Methylmercury availability in New England estuaries as indicated by Saltmarsh Sharp-tailed Sparrow, 2004-2006

(BRI 2007-14)

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1.0 Abstract

As part of an ongoing investigation, we conducted a mercury (Hg) exposure survey of Saltmarsh Sharp-tailed Sparrows (*Ammodramus caudacutus*) on 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 in the same species across several New England states.

We sampled sparrow blood from several estuaries of the Rachel Carson National Wildlife Refuge (NWR) in Maine, Parker River NWR in Massachusetts, Ninigret NWR in Rhode Island, Stewart B. McKinney NWR and a nearby off-refuge site Hammock River in Connecticut, and Scarborough Marsh State Wildlife Management Area (SWMA) in Maine. Sparrow blood Hg levels from Parker River NWR and Ninigret NWR were significantly higher than the concentrations in sparrows sampled in Maine and Connecticut.

Because our results from the 2004-2005 study revealed that sparrows from the Parker River have elevated whole blood Hg levels, in 2006 we initiated a study 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 one year 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 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.

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)

Juvenile Saltmarsh Sharp-tailed Sparrow, Parker River NWR.

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). 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).

Sharp-tailed 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 Sharp-tailed 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. 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 four 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.

3.0 Methods

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 part of the Ninigret NWR complex; therefore both names are used interchangeably in this report. In 2006 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 and Spurwink Marsh (Appendix 2). The focus areas on Parker River NWR included Salt Pannes, Area A, and Sub-Headquarters as well as an area adjacent to the refuge, the Essex County Green Belt (Appendix 3).

3.2 Capture and sampling

All capture and blood sampling occurred from early June to early September 2004-2006. 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 26 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 unharmed within 10-20 minutes of capture.

In 2006 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 in songbird blood (Rimmer et al. 2005), we determined that methylmercury analysis was unnecessary. All blood Hg concentrations are expressed in parts per million (ppm or) 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 2004-2005 are presented in Lane and Evers (2006) 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	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 (Westbrook, Connecticut) 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	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, 8 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 Plum Island. We found that sparrow blood Hg levels at Salt Pannes and Area A were significantly higher than Hg levels at HQ and Essex Co. Green Belt 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 Inter-annual variation

We found a general increasing trend in whole blood Hg concentrations between 2004, 2005 and 2006 within a site with the exception of Chafee Marsh in Rhode Island (Figure 1). 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. 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 1).

There might be several explanations for the increasing 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 occurring later in the summer that influence Hg methylation processes in the salt marsh. Based on our data from Furbish Marsh where we conducted more intensive sampling, it appears that mean blood Hg levels in 2006 were similar to 2005 but both were higher than in 2004 (Figure 3).

Figure 1. Mean whole blood Hg concentrations in Saltmarsh Sharp-tailed Sparrows sampled on consecutive years in New England (red line indicates adverse effect level of 1.18 µg/g Hg in adult songbird blood, see appendix 5 for interpretation).

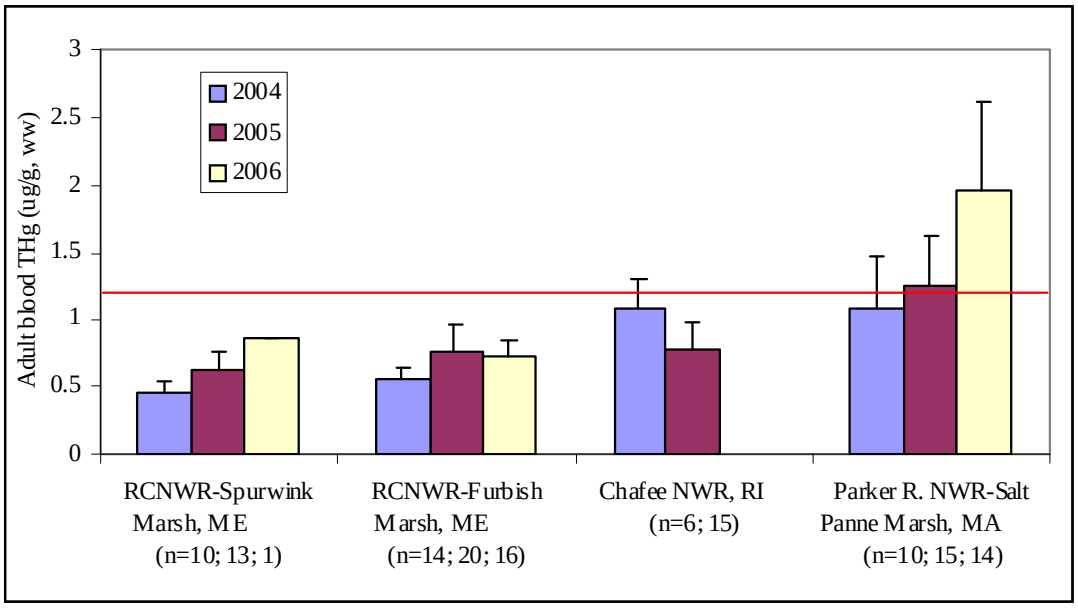
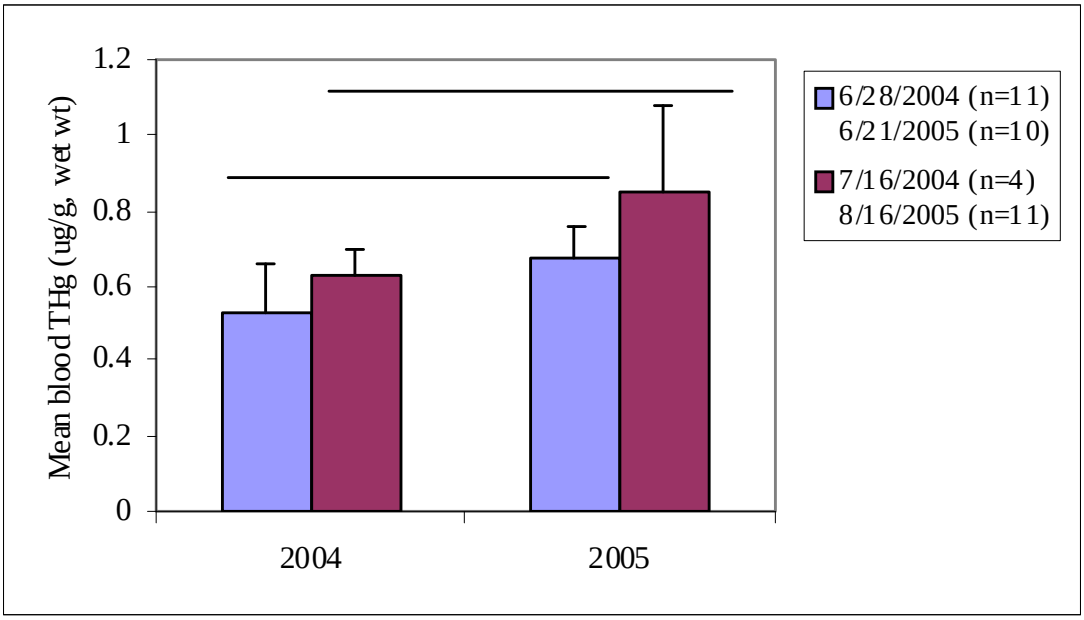


Figure 2. Mean adult whole blood Hg concentrations in Saltmarsh Sharp-tailed Sparrows sampled early in the season (June) and later (in late July-August) on Furbish Road Marsh in Wells, Maine in 2004 and 2005 (black lines indicate means were not significantly different).



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.

4.5 Female vs. nestling blood Hg

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.

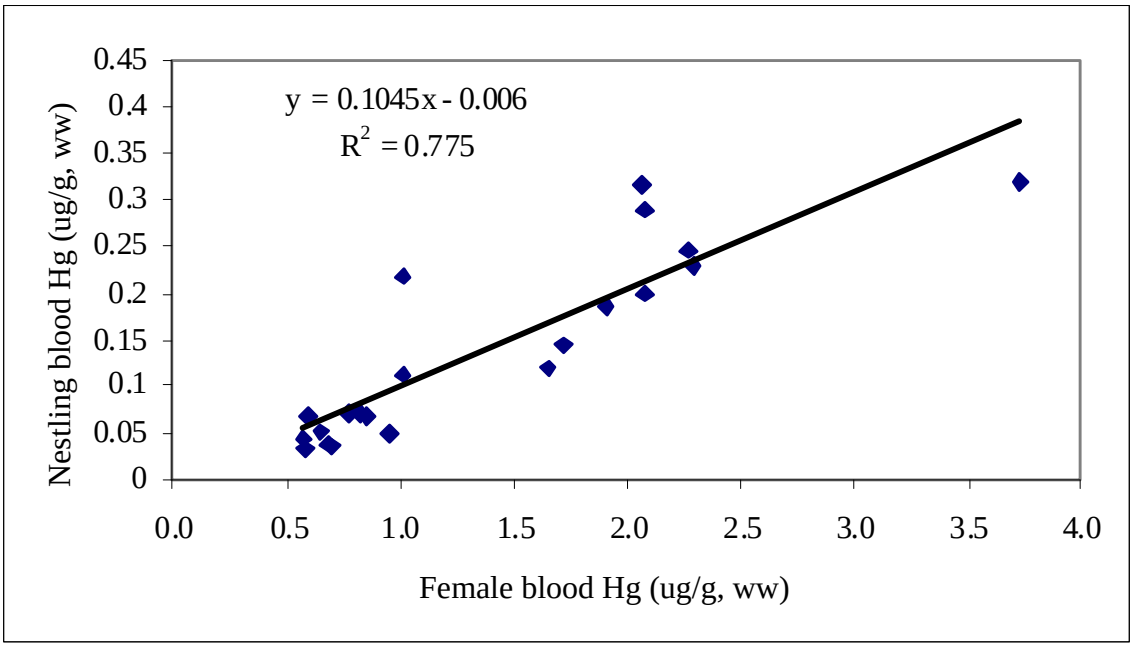
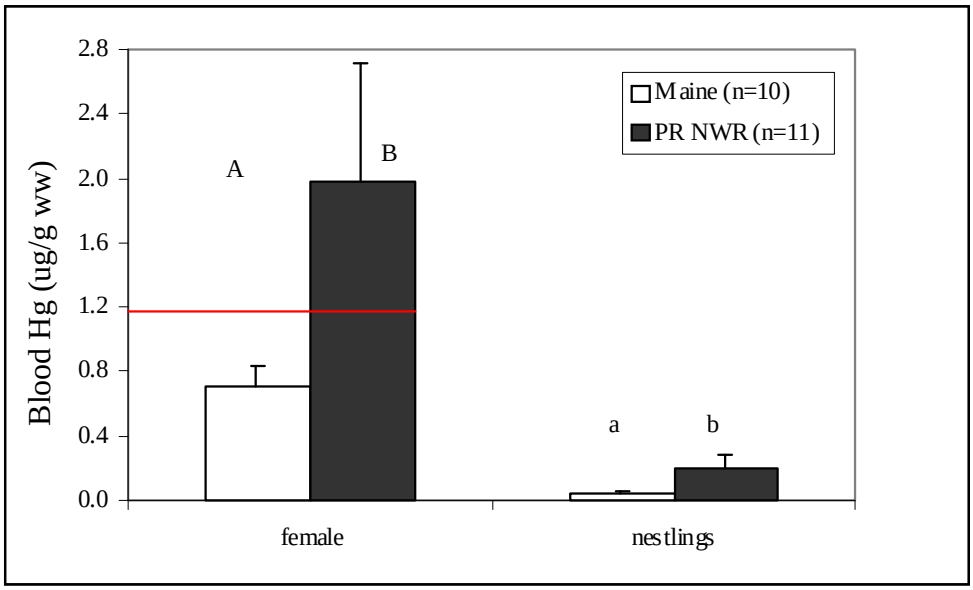


Figure 4. Mean whole blood Hg levels in nesting female Saltmarsh Sharp-tailed Sparrows and their offspring in the Rachel Carson NWR (reference site) in Maine and the Parker River NWR in Massachusetts, 2006 (red line indicates adverse effect level of 1.18 µg/g Hg in adult songbird blood; means with different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



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).

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.

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.

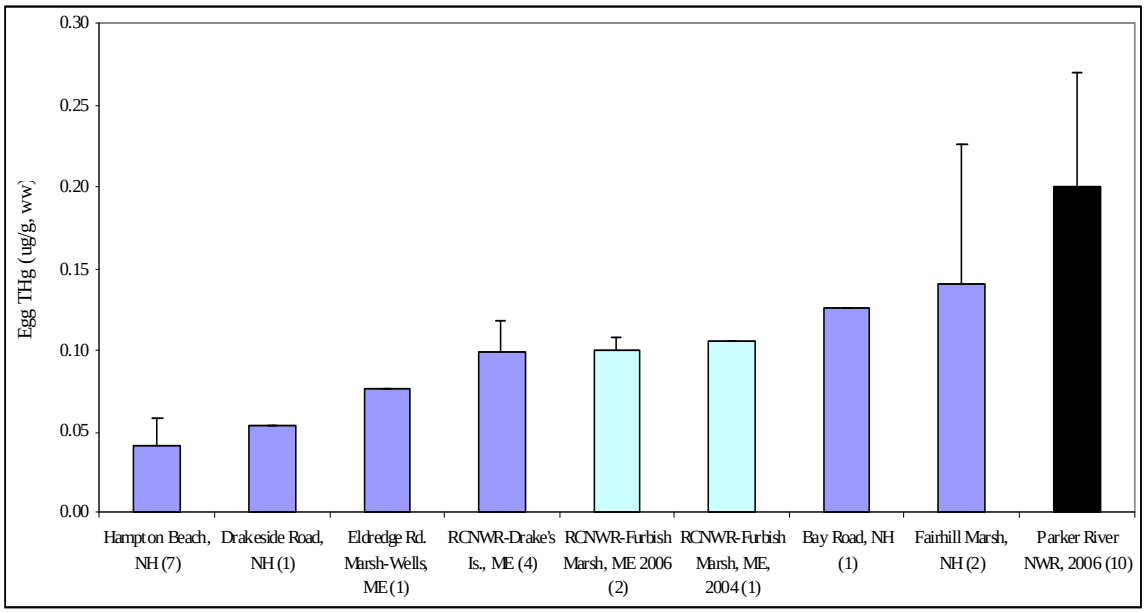
Saltmarsh Sparrows forage entirely in the salt marsh (Greenlaw and Rising 1994, Merriam 1979). On Long Island, New York, Merriam (1979) found that the two most common insect orders in Saltmarsh Sharp-tailed Sparrow's diet were Diptera, ranging between 13 % in June to 47% of all items in July (predominantly 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).

Considering the variety of prey items in the sparrow diet, it might be of benefit to test amphipods and other prey groups from the selected sparrow sites for Hg content.

4.6 Summary of Egg 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 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 pers. comm.) 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 5).

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).



4.7 Reproductive Success

A total of 16 nests (13 with eggs and 3 with chicks) were monitored on Rachel Carson NWR in Maine. 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). 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 laying 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 5).

Table 5. 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).

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	

*Mayfield estimates should be viewed with caution since nests were not visited on a regular schedule.

5.0 Conclusions

Based on the results of three 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.
3. Reproductive success parameters appear to be significantly lower at Parker River NWR than Rachel Carson NWR.
4. Many individual birds have whole blood Hg concentrations approaching 1.18 µg/g Hg- the level at which adverse effects are expected to occur in insectivorous birds.
5. Mercury levels in sparrow blood from all sites sampled in both years were higher in 2006 and 2005 than in 2004 (except RI).
6. Mercury levels in sparrow blood sampled in late July-August appear higher than in birds captured in June-early July.
7. It appears that sparrow eggs may not be the best indicator tissue to use in assessing Hg exposure in the salt marshes.

6.0 Recommendations

1. Continue sampling Saltmarsh Sparrows at the sites with the highest Hg levels to increase sample size and understanding of risk.
2. Collect sparrow blood samples from additional sites in estuaries in proximity to potential possible point sources of Hg.
3. Continue to conduct a vigorous nest monitoring program to determine productivity.
4. Collect prey samples in the study estuaries for diet composition, Hg and isotope analysis. Prey should be collected from items offered to chicks and from within the study site.

7.0 Acknowledgments

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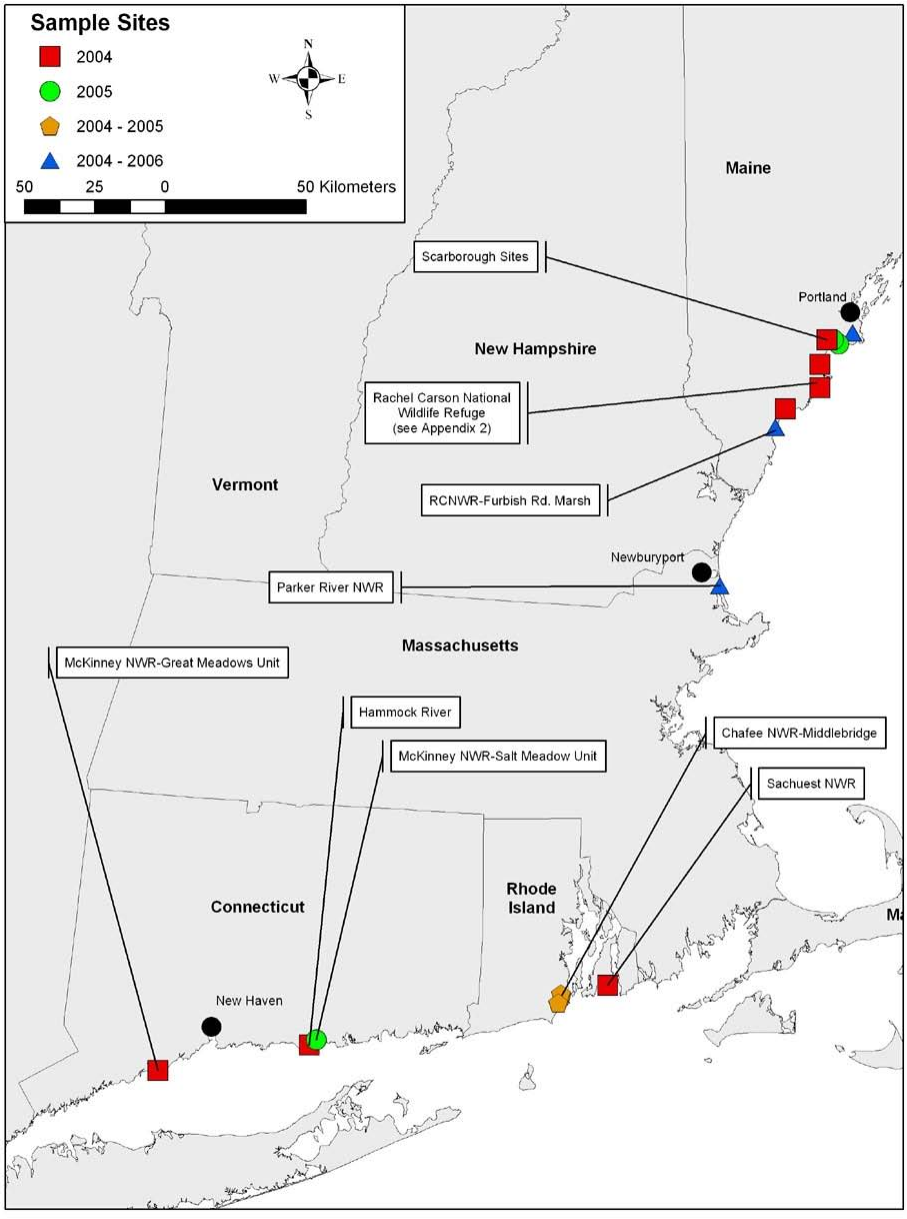
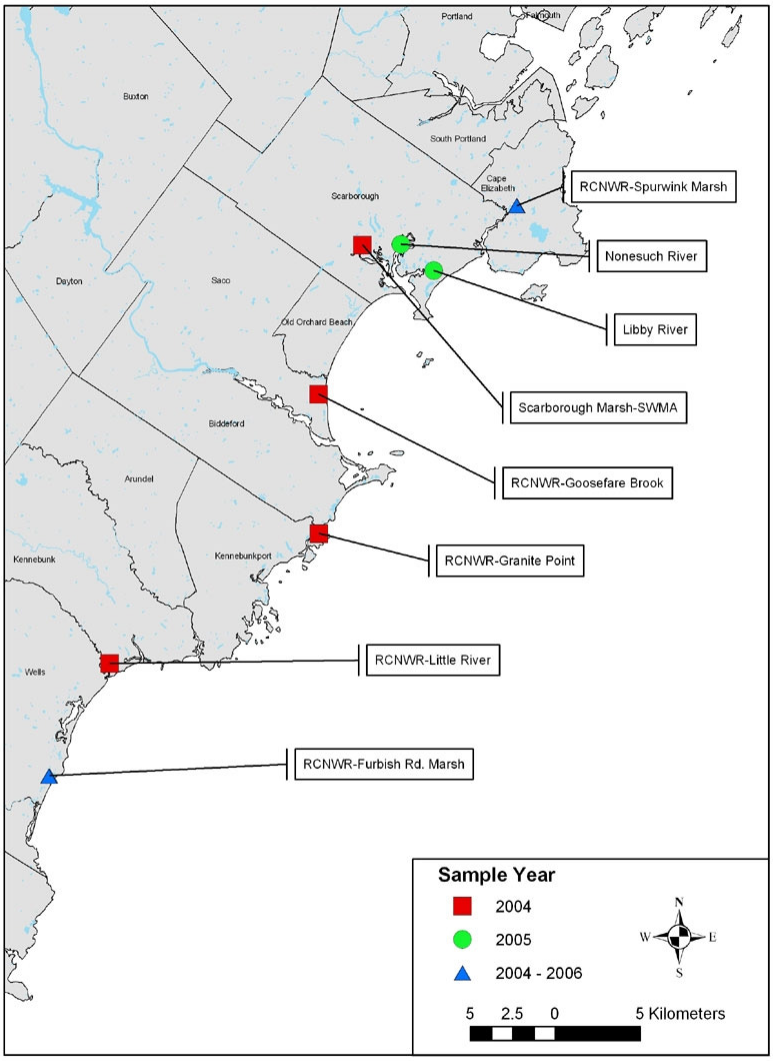
Appendix I. Saltmarsh Sharp-tailed Sparrow sampling locations in New England, 2004-2006. Rachel Carson NWR in Wells (Furbish Marsh) and Parker River NWR in Newburyport were the only study sites in 2006.



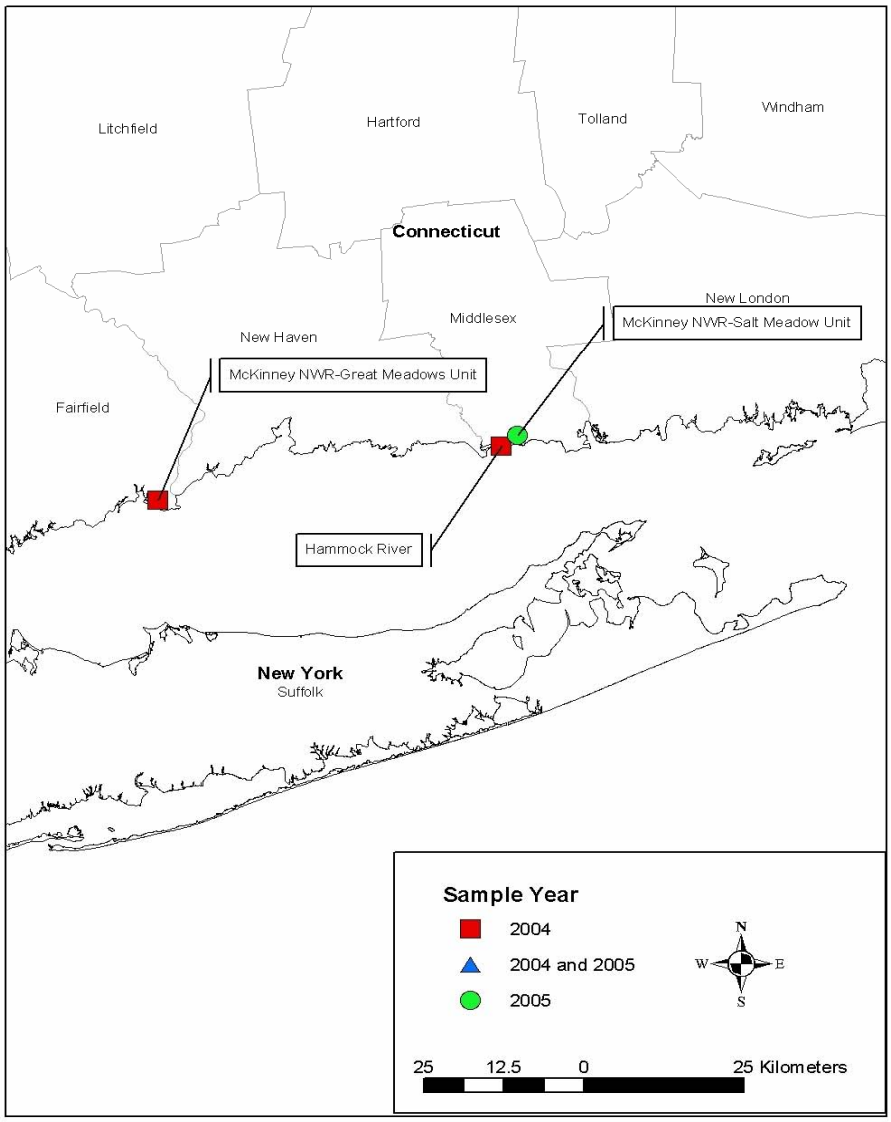
Appendix II. Saltmarsh Sharp-tailed Sparrow sampling locations in the Rachel Carson NWR and other locations in Maine, 2004-2006.



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. Interpretation of Songbird egg and blood Hg Levels, not for distribution.

There are few datasets available that provide toxicity reference value (TRV) for MeHg accumulation and exposure to avian insectivores. Herein is a description of how a TRV of 0.40 µg/g in the egg and 1.18 µg/g in the blood was developed.

Recent laboratory dosing efforts with songbirds by scientists at the U.S. Geological Survey's Patuxent Wildlife Research Center provide the most relevant information for TRV development. Through formal Hg dosing experiments of Tree Swallow (*Tachycineta bicolor*) and Common Grackle (*Quiscalus quiscula*) eggs, based on protocols established for the CALFED-Bay Delta Mercury Project (Heinz 2003), Hg levels that posed a "cause of concern" were developed by Gary Heinz (pers. com.).

The CALFED study is designed to determine the relative sensitivities of MeHg effects on eggs of 17 species. Because the CBR for Mallard (*Anas platyrhenchus*) eggs is established at 0.80 µg/g (ww) (Heinz and Hoffman 2003) and songbird eggs were more sensitive to the negative impacts of MeHg in eggs than mallards (G. Heinz, pers. com), a TRV for songbirds is < 0.80 µg/g (ww). There are two species of songbirds that were used for the Hg dosing experiments – the Tree Swallow and Common Grackle.

Using an endpoint of embryo survival just prior to the hatching date, Heinz (2003) found a significant negative impact in swallow embryo survival at egg Hg levels of 0.80 µg/g (ww). Egg Hg levels of 0.40 µg/g (ww) were not significantly different than the reference condition (p=0.19); however, the 25% fewer eggs hatched compared to the reference level is deemed to be biologically significant. Eggs were not dosed at the 0.60µg/g (ww) level.

Findings with the grackle indicate that it was the most sensitive of the 17 species that underwent the dosing regime; embryo survival was significantly lower than the reference condition at an egg Hg level of 0.10 µg/g (ww). Because of the uncertainty in how experimental Hg doses distribute across the egg and the assumption that artificial Hg transfer to the egg is more toxic than maternal transfer (G. Heinz, pers. com.), an uncertainty factor of four is used based on comparisons between experimental Hg dosing and TRVs for the Mallard in the CALFED study (Heinz 2003)[2]. The TRV for egg Hg levels in the Common Grackle is therefore 0.40 µg/g, (ww) – or 0.10 ug/g x 4.

Development of a TRV for songbird blood

Because bird blood Hg levels were the most regularly collected tissue type, an existing dataset of 99 paired female whole blood and egg Hg levels from Tree Swallows (BRI unpubl. data) was used in concert with seven paired blood and egg Hg levels from three species collected in August 2006 at a western Virginia site, to develop a simple linear

[2] Where, within Mallards, there was a significant difference in embryo survival at a dosed egg Hg level of 3.20 ug/g (ww) (Heinz 2003). This is four times the TRV of 0.80 ug/g (ww) established by Heinz and Hoffman (2003)

regression model that would predict female blood Hg levels based on egg Hg levels. The greater part of this dataset was collected from the floodplain of the Sudbury River – an USEPA Superfund Site. Although there are multiple ways to interpret the datasets, we recommend an analysis that uses the mean predictive model of geometric means of swallow and other songbird paired blood-egg data (Figure a). Approximately 42% of the variability can be predicted using a model of: Egg [Hg] = 0.3366 * (Blood [Hg]) (Figure a).

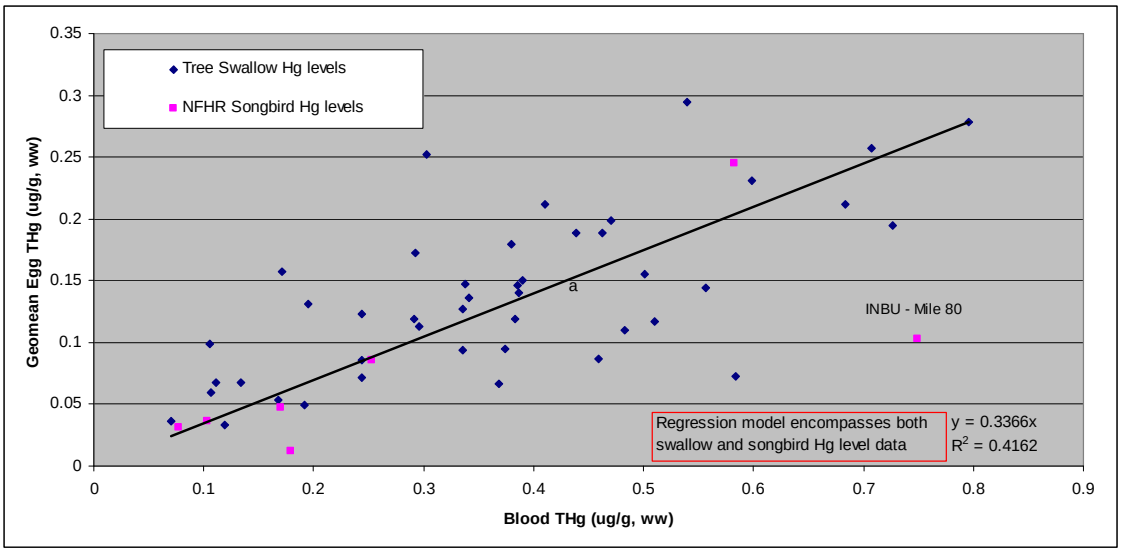


Figure a. Simple linear regression model of blood Hg levels and predicted egg Hg levels[3].

Based on the CALFED egg Hg dosing studies a TRV of 0.40 µg/g (ww) is predictive of a blood Hg CBR of 1.18µg/g (ww) in songbirds (Figure b). Songbirds with blood Hg levels >1.18 µg/g are at risk to greater embryo mortality and subsequent lower reproductive success.

[3] The square symbols in Figure a represent a river in western Virginia.

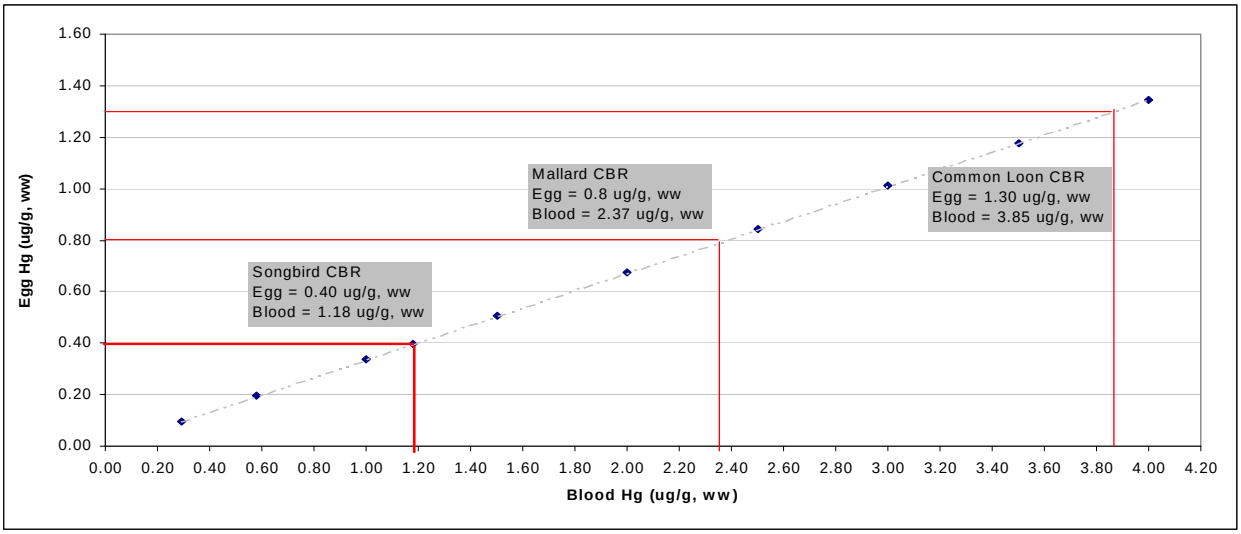


Figure b. Predictive model for avian blood-egg relationship. Red lines depict TRVs for different foraging guilds[1]; the songbird TRV is 0.40 µg/g for eggs and 1.18 µg/g (ww) for whole blood [4].

[1] Where, within Mallards, there was a significant difference in embryo survival at a dosed egg Hg level of 3.20 ug/g (ww) (Heinz 2003). This is four times the level of 0.80 ug/g (ww) established by Heinz and Hoffman (2003)

[4] Basis for CBRs are from: Heinz and Hoffman (2003) for the Mallard, and Evers et al. (2003) for the Common Loon.