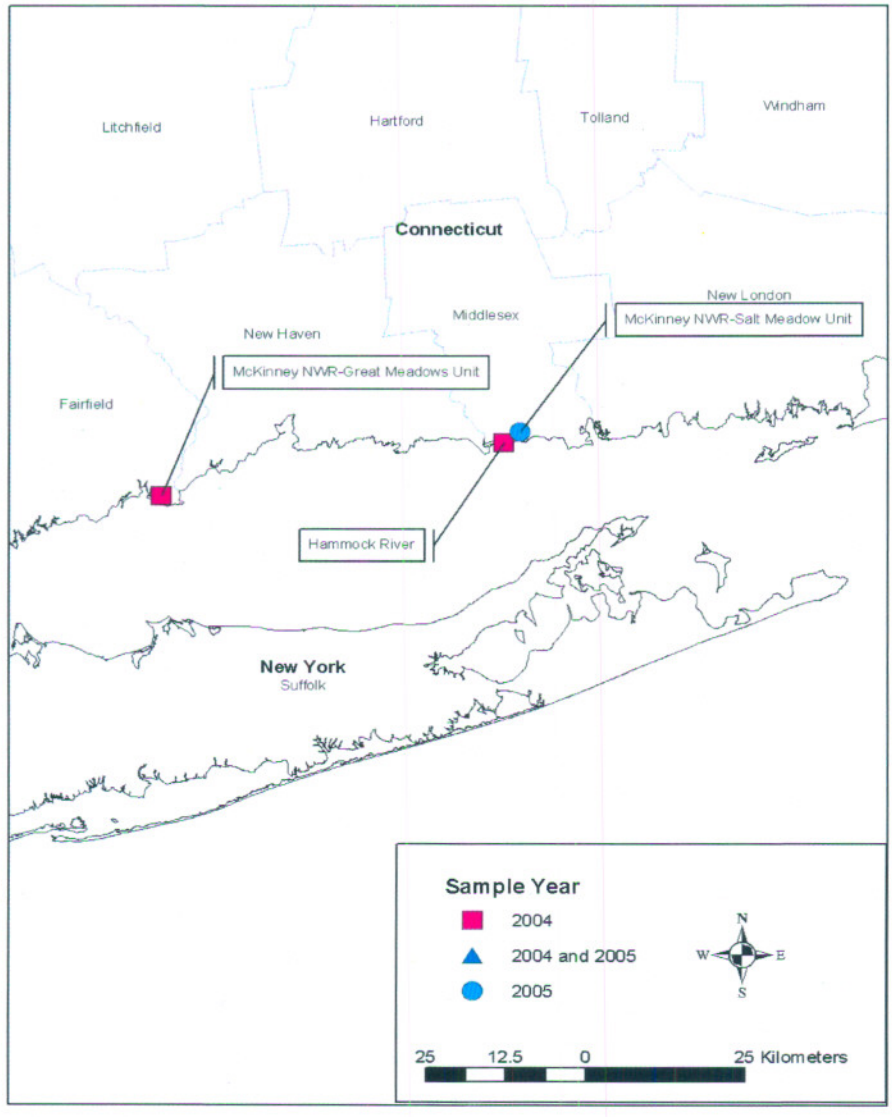


Appendix III. Saltmarsh Sharp-tailed Sparrow sampling locations in Parker River NWR, Massachusetts, 2004 –2006, (M=male, F=female, HY=hatch year birds. Lot 2 and Salt Pannes study sites were combined into one site (Salt Pannes) for the purposes of statistical analysis. [1]

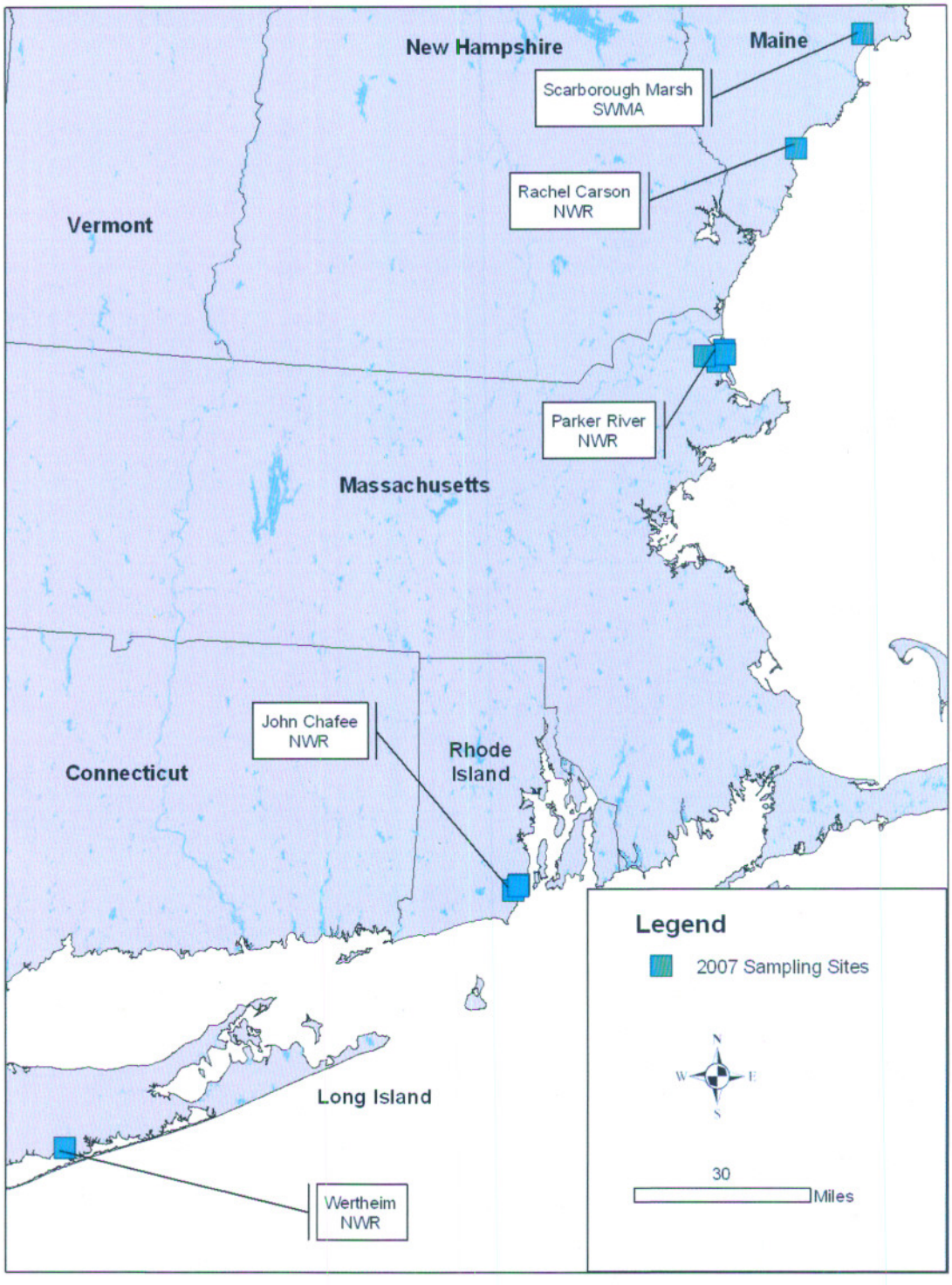


[1] Map generated by Nancy Pau, USFWS, Parker River NWR

Appendix IV. Saltmarsh Sharp-tailed Sparrow sampling locations in Connecticut, 2004 and 2005.



Appendix V. Saltmarsh Sharp-tailed Sparrow sampling locations, 2007.



Appendix VI. Organochlorine concentrations (ppm, ww) in failed Saltmarsh Sharp-tailed eggs collected in 2007 at Parker River NWR.

	Nest #	#1	#1	#1	#13	#17	#20	#20	#20	#23	#24
	Egg #	1	2	3	1 & 2	1	1	2	3	1	1
	Sample Date	6/25/07	6/25/07	6/25/07	6/26/07	7/10/07	6/26/07	6/26/07	6/26/07	7/9/07	7/13/07
	Composite Sample	N	N	N	Y	N	N	N	N	N	N
% Lipid	Percent Result	4.88	5.78	2.72	5.28	6.54	4.12	5.22	4.24	5.52	4.14
% Moisture	Percent Result	81.1	82.8	85.2	82.4	80	87.6	84	86.2	79.2	84.2
units		ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g
alpha BHC	Wet W?DL (0.002)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
alpha chlordane	Wet W?DL (0.002)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
beta BHC	Wet Weight Result	0.005	0.014	0.005	0.004	0.005	0.004	0.002	0.003	0.002	0.006
beta BHC	ww det limit	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
cis-nonachlor	Wet W?DL (0.002)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
delta BHC	Wet W?DL (0.002)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
dieldrin	Wet Weight Result	0.009	0.008	0.008	0.005	0.01	0.002	0.002	0.002	0.002	0.01
dieldrin	ww det limit	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
endrin	Wet W?DL (0.002)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
gamma BHC	Wet Weight Result	0.002	0.002	0.002	0.003	0.002	0.002	0.002	0.002	0.002	0.005
gamma chlordane	Wet Weight Result	0.004	0.002	0.002	0.01	0.007	0.002	0.002	0.002	0.002	0.002
gamma chlordane	ww det limit	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
HCB	Wet W?DL (0.002)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
heptachlor epoxide	Wet Weight Result	0.002	0.004	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
heptachlor epoxide	ww det limit	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
mirex	Wet Weight Result	0.038	0.026	0.02	0.002	0.002	0.002	0.002	0.002	0.002	0.002
mirex	ww det limit	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
o,p'-DDD	Wet W?DL (0.002)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
o,p'-DDE	Wet W?DL (0.002)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
o,p'-DDT	Wet W?DL (0.002)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
oxychlordane	Wet W?DL (0.002)	0.002	0.009	0.002	0.01	0.015	0.002	0.011	0.002	0.002	0.007
oxychlordane	ww det limit	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
p,p'-DDD	Wet W?DL (0.002)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
p,p'-DDE	Wet Weight Result	0.22	0.2	0.16	0.12	0.3	0.18	0.24	0.17	0.044	0.082
p,p'-DDE	ww det limit	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
p,p'-DDT	Wet W?DL (0.002)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
PCB-TOTAL	Wet Weight Result	0.75	0.39	0.34	0.38	0.71	0.32	0.56	0.41	0.33	0.34
PCB-TOTAL	ww det limit	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
toxaphene	Wet W?MDL(0.05)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
trans-nonachlor	Wet W?DL (0.002)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002

Cont.

	Nest #	#27	#27	#27	#28	#34	#6
	Egg #	1	2	3 & 4	1	1 & 2	1 & 2
	Sample Date	7/13/07	7/13/07	7/13/07	6/25/07	7/16/07	6/26/07
	Composite Sample	N	N	Y	N	Y	Y
% Lipid	Percent Result	4.34	4.54	3.48	3.42	5	5.6
% Moisture	Percent Result	80.6	80.7	81	84.2	79.8	84.1
units		ug/g	ug/g	ug/g	ug/g	ug/g	ug/g
alpha BHC	Wet W?DL (0.002)	0.002	0.002	0.002	0.002	0.002	0.002
alpha chlordane	Wet W?DL (0.002)	0.002	0.002	0.002	0.002	0.002	0.002
beta BHC	Wet Weight Result	0.006	0.002	0.004	0.004	0.005	0.005
beta BHC	ww det limit	0.002	0.002	0.002	0.002	0.002	0.002
cis-nonachlor	Wet W?DL (0.002)	0.002	0.002	0.002	0.002	0.002	0.002
delta BHC	Wet W?DL (0.002)	0.002	0.002	0.002	0.002	0.002	0.002
dieldrin	Wet Weight Result	0.002	0.002	0.002	0.012	0.009	0.002
dieldrin	ww det limit	0.002	0.002	0.002	0.002	0.002	0.002
endrin	Wet W?DL (0.002)	0.002	0.002	0.002	0.002	0.002	0.002
gamma BHC	Wet Weight Result	0.002	0.002	0.002	0.008	0.002	0.002
gamma chlordane	Wet W?DL (0.002)	0.002	0.002	0.002	0.002	0.002	0.002
HCB	Wet W?DL (0.002)	0.002	0.002	0.002	0.002	0.002	0.002
heptachlor epoxide	Wet W?DL (0.002)	0.002	0.002	0.002	0.002	0.002	0.002
mirex	Wet W?DL (0.002)	0.002	0.002	0.002	0.002	0.002	0.002
o,p'-DDD	Wet W?DL (0.002)	0.002	0.002	0.002	0.002	0.002	0.002
o,p'-DDE	Wet W?DL (0.002)	0.002	0.002	0.002	0.002	0.002	0.002
o,p'-DDT	Wet W?DL (0.002)	0.002	0.002	0.002	0.002	0.002	0.002
oxychlordane	Wet W?DL (0.002)	0.002	0.002	0.002	0.006	0.007	0.002
oxychlordane	ww det limit	0.002	0.002	0.002	0.002	0.002	0.002
p,p'-DDD	Wet W?DL (0.002)	0.002	0.002	0.002	0.002	0.002	0.002
p,p'-DDE	Wet Weight Result	0.072	0.067	0.058	0.071	0.08	0.1
p,p'-DDE	ww det limit	0.002	0.002	0.002	0.002	0.002	0.002
p,p'-DDT	Wet W?DL (0.002)	0.002	0.002	0.002	0.002	0.002	0.002
PCB-TOTAL	Wet Weight Result	0.21	0.183	0.15	0.18	0.28	0.47
PCB-TOTAL	ww det limit	0.01	0.01	0.01	0.01	0.01	0.01
toxaphene	Wet W?DL (0.05)	0.05	0.05	0.05	0.05	0.05	0.05
trans-nonachlor	Wet W?DL (0.002)	0.002	0.002	0.002	0.002	0.002	0.002